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Rural Road Link Design

DN-GEO-03031
April 2017

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TII Publications



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Updates to TII Publications resulting in changes to Rural Road Link Design DN-GEO-03031

Date: April 2017

Amendment Details:

This Standard supersedes DN-GEO-03031 dated February 2012. The principle changes from the previous standard are:

- a) DN-GEO-03032 for Type 2 and Type 3 Dual Carriageways has been amalgamated into DN-GEO-03031.
- b) Design Speed bands A and B removed from Figure 1.1 and text.
- c) Type 2 Dual Carriageway included in Table 1.1.
- d) New Clause to cover Design Speed for Type 2 and 3 Dual Carriageway roads.
- e) For Motorways and Dual Carriageways a one-step Relaxation below the Desirable Minimum Stopping Sight Distance to the high object in combination with an uphill gradient Relaxation is now permitted.
- f) An amended definition for Hidden Dip along with illustrative diagrams is now included.
- g) Where a parapet or VRS extends above the high object a Relaxation below the desirable Minimum Stopping Sight distance may be permitted. Examples of where this may occur have been included.
- h) Tables 2.1 and 2.2, included previously in Annex B, showing the permitted Relaxation to Stopping Sight Distance remote from and on the approaches to a junction have been amended and are included in Chapter 2.
- i) Road camber requirements for online upgrading of existing roads to Type 3 Dual Carriageway are now included.
- j) A new paragraph entitled Length of Superelevation Development to replace Appearance and Drainage.
- k) New table 3.1 included for lane widening on curves.
- l) A paragraph has been included to describe broken back curves and to state that they shall be avoided.
- m) A gradient requirement has been included for online upgrading of existing roads to Type 3 Dual Carriageway.
- n) The climbing lane requirements have been amended to state that one should be only considered if it is needed and can be justified. The climbing lane requirements for Type 1, 2 and 3 Dual Carriageways and Motorways have been amended.
- o) The junction treatment at Major Road requirements for Type 3 Dual Carriageways have been amended.
- p) The use of radii in Band C is now regarded as a Departure from standard for new road schemes and a Relaxation from standard for online improvements.
- q) Type 2 and 3 Dual Carriageway requirements have been incorporated into Chapter 8.

- r) Design Standards for emergency accesses have been included.
- s) Specific road camber requirements on narrow local roads have been included.
- t) A new Chapter 11 has been included entitled 'Geometric Design to Enhance Surface Drainage of Carriageways'. This incorporates the design requirements included in DN-GEO-03057.
- u) The design requirements for non-motorised users have been incorporated into this document to include:
 - i) Design speeds for cyclists
 - ii) Dynamic and Stopping Sight Distances for Cyclists
 - iii) Horizontal Alignment for Cycle Facilities
 - iv) Gradients for Cycle Facilities

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Foreword

Introduction

This Standard applies to Single and Dual Carriageway roads (including Motorways) in rural areas. It also applies to single carriageway Urban Relief Roads and Urban Dual Carriageways and Motorways. It does not apply to Urban Streets; these should be designed in accordance with the Design Manual for Urban Roads and Streets. The standard 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 sets out 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. Single Carriageway design is given particular emphasis in order to provide clearly identifiable sections for overtaking.

For minor improvements to existing roads refer to DN-GEO-03030 - Guidance on Minor Improvements to National Roads.

Definitions

Particular terms used in this Standard are defined as follows:

- a) **All-purpose road:** A road for the use of all classes of traffic (e.g. not a Motorway).
- b) **Motorway:** A divided multi-lane road as defined in Section 43 of the Roads Act.
- c) **Central reserve:** The area which separates the carriageways of a dual carriageway or Motorway. Note that this includes any offside hard strips.
- d) **Cycle Facilities:** Refers to all types of measures which improve conditions for cyclists and include:
 - i. **Cycleways:** a public road or proposed public road reserved for the exclusive use of cyclists or cyclists and pedestrians.
 - ii. **Cycle Track:** Part of a road, including part of a footway or part of a roadway, which is reserved for the use of pedal cycles and from which all mechanically propelled vehicles, other than mechanically propelled wheelchairs, are prohibited from entering except for the purpose of access.
 - iii. **Cycle Lane:** part of the carriageway of a road reserved primarily for use by cyclists. The cycle lane forms part of the road and it is located within the contiguous road surface. A cycle lane can also be referred to as an on-road cycle track.
 - iv. **Shared Use Cycle and Pedestrian Facilities:** A Cycle Track or Cycleway that is provided for both cycle and pedestrian use.
 - v. **Shared roads with Motor Vehicles:** A road under low speed/low vehicular traffic flow conditions that is also provided for both cycle and pedestrian use.
 - vi. **Greenway:** a Cycleway that caters for pedestrian and cyclists in a recreational environment
 - vii. **Cycle Network:** is a defined collection of routes which connect key origins and destinations in a specified area for cyclists.
- e) **Departure:** A design parameter which does not comply with the requirements of this design standard. See GE-GEN-01005 - Departures from Standards and Specification for further details.

- f) **Design Speed:** The parameter that is used to determine geometric design of a road or cycle facility.
- g) **Express Road:** An Express Road is a legal category of road designed for motor traffic, which is accessible primarily from interchanges or controlled junctions and which:
 - i. prohibits stopping and parking on the running carriageway; and
 - ii. does not cross at grade with any railway or tramway track.
- h) **Hard Shoulder:** Surfaced strip, greater than 1.5m wide or greater, 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 not form part of the verge.
- i) **Hard Strip:** Surfaced strip, not more than 1.5m wide, that abuts a carriageway. A hard strip forms part of the verge.
- j) **Heavy Goods Vehicle:** Vehicles designed and constructed for the carriage of goods. Heavy Goods Vehicle refers to vehicle categories N2 (maximum mass between 3.5 tonnes and 12 tonnes) and N3 (maximum mass exceeding 12 tonne).
- k) **National, Regional, Local and Public Roads:**
 - i. A **National Road** is a public road or a proposed public road which is classified or is intended to be classified as a national road under Section 10 of the Road Act (1993).
 - ii. A **Regional Road** is a public road or a proposed public road which is classified or is intended to be classified as a regional road under Section 10 of the Road Act (1993).
 - iii. A **Local Road** is a public road or a proposed public road other than a national road or a regional road.
 - iv. A **Public Road** is a road over which a public right of way exists (or will exist in the case of a proposed public road) and the responsibility for the maintenance of which lies with the Road Authority.
- l) **Relaxation:** A design parameter which complies with this standard but does not meet the Desirable Minimum standards. See GE-GEN-01005 - Departures from Standards and Specification for further details.
- m) **Rural Road:** A road outside of built-up areas including:
 - i. Single Carriageway roads;
 - ii. All-purpose Dual Carriageway roads; or
 - iii. Motorways.
- n) **Type 1 Dual Carriageway:** A divided all-purpose road with a minimum of two lanes and hard shoulder in each direction constructed to the geometric standards of DN-GEO-03031 and CC-SCD-00006.
- o) **Type 2 Dual Carriageway:** A divided all-purpose road with two lanes and hard strip in each direction constructed to the geometric standards of DN-GEO-03031 and CC-SCD-00005.
- p) **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 DN-GEO-03031 and Standard Construction Details CC-SCD-00004. The two-lane section alternates with a one-lane section at intervals of 2km approximately.

- q) **Type 1 Single Carriageway:** An all-purpose road with a 3.65m lane in each direction constructed to the geometric standards of DN-GEO-03031 and CC-SCD-00001.
- r) **Type 2 Single Carriageway:** An all-purpose road with a 3.50m lane in each direction constructed to the geometric standards of DN-GEO-03031 and CC-SCD-00002.
- s) **Type 3 Single Carriageway:** An all-purpose road with a 3.00m lane in each direction constructed to the geometric standards of DN-GEO-03031 and CC-SCD-00003.
- t) **Urban Street:** A road within a built-up area where the primary purpose of the road is to provide direct access to premises.
- u) **Urban Relief Road:** An urban road where the primary purpose of the road is to facilitate the movement of traffic and avoid congestion or other obstacles to movement.
- v) **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.
- w) **Wide Motorway:** A Motorway with a 7.50m lane in each direction and a central reserve of 9m or 16m constructed to the geometric standards of CC-SCD-00008.

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 TII Publications standards refer to Absolute Minimum values of parameters within this Standard. Where this occurs, the reference shall be taken to mean one Design Speed step below the Desirable Minimum value.

Implementation

This Standard shall be used for the design of all new or improved National Roads including motorways unless otherwise agreed with Transport Infrastructure Ireland (TII). All roads affected by National Roads projects shall also be designed in accordance with this Standard unless otherwise agreed with the relevant Road Authority. The design of Local and Regional Roads which are constructed or improved as part of a National Road Scheme shall be designed in accordance with Chapter 10 of this Standard.

Scope

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 and sustainable 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 for motorists, pedestrians and cyclists. Overall, the flexibility for design introduced by this Standard will enable economic and sustainable designs to be prepared, minimising both the construction costs and the impact of new roads and road improvements on the environment.

Throughout this Standard, there are references to the use of cost/benefit analyses. These should be used at all stages to test the economic performance of alternative scheme designs and inform the design decision making process.

Interpretation

This Standard contains various criteria and maximum/minimum levels for achieving a desirable level of performance in terms of road safety, operation, economic and environmental effects and sustainability. In most cases, with care, designs can be achieved which do not utilise the lowest levels of design parameters given. At highly constrained locations on new roads or major improvements, it may not be possible to justify even the lowest levels of design parameters, due to high costs, low traffic levels, environmental effects, and safety etc. In some cases, sufficient advantages might justify either a Relaxation within the standards or, in more constrained locations, a Departure from the standards. 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 Relaxations and Departures are given throughout this Standard.

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

1. Design Speed

The road alignment shall be designed so as to ensure that standards of curvature, visibility, superelevation, etc. provide for a Design Speed which shall be consistent with the anticipated vehicle speeds on the road. Design speed is related to road characteristics and is not directly related to mandatory speed limits. 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 always an inherent economic trade-off between the construction and environmental costs of alternative alignments of different Design Speeds, and their user benefits.

1.1 Factors affecting speed

Vehicle 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 detailed in the following sub-sections.

1.1.1 Alignment Constraint, A_c

This measures the degree of constraint imparted by the road alignment, and is measured by:

- Dual Carriageways: $A_c = 6.6 + B/10$
- Single Carriageways: $A_c = 12 - VISI/60 + 2B/45$

Where:

- B = Bendiness (total angle the road turns through), degrees/km;
- $VISI$ = Harmonic Mean Visibility, m (see Appendix A).

1.1.2 Layout Constraint, L_c

This measures the degree of constraint imparted by the road cross-section, verge width and frequency of junctions and accesses. Table 1.1 shows the values of L_c relative to cross-section features and density of access, expressed as the total number of junctions, lay-bys and direct accesses (other than single field accesses) per km (see DN-GEO-03060), 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 1.1: Layout Constraint, Lc km/h

Road Type	Single 2 Lane						Dual 2 Lane		Dual 3 Lane	Type 2 Dual		Type 3 Dual		Wide Dual 2 Lane	
	6.0m		7.0m		7.3m		Dual 7.0m		Dual 10.5m	Dual 7.0m		Dual 7.0m Single 3.5m		Dual 7.5m	
Carriageway Width (ex hard strips)	6.0m		7.0m		7.3m		Dual 7.0m		Dual 10.5m	Dual 7.0m		Dual 7.0m Single 3.5m		Dual 7.5m	
Degree of Access to Junctions	H	M	M	H	M	L	M	L	L	L	M	L	M	L	L
With hard shoulder					21	19	10	9	5					5	4
Without hard shoulders															
With 3.0m Verge	29	26	25	23	23	21	12	11	6	12	13	18	20		
With 1.5m Verge	31	28		27											
With 0.5m Verge	33	30													

1.1.3 Mandatory Speed Limits

Mandatory Speed Limits may be set at a lower speed than the driver might naturally adopt in the absence of such restriction and will act as a further constraint on speed in addition to that indicated by Lc. Conversely the Design Speed may often be further restricted by the alignment and layout constraints despite the nationally applied Mandatory Speed Limits of:

- 120km/h for Motorways,
- 100km/h for Type 1, 2 and 3 Dual Carriageways and all Single Carriageway National Roads, and
- 80km/h for Regional and Local roads,

The maximum Design Speeds for Mandatory Speed Limits are indicated in Table 1.2.

Table 1.2: Maximum Design Speeds for Mandatory Speed Limits

Speed Limit	Design Speed
km/h	km/h
50	60
60	70
80	85
100	100
120	120

1.2 Selection of Design Speed

1.2.1 New Rural Roads

Design Speed shall be derived from Figure 1.1, which shows the variation in speeds for a given Lc against Ac.

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 shall be recalculated to check that it has not changed.

On Type 3 Single Carriageway roads, a trial Design Speed of 85km/h shall be chosen as the initial choice. This may result in the Design Speed calculated in accordance with the above procedure being less than the mandatory speed limit of the road. In such cases:

- On Type 3 Single Carriageway National Roads, a Design Speed of 85km/h shall be recorded as a Relaxation. Such a Relaxation may be coincident with other Relaxations and would not require a Departure from Standard.
- The imposition of a Mandatory Speed Limit of 80km/h for the entire length of the alignment and adjacent sections may be considered appropriate when an 85km/h Design Speed has been calculated.

For Type 2 and 3 Dual Carriageway roads, a Design Speed greater than 100 km/h on National Roads shall not be used.

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 in accordance with the Departures section at the end of this Chapter.

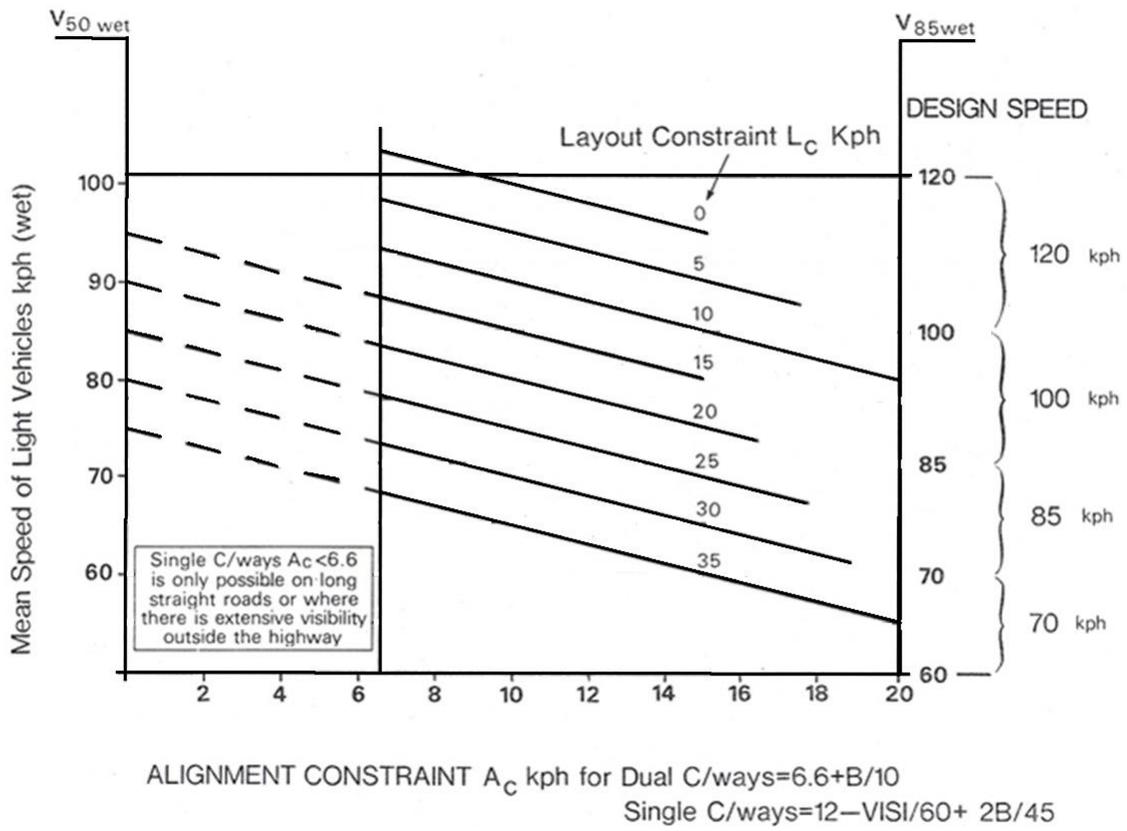
1.2.2 Existing Rural Road Improvements:

This standard does not address minor improvements to National Roads. Refer to DN-GEO-03030 for guidance.

Design speeds for Regional and Local Roads constructed or improved as part of a National Road scheme are to be derived in accordance with Chapter 10 of this Standard;

For all other road improvements, Design Speed shall be derived in a similar manner to new Rural Roads as outlined above, with A_c 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 A_c 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.

Figure 1.1: Selection of Design Speed (Rural Roads)



1.3 Design Speed Related Parameters

The Design Speed bands 120, 100, 85 km/h etc. dictate the minimum geometric parameters for the design according to Table 1.3. Table 1.3 shows Desirable Minimum values and values for certain Design Speed steps below Desirable Minimum.

Table 1.3: Design Speed Related Parameters

DESIGN SPEED (km/h)	120	100	85	70	60	V ² /R
STOPPING SIGHT DISTANCE m						
Desirable Minimum Stopping Sight Distance	295	215	160	120	90	
One Step below Desirable Minimum	215	160	120	90	70	
Two Steps below Desirable Minimum	160	120	90	70	50	
Horizontal Curvature m						
Minimum R ⁺ without elimination of Adverse Camber and Transitions	2880	2040	1440	1020	720	5
Minimum R ⁺ with Superelevation of 2.5%	2040	1440	1020	720	510	7.07
Minimum R with Superelevation of 3.5%	1440	1020	720	510	360	10
Desirable Minimum R with Superelevation of 5%	1020	720	510	360*	255*	14.14
One Step below Desirable Min R with Superelevation of 7%	720	510	360	255*	180*	20
Two Steps below Desirable Min R with Superelevation of 7%	510	360	255	180*	127*	28.24
Three Steps below Desirable Min R with Superelevation of 7%			180	127*	90*	40
Four Steps below Desirable Min R with Superelevation of 7%			127	90*	65*	56.56
Vertical Curvature – Crest						
Desirable Minimum Crest K Value	182	100	55	30	17	
One Step below Desirable Min Crest K Value	100	55	30	17	10	
Two Steps below Desirable Min Crest K Value	55	30	17	10	6.5	
Vertical Curvature – SAG						
Desirable Minimum Sag K Value	53	37	26	20	13	
One Step below Desirable Min Sag K Value	37	26	20	13	9	
Two Steps below Desirable Min Sag K Value	26	20	13	9	6.5	
** Absolute Minimum Vertical Curve Length to be used on Dual Carriageways	240	200	-	-	-	
Overtaking Sight Distances						
Full Overtaking Sight Distance FOSD m.	N/A	580	490	410	345	
FOSD Overtaking Crest K Value	N/A	400	285	200	142	

Notes

* Not to be used in the design of single carriageways (see Horizontal and Vertical Curve Design sections in Chapter 7).

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 (%) (See Vertical Curves Section of Chapter 4).

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

** Notwithstanding the minimum vertical curve K values contained in Table 1.3 for Dual Carriageways the selected K value shall be sufficiently large to ensure compliance with the Absolute Minimum Vertical Curve length indicated.

1.4 Design Speed for Cyclist

It is recommended that all cycle facilities have a design speed of 30 km/h. However, on approach to junctions a reduced design speed of 10 km/h is acceptable (over short distances). It is important to note that for cycle facilities located on long downward slope sections (steeper than 5% and longer than 150 m), a design speed of 50 km/h should be implemented.

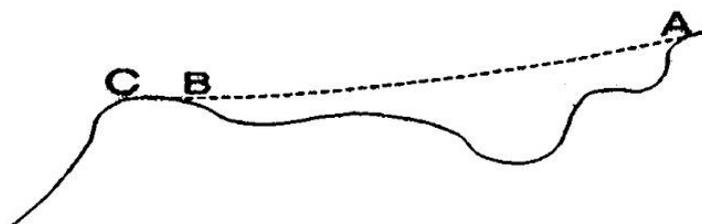
1.5 Changeover of Design Speed Standards

Transitions between sections of carriageway with different Design Speeds shall be designed carefully so as not to present the road users 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.

1.6 Connection to Existing Roads

Care shall be taken where an improved section re-joins 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 1.2 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 to DN-GEO-03030 for guidance on route consistency for minor improvements to existing roads.

Figure 1.2: Connection to Existing Road



1.7 Selection of Parameter Values

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 permitted: in such cases Departures from Standards would be required. See the Horizontal and Vertical Curve Design Sections in Chapter 7.

1.8 Relaxations

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.

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. Details of Relaxations for sight distance are given in Chapter 2, for horizontal alignment in Chapter 3, and for vertical alignment in Chapter 4.

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 and sustainability 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 shall be compared against options that would meet Desirable Minimum standards.

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 collision potential of a constrained alignment has been minimised by applying layout design principles based upon the knowledge currently available.

1.8.1 Relaxation Principles

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.

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

- a) Isolated from other Relaxations;
- b) Isolated from junctions;
- c) One where drivers have Desirable Minimum Stopping Sight Distance;
- d) Subject to momentary visibility impairment only;
- e) One that would affect only a small proportion of the traffic;
- f) On straightforward geometry readily understandable to drivers;
- g) On a road with no frontage access;
- h) One where traffic speeds would be reduced locally due to adjacent road geometry (e.g. uphill sections, approaching roundabouts and priority junctions where traffic has to yield or stop etc.), or speed limits;
- i) Impacting on pedestrians and cyclists.

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

- a) Collision prevention or mitigation measures (e.g. increased skidding resistance, Vehicle Restraint System (VRS), etc.);
- b) Warning signs and road markings to alert the driver to the layout ahead. The designer should assess the potential for sign clutter when considering provision of warning signs.

The designer shall 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.

Values for sight distance, horizontal curvature and vertical curvature shall not be less than those given in Table 1.3 for each Design Speed and the appropriate number of Design Speed steps.

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

1.8.2 Combinations of Relaxations

A combinations of Relaxations of the alignment standards at any one location set out in Chapters 1 to 4 of DN-GEO-03031 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) 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 (one step Relaxation or steeper) with a permitted Relaxation of the horizontal alignment, gradient or superelevation. However, there shall be no Relaxation in the Stopping Sight Distance at such locations.
- c) Stopping Sight Distance Relaxations to the low object at VRS and parapets (see the Obstructions to Sight Distance section in Chapter 2) may be coincident with other Relaxations, provided appropriate Stopping Sight Distance in accordance with sub-paragraphs a) and b) above is obtained to a 1.05m high object.
- d) A Relaxation (or permitted combination of Relaxations) of one of the geometric parameters in DN-GEO-03031 is permitted in combination with a Relaxation from another current design standard in the TII Publications (Standards) suite of documents other than DN-GEO-03031. In such circumstances any Relaxations from another standard shall be deducted from the maximum permissible number of Design Speed steps that the requirements of this standard may be relaxed, as provided for in Chapters 1 to 4.
- e) For Motorways and Dual Carriageways one-step Relaxation below the Desirable Minimum Stopping Sight Distance to the high object in combination with an uphill gradient Relaxation shall be permitted.
- f) No other combinations of Relaxations are permitted. If used, they shall be treated as Departures.

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 is not a permitted combination of Relaxations and shall be treated as a Departure.

Relaxations are not permitted for either of the overtaking sight distance parameters given in Table 1.3.

The geometric parameters of cycle facilities will generally be determined by the road standards relating to motorised vehicles as they generally exceed those of cyclists. Where there is a relaxation in both the cycle facility design standards and the road design standards, this combination is not considered a Departure.

1.8.3 Immediate Approaches to Junctions

The following Relaxations are **NOT** permitted on the immediate approaches to junctions, because of safety concerns:

- a) Relaxations below Desirable Minimum Stopping Sight Distance other than Relaxations to the low object at central reserve VRS (see Sections 2.4 and 2.6);
- b) Relaxations below Desirable Minimum in vertical curvature for crest curves (see Relaxations for Crest Curves in Chapter 4). This requirement takes precedence over the requirements for Non-Overtaking Sections and Vertical Curve Design in Chapter 7;
- c) Relaxations more than one Design Speed step below Desirable Minimum for sag curves (see Relaxations for Sag Curves in Chapter 4).

For the purposes of this Standard the immediate approaches to a junction shall be:

- a) For at grade priority 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.
- e) For the purposes of this Standard the term 'junction' shall include a lay-by (see DN-GEO-03046). 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 DN-GEO-03060). The immediate approaches to a vehicular access are as defined for a junction in the previous paragraphs.

1.9 Departures

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 Transport Infrastructure Ireland for approval **before** incorporation into a design layout to ensure that safety is not significantly reduced.

For further information on Departure from Standards and Relaxations refer to GE-GEN-01005.

2. Sight Distance

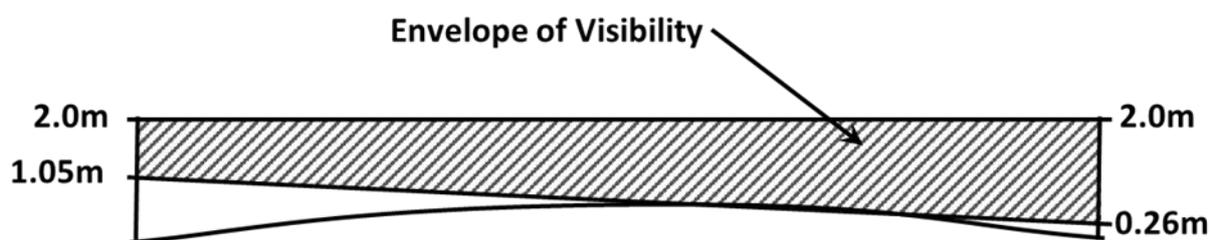
2.1 Stopping Sight Distance

Table 1.3 shows the Stopping Sight Distance (SSD) appropriate for each Design Speed.

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 above the road surface, as shown in Figure 2.1. It shall be checked in both the horizontal and vertical planes, between any two points within the visibility envelope shown in Figure 2.1. The check shall be carried out along a line in the centre of the lane on the inside of the curve (for each carriageway on Dual Carriageways).

The Designer shall also comply with dynamic sight distance requirements associated with the provision of cycle facilities on Type 2 and Type 3 Single and Dual Carriageways. .

Figure 2.1: Measurement of Stopping Sight Distance



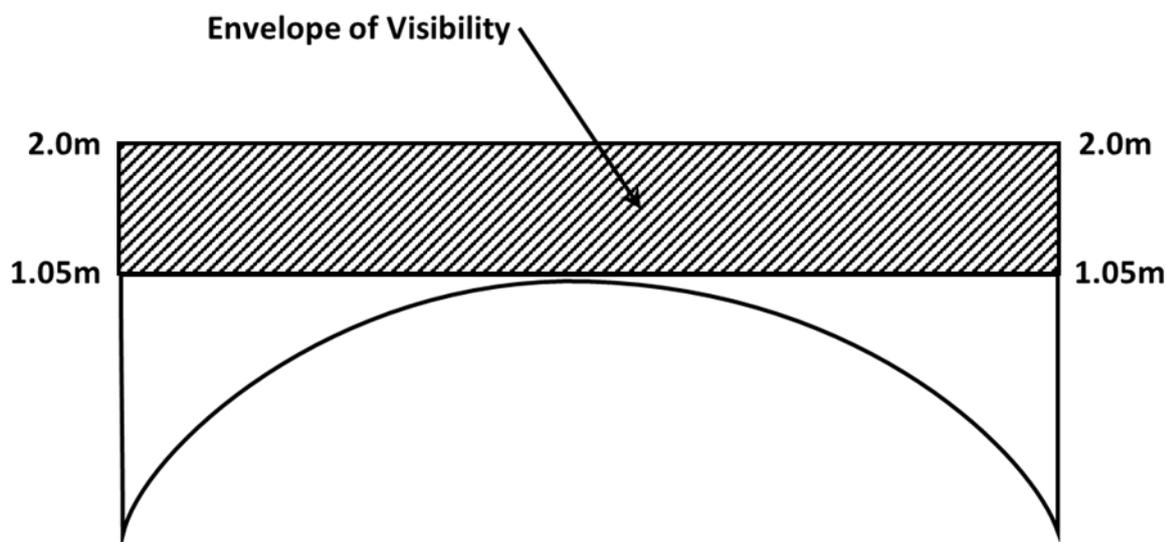
2.2 Full Overtaking Sight Distance

Table 1.3 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.

FOSD shall be provided between points 1.05m and 2.00m above the centreline of the carriageway as shown in Figure 2.2, and shall be checked in both the horizontal and vertical planes throughout the full length of the overtaking section. To avoid the creation of Hidden Dips within an overtaking section, the designer should be aware of certain vertical alignment layouts where the vertical height between the underside of the 1.05m sight line and the road surface exceeds 1.05m at any point within the overtaking section. A Hidden Dip may be created if this 1.05m value is exceeded as described in Chapter 7.

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 2.2: Measurement of FOSD



2.3 Coordinated Design of Single Carriageways

It will frequently be more economical to design a single carriageway road so as to provide clearly identifiable Overtaking Sections with FOSD in relatively level areas. Where constraints on the alignment would result in high cost or environmental implications, climbing lanes at hills, interspersed with non-overtaking sections may be a suitable solution. The detailed standards and design considerations regarding the coordinated design of such links are given in Chapters 6 and 7.

2.4 Obstructions to Sight Distance

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 shall, wherever possible, be sited on straights or on the outside of curves, where stopped vehicles will not obstruct sightlines.

Long bridge parapets or VRS 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 VRS. Relaxations below the Desirable Minimum Stopping Sight Distance to the low object may be permitted in such situations. In certain situations the bridge parapet or VRS may extend above the high object height (e.g. railway bridge parapets, noise barriers or VRS on crest curves). Relaxations below the Desirable Minimum Stopping Sight Distance to the low object and high object may be appropriate in such situations. Refer to Tables 2.1 and 2.2.

2.5 Sight Distance for Cyclists

The distance at which a cyclist has visibility of potential hazards is an important design parameter. The greater the visibility a cyclist has, the greater their comfort and safety on the cycle facility. Along on-road cycle facilities the visibility parameters will be determined by existing road standards which relate to motorised vehicles which exceed those of cyclists.

2.6 Relaxations in Sight Distance

In the circumstances described in the Relaxations Section of Chapter 1, 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: 1 step
- Single and Dual carriageways: 2 steps

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

For Motorways 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.

For Motorways 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 VRS, may be extended by 1 Design Speed step, provided the appropriate Stopping Sight Distance in accordance with Chapter 1 and the permitted number of Design Speed steps below the Desirable minimum for the road type as outlined above is available to the high object.

On or near the bottom of long grades on Motorways and 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.

The scope for Relaxations shall be reduced by 1 Design Speed step immediately following an Overtaking Section on single carriageway roads (see Chapter 7, Overtaking Sections).

Relaxations below Desirable Minimum Stopping Sight Distance, other than Relaxations to the low object at central reserve VRS as described in Section 2.4, are not permitted on the immediate approaches to junctions as defined in Chapter 1.

Refer to Table 2.1 and 2.2 below for the range of permitted Relaxation combinations relating to Sight Distance.

Table 2.1: Permitted Relaxation of Stopping Sight Distance Remote from a Junction

	Associated Relaxation	Motorways		Type 1, 2 and 3 Dual Carriageways		Type 1, 2 and 3 Single Carriageways	
		High Object	Low Object ¹	High Object	Low Object ¹	High Object	Low Object ¹
1	No Relaxation in horizontal curvature, vertical curvature, gradient or superelevation.	1 Step ^{2,3}	2 Steps ³	2 Steps ³	2 Steps ³	2 Steps ⁵	2 Steps ⁵
2	1 Step Relaxation in horizontal curvature.	1 Step ^{2,3}	2 Steps ³	1 Step ^{2,3}	2 Steps ³	1 Step ^{2,4,5}	2 Steps ⁵
3	2 Step Relaxation in horizontal curvature.	None ²	1 Step	None ²	1 Step	None ^{2,4}	1 Step ^{4,5}
4	3 Step Relaxation in horizontal curvature.	None ²	None ²	None ²	None	None ^{2,4}	None ^{2,4}
5	4 Step Relaxation in horizontal curvature.	None ²	None ²	None ²	None	None ^{2,4}	None ^{2,4}
6	Relaxation in vertical curvature.	None ²	1 Step	None ²	1 Step	None ^{4,5,6}	1 Step ^{4,5}
7	Uphill Gradient Relaxation	1 Step ²	2 Steps	1 Step ²	2 Steps	None ^{2,4}	1 Step ^{4,5}
8	Downhill Gradient Relaxation	None ²	1 Step	None ²	1 Step	None ^{2,4}	1 Step ^{4,5}
9	Superelevation Relaxation.	None ²	1 Step	None ²	1 Step	None ^{2,4}	1 Step ^{4,5}

Notes:

1. Where the number of Relaxations to the low object exceeds that for the high object the additional steps are only permitted in relation to visibility restricted by a VRS or parapet.
2. May be extended by 1 step at momentary obstructions, see Section 2.6.
3. Reduced by 1 step on long downgrades steeper than 3%, see paragraph 2.6.
4. Extended by 1 step at the top of long up gradients steeper than 4%, see paragraph 2.6.
5. Reduced by 1 step immediately following an overtaking section, see paragraph 2.6.
6. See paragraph 7.8 b) regarding the use of crest curves to avoid the potential introduction of unsafe overtaking on single carriageways.

Table 2.2: Permitted Relaxation of Stopping Sight Distance in the Vicinity of a Junction

	Associated Relaxation	Motorway		Type 1, 2 and 3 Dual Carriageways		Type 1, 2 and 3 Single Carriageways	
		High Object	Low Object ¹	High Object	Low Object ¹	High Object	Low Object
1	No Relaxation in horizontal curvature, vertical curvature, gradient or superelevation.	None	1 Step	None	1 Step	None	None
2	1 Step Relaxation in horizontal curvature.	None	1 Step	None	1 Step	None	None
3	2 Step Relaxation in horizontal curvature	None	1 Step	None	1 Step	None	None
4	3 Step Relaxation in horizontal curvature	None	None	None	None	None	None
5	4 Step Relaxation in horizontal curvature	None	None	None	None	None	None
6	Relaxation in vertical curvature	None	1 Step	None	1 Step	None	None
7	Gradient Relaxation	None	1 Step	None	1 Step	None	None
8	Superelevation Relaxation	None	1 Step	None	1 Step	None	None

Notes:

1. Where the number of Relaxations to the low object exceeds that for the high object the additional steps are only permitted in relation to visibility restricted by a central reserve VRS or parapet. No Relaxation is permitted in relation to a verge barrier or parapet in the vicinity of a junction

3. Horizontal Alignment

3.1 Road Camber

On sections of road with radii greater than that shown in Table 1.3 for Minimum R without elimination of Adverse Camber and Transitions (i.e. $V^2/R < 5$), the superelevation or camber shall be 2.5%, falling from the centre of single carriageways, or from the central reserve of Dual Carriageways, to the outer channels. This ensures that any vehicle drift down the superelevation on a straight alignment or on a large radius bend is away from opposing or overtaking traffic. As a Relaxation it may be appropriate to eliminate adverse camber on larger radii for aesthetic or drainage reasons (see Section 3.6) but this should only be done where justified on safety grounds.

For on-line upgrading of existing roads to Type 3 Dual Carriageways, it is acceptable for the crown to be located within a traffic lane.

3.2 Superelevation

On horizontal curves, adverse camber shall be replaced by favourable superelevation of 2.5% or more when the radius is less than that shown in Table 1.3 for 'Minimum R without elimination of adverse camber and transitions' (i.e. $V^2/R > 5$).

On radii less than those shown in Table 1.3 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

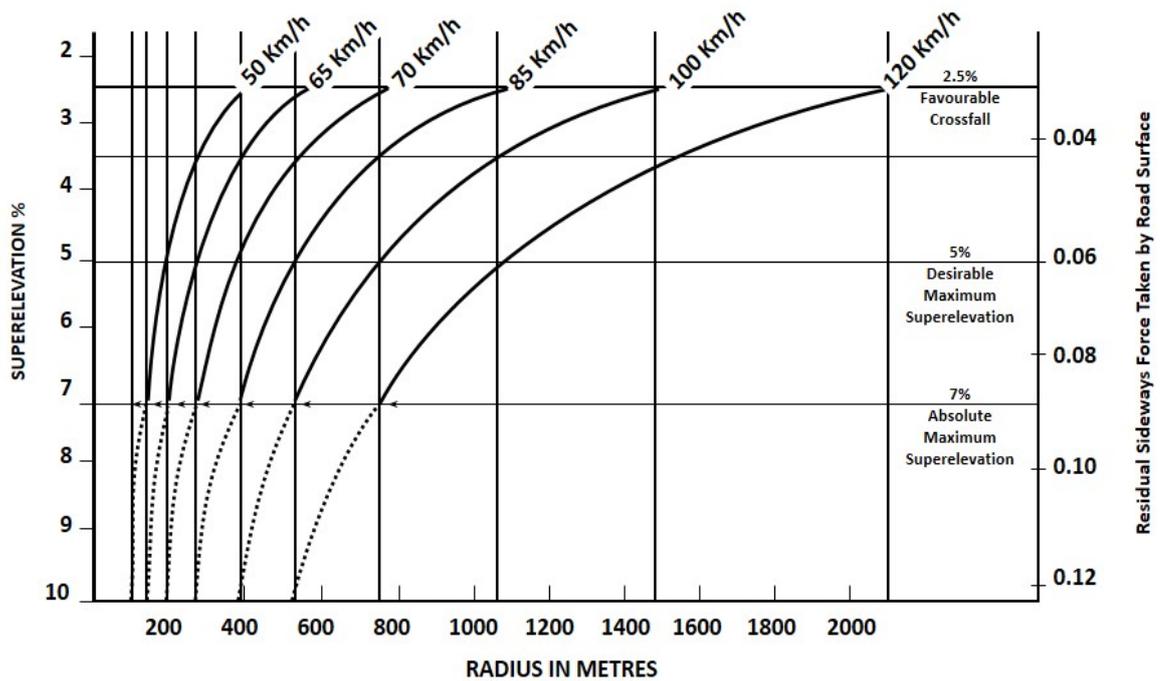
S = Superelevation, %.

On Rural Roads superelevation shall not exceed 7%.

Figure 3.1 shows the appropriate superelevation for the range of Design Speeds. Sharper radii than the Desirable Minimum values shown in Table 1.3 result in steep superelevations which should be avoided if possible. It is essential to maintain adequate skidding resistance and good drainage at all superelevations.

Superelevation is not required as part of the design of cycle facilities.

Figure 3.1: Superelevation of Curves



3.3 Horizontal Alignment for Cycle Facilities

In order for a cyclist to achieve a safe and comfortable rides sufficient horizontal radii are required. Horizontal radii below the values recommended may create difficulties for cyclists to keep their balance or lose momentum having to apply their brakes on approach to the curve. The provision of tight horizontal radii can compromise safety and the attractiveness of the cycle facility.

On approach to obstacles and/or major junctions the introduction of tight horizontal radii on the cycle facility can be used as a speed inhibitor. The introduction of tight horizontal radii needs to be accompanied by appropriate warning signage on the cycle facility. The designer must consider the potential for sign clutter for on road cycle facilities.

Table 3.1 presents the recommended horizontal radii that shall apply for the different design speeds.

Table 3.1: Recommended Horizontal Radii (m) for different Design Speeds

Design Speed (km/h)	Minimum Horizontal Radius (m)
10 km/h	4
30 km/h	25
50 km/h	94

3.4 Desirable Minimum Radius

The Desirable Minimum radii, corresponding to a superelevation of 5% (i.e. $V^2/R = 14.14$) are shown in Table 1.3 in Chapter 1.

3.5 Relaxations in Horizontal Alignment

In the circumstances described in Section 1.8, Relaxations below the Desirable Minimum 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, Dual Carriageways and Type 1 Single Carriageway Roads:	2 steps
Type 2 Single Carriageway Roads:	3 steps
Type 3 Single Carriageway Roads:	4 steps

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.

The scope for Relaxations shall be reduced by 1 Design Speed step immediately following an Overtaking Section on single carriageway roads (see Chapter 7, Overtaking Sections).

3.6 Length of Superelevation Development

The length required for superelevation application shall be sufficiently adequate to ensure satisfactory driver comfort and a good visual appearance. Higher design speeds and wider carriageways will necessitate longer application lengths to meet these criteria; however the influence of rollover application on surface drainage conditions must be taken into account. If superelevation is applied so gradually as to create large almost flat areas of road pavement, rainfall runoff will build up on the carriageway surface and increase the potential for aquaplaning. Therefore, in certain circumstances, the design length of superelevation development must accommodate the need for comfort and appearance without compromising surface drainage.

A satisfactory appearance can usually be achieved by ensuring that the road pavement edge profile does not vary in grade by more than 1% from that of the line about which the carriageway is pivoted, i.e. axis of rotation.

On Motorways and Dual Carriageways, a smoother edge profile shall be provided by reducing the variation in grade of the edge profile to a maximum of 0.5% with ample smoothing of all changes in edge profile.

It should be stressed that the above guidance represents the ideal scenario in considering both driver comfort and visual appearance, but is unlikely to be achievable where longitudinal gradients are low and surface drainage is problematic. Where there is a need to manage the drainage paths of rainfall runoff, the variation in grade of the edge profile should be progressively increased and a linear application of superelevation adopted. However, the relative gradient between the pavement edge and axis of rotation must not be increased beyond a maximum value of 1% on the roads to ensure driver comfort is not unduly compromised.

Areas susceptible to drainage problems shall be identified at an early stage in the design process, before the alignment is fixed. Rollover areas shall be checked by triangulation of three dimensional road models to ensure that no point on the road pavement has a gradient of less than 1%. This represents the net resultant gradient taking into account carriageway superelevation and longitudinal gradient.

Where an alignment is tying into an existing road, every effort should be made to satisfy the 1% net resultant gradient requirement but in certain circumstances this may not be achievable. In such cases, a Departure from Standards shall be required.

The associated Water Film Depth on the carriageway must also be checked in line with the procedure in Chapter 11 to ensure it is below the maximum depth allowable for that road type.

3.7 Application of Superelevation

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 Section 3.10.2).

3.8 Widening on Curves

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.

The following table provides the minimum lane widths necessary for a 16.5m articulated vehicle to complete the turning manoeuvre. This vehicle has the largest swept path of vehicles permitted on Irish roads by the Road Safety Authority due to its long trailer length and minimal articulation points. The lane width is based on the width the vehicle occupies along the curve and a horizontal clearance of 0.60m

Table 3.2: Minimum Lane Width on Curves

Curve Radius (m)	Minimum Lane Width along curve (m)
500	3.35
400	3.50
350	3.50
300	3.50
250	3.50
200	3.65
180	3.65
160	3.65
140	3.75
120	3.80
100	3.95
90	4.00
80	4.10
70	4.25
60	4.40
50	4.65
40	5.00

Notes:

1. If the tangent lane width on the approach to the bend is wider than the minimum required lane width in Table 3.2, the width of the approach lane should be maintained through the length of the curve.
2. If the curve radius is $\leq 40\text{m}$, a swept path analysis shall be used to consider the movements of an articulated truck of 16.5m length.
3. For curves greater than 500m, the minimum lane width relevant to the carriageway type as per DN-GEO-03036 shall be provided.
4. Rate of change of cross-section width should be as per the transition tapers contained in Table 3.3 appropriate to the design speed of the road.

3.9 Lane Width Reductions at Pinch Points

At points of particular difficulty on Wide Motorways, 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.

3.10 Transitions

Transition curves shall be provided on any curve the radius of which is less than that shown in Table 1.3 for Minimum R without elimination of Adverse Camber and Transitions.

3.10.1 Length of Curve

The basic transition length shall be derived from the formula:

$$L_1 = \frac{V^3}{46.7 \times q \times R}$$

where:

L_1 = Length of transition (m)

V = Design Speed (km/h)

q = Rate of increase of centripetal acceleration (m/sec³) travelling along curve at constant speed V

R = Radius of curve (m).

q should normally not exceed 0.3m/sec³. However, in difficult cases the value of q may be increased up to 0.6 m/sec³ as a Relaxation. On curves which are greater than 4 steps below Desirable Minimum as specified in Table 1.3 for the appropriate Design Speed, the length of transition should normally be limited to $\sqrt{(24R)}$ metres.

3.10.2 Application of Superelevation

The length required for the linear application of superelevation can be calculated from the formula:

$$L_2 = \frac{W \times \Delta S}{\Delta G}$$

where:

L_2 = Length of progressive superelevation (m)

W = Width of pavement from centreline/pivot point to carriageway edge which includes running carriageway, hard shoulders and hard strips (m)

ΔS = Total change in superelevation (%)

ΔG = Rate of change of carriageway edge profile gradient (%). Apply 0.5 for dual carriageways and motorways or 1.0 for single carriageway roads.

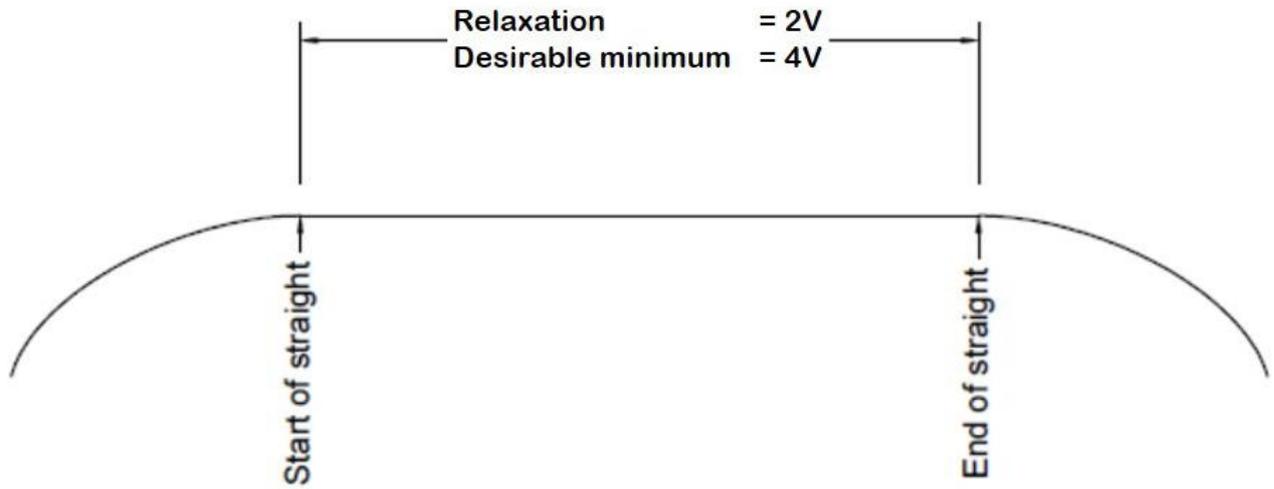
Super-elevation or elimination of adverse camber shall generally be applied on or within the length of the transition curve from the arc end. The basic transition length appropriate to the Design Speed (L_1) however, will often result in insufficient transition length to accommodate superelevation turnover appropriate to the width of the pavement (L_2). In such cases longer transitions shall be provided to match the superelevation design. Refer to the requirements within the Length of Superelevation Development section earlier in this Chapter and to the requirements for the drainage of surface water from the road pavement described in Chapter 11. On existing roads without transitions, between $1/3$ and $2/3$ of the superelevation shall be introduced on the approach straight and the remainder at the beginning of the curve.

3.11 Horizontal Broken Back Curves

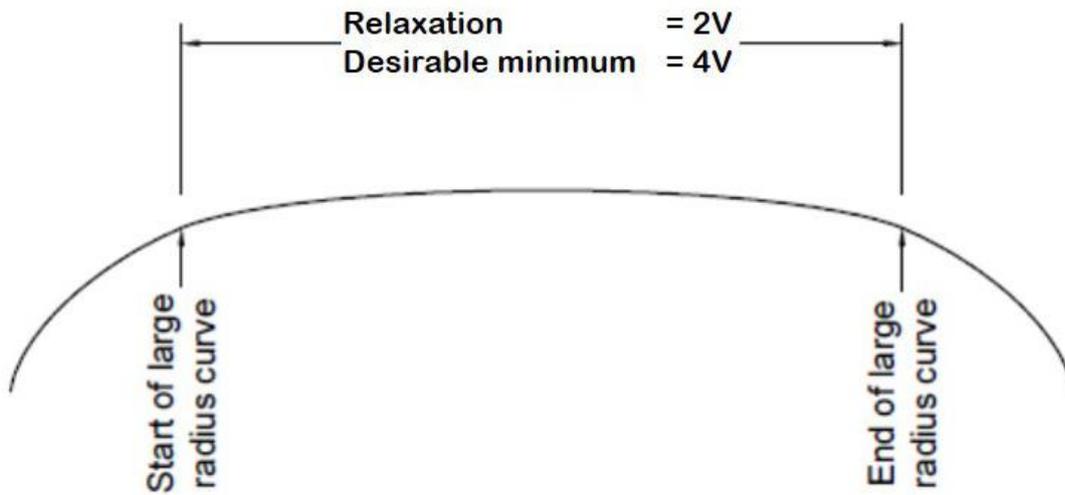
A horizontal broken back curve consists of two curves in the same direction joined by a short straight or large radius curve less than $2V$ in length, where V is the Design Speed (km/h). The provision of horizontal broken back curves shall be avoided as without sufficient separation between the curves it is virtually impossible to provide the correct amount of superelevation throughout. They also create confusion as drivers do not expect successive curves to be in the same direction and create an unpleasant view of the roadway. To avoid issues in relation to horizontal broken back curves, the Desirable Minimum length to be achieved between curves shall be $4V$, a length of $2V$ can be applied as a Relaxation as illustrated in Figure 3.2.

Where the length of the straight or curve between the two curves is less than $2V$ the designer shall either replace the horizontal broken back curve with a single curve or increase the separation length to $2V$.

Figure 3.2: Horizontal Broken Back Curves



Horizontal Broken Back Curves (joined by straight)



Horizontal Broken Back Curves (joined by large radius curve)

3.12 The Effect of Sight Distance at Horizontal Curves

3.12.1 Stopping Sight Distance

When the road is in a cutting, or at bridge crossings, it may be necessary to widen central reserves, verges or increase bridge clearances to ensure that the appropriate Stopping Sight Distance is not obstructed. Figure 3.3 shows the maximum central offset required for a single carriageway 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 VRS, would be required to maintain Desirable Stopping Sight Distances on horizontal radii below Desirable Minimum. Where a road is on an 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.

3.12.2 Full Overtaking Sight Distance

Figure 3.4 shows the maximum central offset required for a single carriageway 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.

3.13 Rate of Change of Cross-Section Width

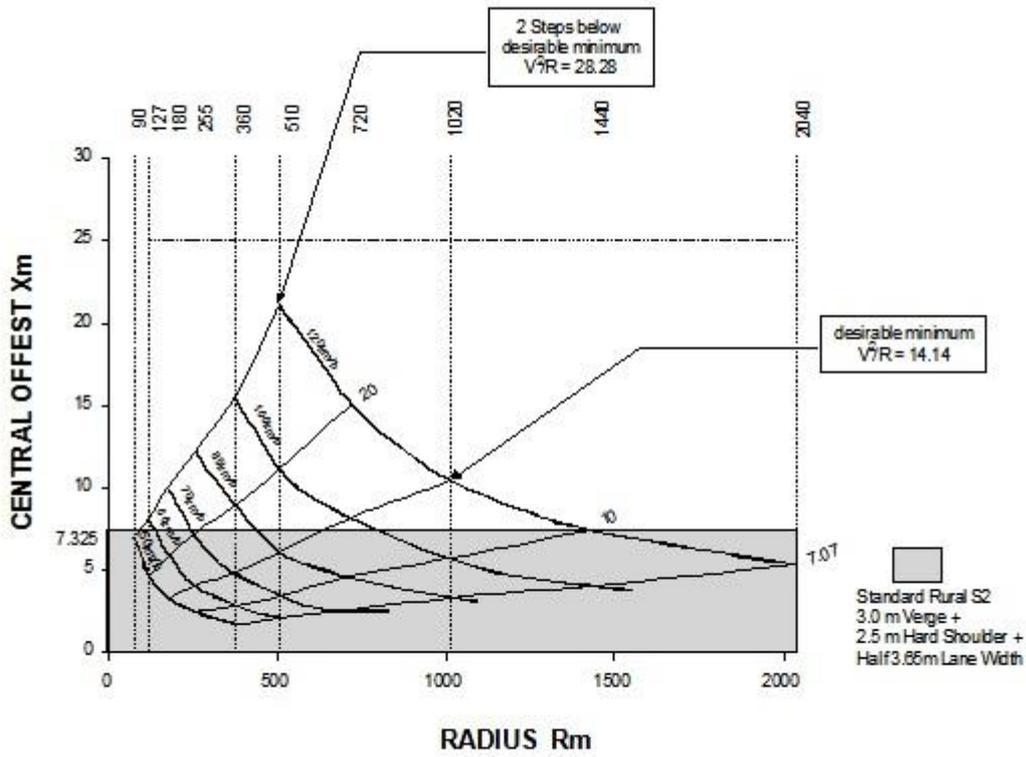
Numerous changes in the cross-section are not desirable and a consistent width is to be preferred. Notwithstanding this, over the length of a route variations in the cross-section are likely to be required.

Table 3.2 shows the required mainline rate of change in width. In all cases where Table 3.2 is used, the transition taper should correspond with the higher design speed of the two adjoining links under consideration. See DN-GEO-03060 for the layout of Merges and Diverges.

Table 3.3: Mainline Rate of Change of Width

Design Speed km/h	Transition taper
60	1/30
70	1/35
85	1/45
100	1/60
120	1/70

Figure 3.3: Verge Widening for Desirable Minimum Stopping Sight Distance



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

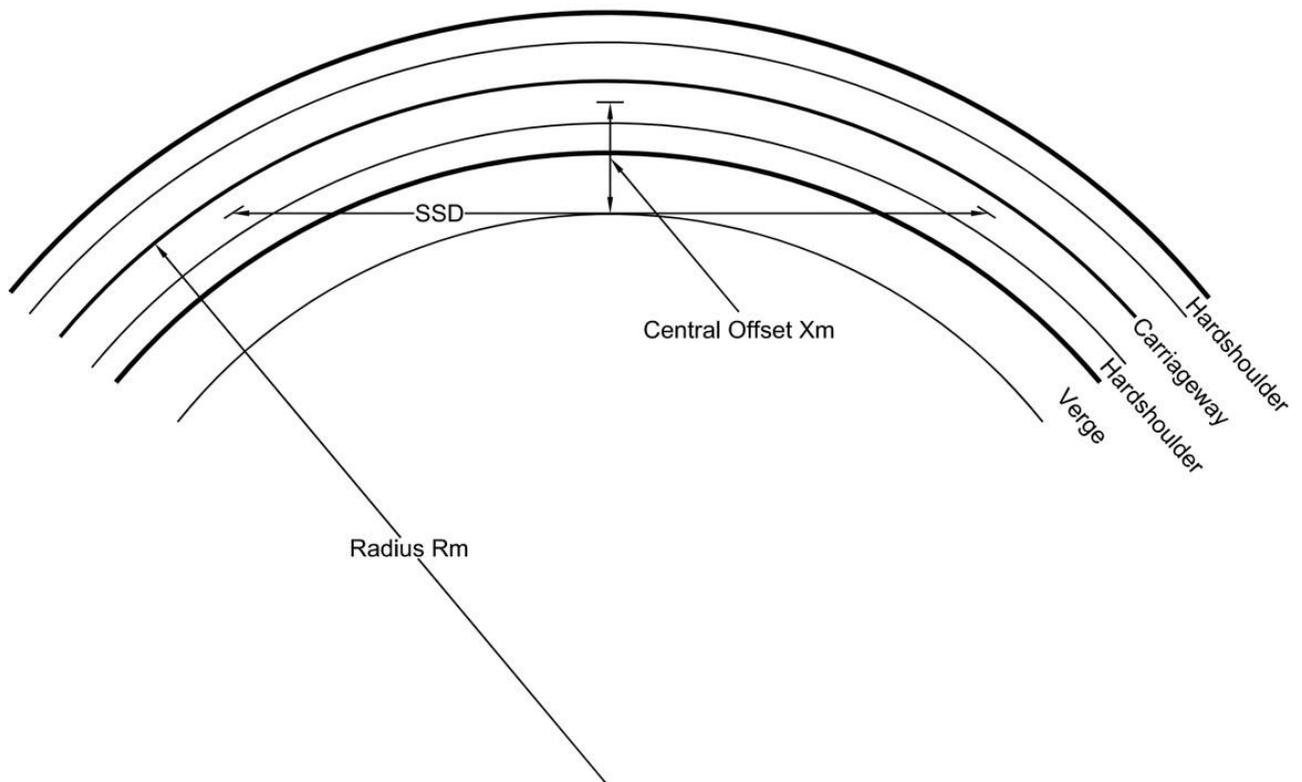
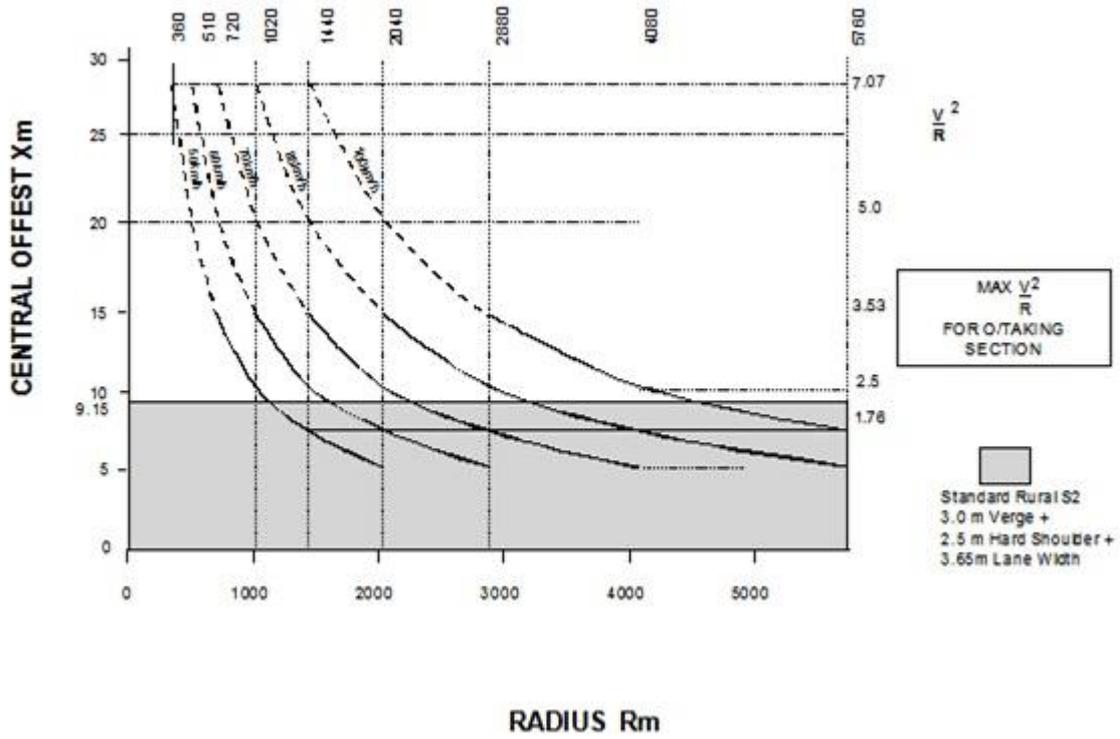
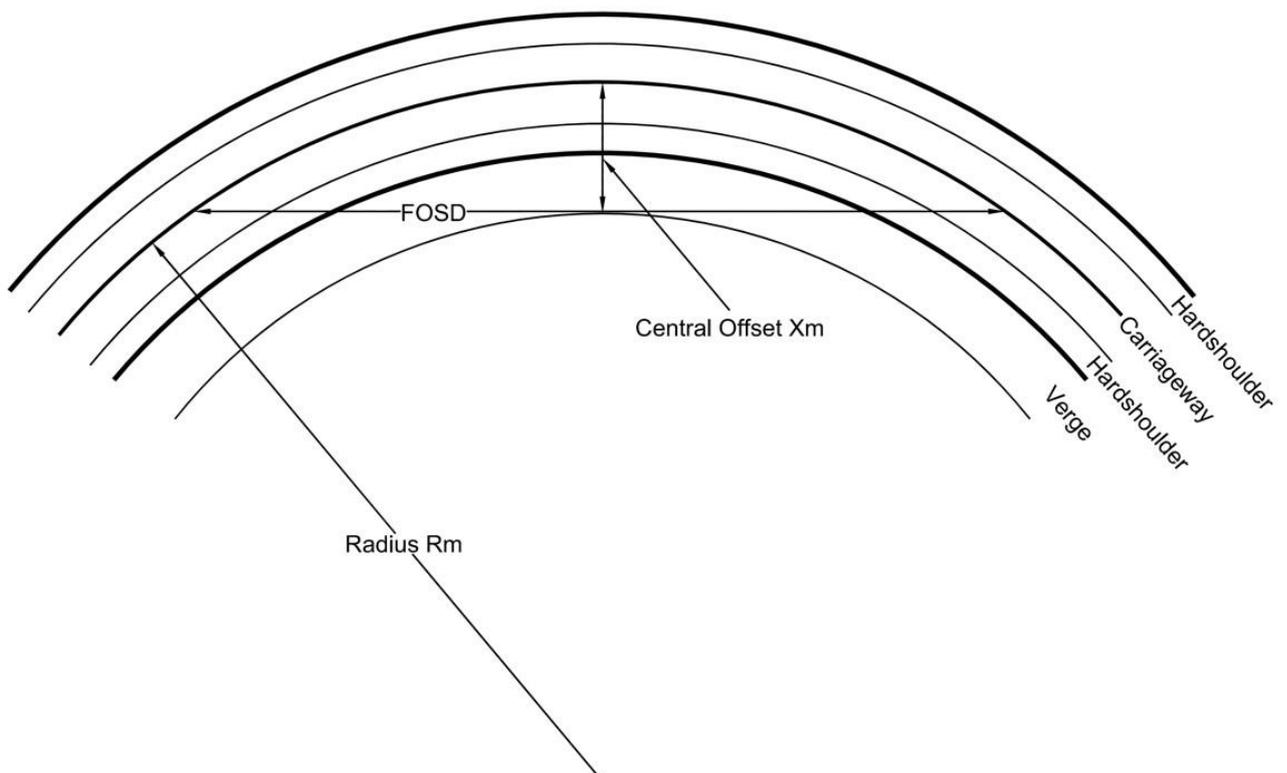


Figure 3.4: Verge Widening for Full Overtaking Sight Distance



The values of X are the maxima and apply where FOSD < curve length.



4. Vertical Alignment

4.1 Gradients for Motorised Vehicles

4.1.1 Maximum Gradients

The Desirable Maximum gradient for design shall be as outlined in Table 4.1.

Table 4.1 Desirable Maximum Gradients

	Desirable Max Grade
Motorways and Type 1 Dual Carriageways	3%
Type 2 and 3 Dual Carriageways*	4%
Type 1 and 2 Single Carriageways	5%
Type 3 Single Carriageways	6%
Other Local Roads	7%

*For on-line upgrading of existing roads to Type 3 Dual Carriageways, a Relaxation to 6% is acceptable for the Maximum Grade.

However, in hilly terrain steeper gradients will frequently be required, particularly where traffic volumes are low.

4.1.2 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 collisions. 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 those outlined in Table 4.2.

Table 4.2 Maximum Gradients Hilly Terrain

	Main x Grade with Relaxation
Motorways and Type 1 Dual Carriageways	4%
Type 2 and 3 Dual Carriageways*	5%
Type 1 and 2 Single Carriageways:	6%
Type 3 Single Carriageways	7%
Other Local Roads	8%

*For on-line upgrading of existing roads to Type 3 Dual Carriageways, a Relaxation to 6% is acceptable for the Maximum Grade.

4.1.3 Minimum Gradients

For effective drainage with kerbed roads a minimum gradient of 0.5% shall 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. Longitudinal drainage paths must be provided by combined kerb and drainage systems with minimum gradients of 0.5%. Combined kerb and drainage systems may be avoided by using surface water channels, filter drains or over the edge drainage where kerbs are inappropriate, e.g. in rural areas.

In areas of superelevation to nominal camber roll-overs, the minimum longitudinal gradients may need to be as high as 2% to provide adequate drainage for the road pavement surface. Once the alignment is fixed, roll over areas shall be checked by triangulation of three dimensional road models to ensure that no point on the road pavement has a gradient of less than 1%. These models shall take into account pavement construction tolerances. For further advice refer to Section 3.6 and see Chapter 11.

4.2 Gradients for Cycle Facilities

The overall gradient along a cycle route is an important design consideration. Comfort and attractiveness of a cycle facility will be greatly increased if the route follows a shallow gradient.

The physical limitations of a cyclist to climb steep inclines and maintain speed, and their ability to stop when descending steep inclines are impacted by the gradient of the cycle facility.

Table 4.3 presents the maximum vertical gradients on a cycle facility.

Table 4.3 Gradient Requirements for Cycle Facilities

	Gradients
Desirable Maximum	3%
One Step Below Desirable Maximum	5%
Two Steps Below Desirable Maximum	10%

4.3 Vertical Curves

4.3.1 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 the relevant Design Speed. The use of the permitted vertical curve parameters will normally meet the requirements of visibility. However Stopping Sight Distance shall 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.

4.3.2 K Values

Curvature shall be derived from the appropriate K value in Table 1.3. 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:-

- Desirable Min = $182 \times 5 = 910\text{m}$
- One step below Des Min = $100 \times 5 = 500\text{m}$.

Where the Desirable Minimum curve length calculated is less than the absolute minimum curve length indicated in Table 1.3 for dual carriageways and motorways, the absolute minimum curve length shall be used to avoid localised kinks in the vertical alignment.

4.3.3 Crest Curves

The two factors that affect the choice of crest curvature are visibility and comfort. At all Design Speeds in Table 1.3 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.

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 Chapter 7, Non-overtaking Crests).

4.3.4 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° 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 1.3.

4.3.5 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.

4.3.6 Hidden Dips

The vertical alignment design of a road should avoid the creation of Hidden Dips in the upcoming road layout, as this can cause hazardous overtaking sections of road. Chapter 7 provides guidance on vertical alignment design to prevent the design of such situations.

4.4 Relaxations in Vertical Alignment

4.4.1 Crest Curves

In the circumstances described in Section 1.8, 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: 1 step

Single and Dual Carriageways: 2 steps

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

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.

The scope for Relaxations shall be reduced by 1 Design Speed step immediately following an Overtaking Section on single carriageway roads.

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

Relaxations below Desirable Minimum are not permitted on the immediate approaches to junctions as defined in Chapter 1.

4.4.2 Sag Curves

In the circumstances described in Section 1.8, 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: 1 step

Single and Dual Carriageways: 2 steps

However, in the circumstances described in the following paragraphs, the scope for Relaxations shall be reduced as described.

The scope for Relaxations shall be reduced by 1 Design Speed step immediately following an Overtaking Section on single carriageway roads (see Chapter 7, Overtaking Sections).

Relaxations more than one Design Speed step below Desirable Minimum are not permitted on the immediate approaches to junctions as defined in Chapter 1.

5. Climbing Lanes

5.1 Introduction

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 carriageway roads 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.

This chapter outlines the design principles and other factors which should be considered by designers when introducing climbing lanes to new or existing carriageways.

A climbing lane should only be considered if it is needed and can be justified as outlined in this chapter.

Priority junctions and direct accesses onto National Roads shall not be located on climbing lane sections. Refer to DN-GEO-03060 standard for further details.

In some cases a detailed scheme appraisal, as outlined in the following section, may provide justification for a climbing lane even when the above criteria are not met.

5.2 Scheme Appraisal

Consideration of the need for and justification of a climbing lane shall 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:

- a) Economy: reduction in travel times, vehicle operating costs and journey time reliability;
- b) Environment: effects on environmental intrusion, reduction in driver frustration, noise and air pollution;
- c) Safety: reduction in collisions.

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 effects of long steep gradients on the downhill carriageway should also be considered.

5.2.1 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.

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

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.

5.2.2 Economy

The criteria for provision of climbing lanes on single carriageway roads outlined in this chapter will determine if a climbing lane is economically justified in most cases, provided there are no high cost elements along the relevant length of road.

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

5.2.3 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 may 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.

Driver frustration should form part of the environmental appraisal process for single carriageway roads. Whilst useful engineering data relating to driver frustration is scarce, careful consideration should be given to the provision of adequate overtaking opportunities as described in detail in Chapter 7.

5.2.4 Safety

Climbing lanes help to relieve driver frustration and provide a safer overtaking environment, particularly on single carriageway roads.

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

Where the criteria for provision of climbing lanes outlined in the following section 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 HGVs. 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.

5.3 Single Carriageways

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 Figure 5.3). As the cost of provision of the climbing lane in such cases will be small, climbing lanes shall generally be provided on gradients greater than 2% wherever the risen height (H) exceeds 15m and the traffic flow will exceed 6,000 Annual Average Daily Traffic (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.

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

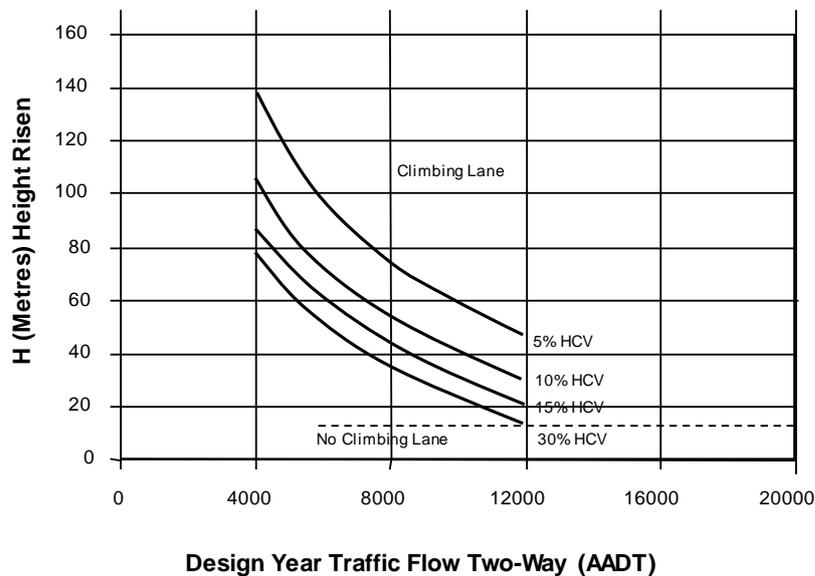
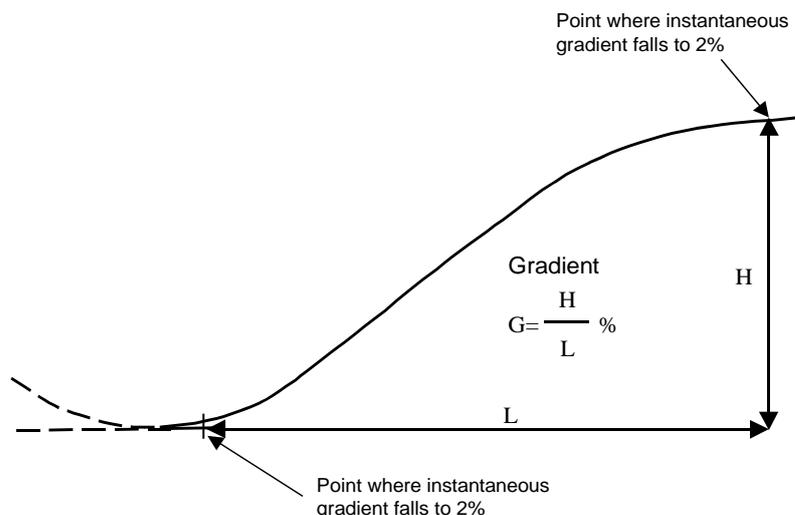


Figure 5.2: Definitions for Climbing Lanes



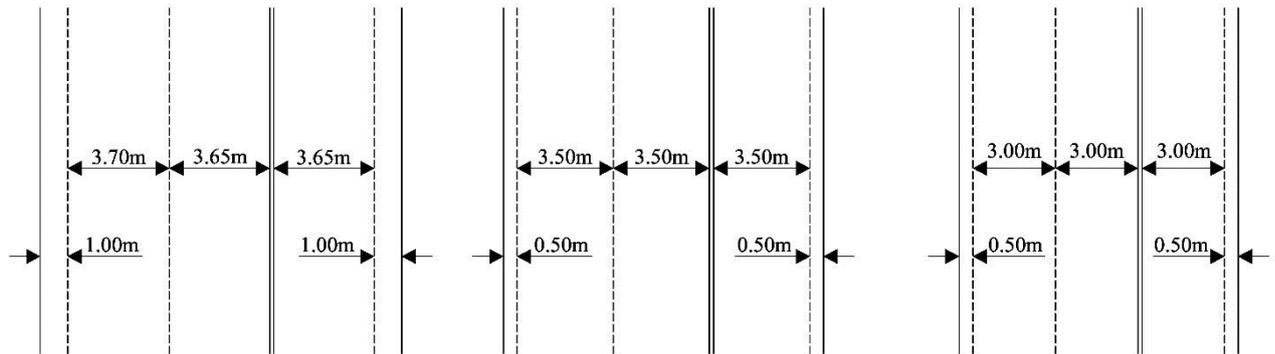
5.3.1 Length of Climbing Lanes

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 shall 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 collision risk that is exacerbated by bends in the road. High collision rates are associated with average bendiness (irrespective of the climbing lane length) in excess of 50degs/km.

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.

Lane Widths: The cross-sections of single carriageways including climbing lanes shall be as shown in Figures 5.3(a) to (c).

Figure 5.3: Climbing Lanes on Single Carriageways



(a): On Type 1 Single Carriageway

(b): On Type 2 Single Carriageway

(c): On Type 3 Single Carriageway

Notes:

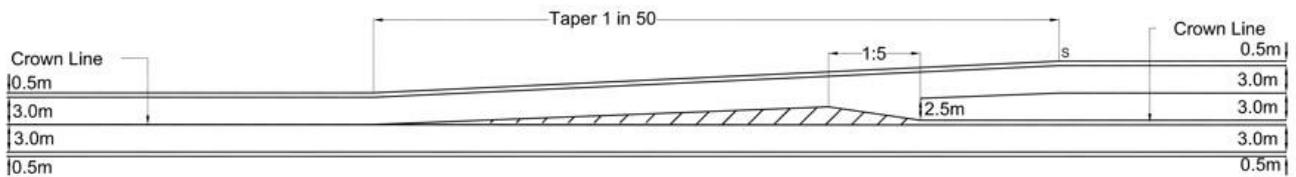
1. For standard road cross-sections, see DN-GEO-03036 and Standard Construction Details for Road Type and Cross Section.

5.3.2 Layout at Start of Climbing Lane

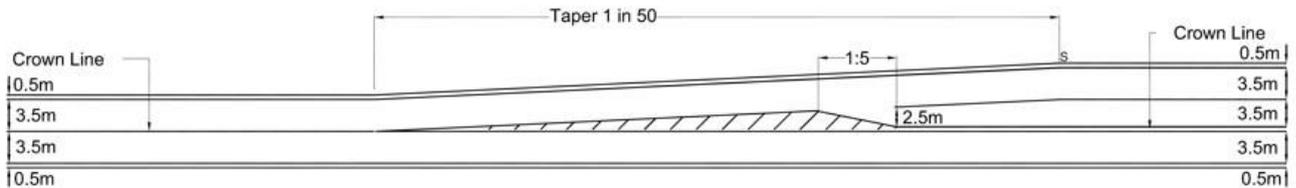
The full width of the climbing lane shall be provided at a point 'S', 100m uphill from the 2% point of sag curve, and preceded by a taper of 1 in 50, as shown in Figure 5.4. The length of the taper shall be such that traffic in the lane which is required to experience the greatest lateral shift over the length of the taper does so at 1 in 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 in 40.

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

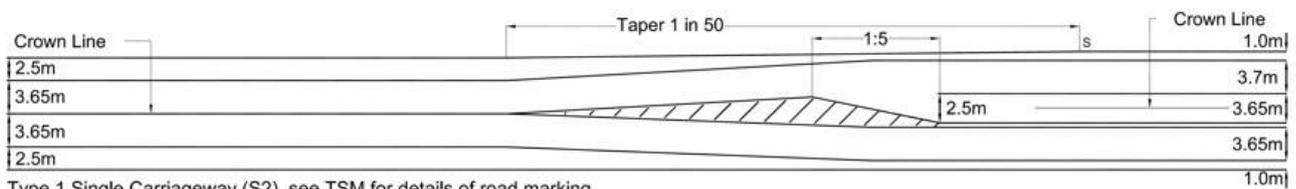
Figure 5.4: Start of Climbing Lane



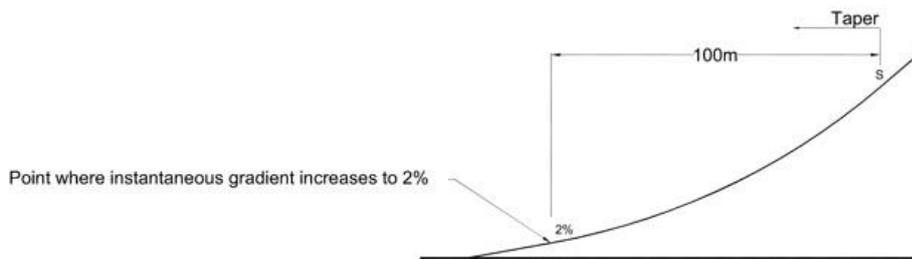
Type 3 Single Carriageway (S2), see TSM for details of road marking



Type 2 Single Carriageway (S2), see TSM for details of road marking



Type 1 Single Carriageway (S2), see TSM for details of road marking



NOTES: (1) S: Start point of Climbing Lane
(2) Widening of road pavement may be centred or on one side only for both road types

5.3.3 Layout at End of Climbing Lane

The full width of the climbing lane shall be maintained until a point 'F', at least 200m 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 in 150 for the lane marking which has the greatest lateral shift, as shown in Figure 5.5. On a Type 2 single carriageway, the full width of the paved surface (including hard strips) of the climbing lane section shall be maintained up to the end of the taper and for a distance of 200m, followed by a taper of 1 in 70 to the normal paved width (see Figure 5.5).

The alignment at the end of the climbing lane shall place the onus on the driver in the right hand lane to re-join 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 in 120 as a Relaxation. Advance warning signs shall be provided as required by the TSM. Care should be taken to ensure that the return to a single lane does not coincide with junctions or a sharp curve.

Consideration shall 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 the climbing lane is part of an overall route strategy for overtaking (see the Overtaking Value section of Chapter 7) and the climbing lane is extended to maximise overtaking opportunities;
- c) If HGVs or slow moving vehicles currently cause problems at the end taper of an existing climbing lane, the lane may be extended where HGVs are picking up speed as the road begins to descend from the crest of the hill.

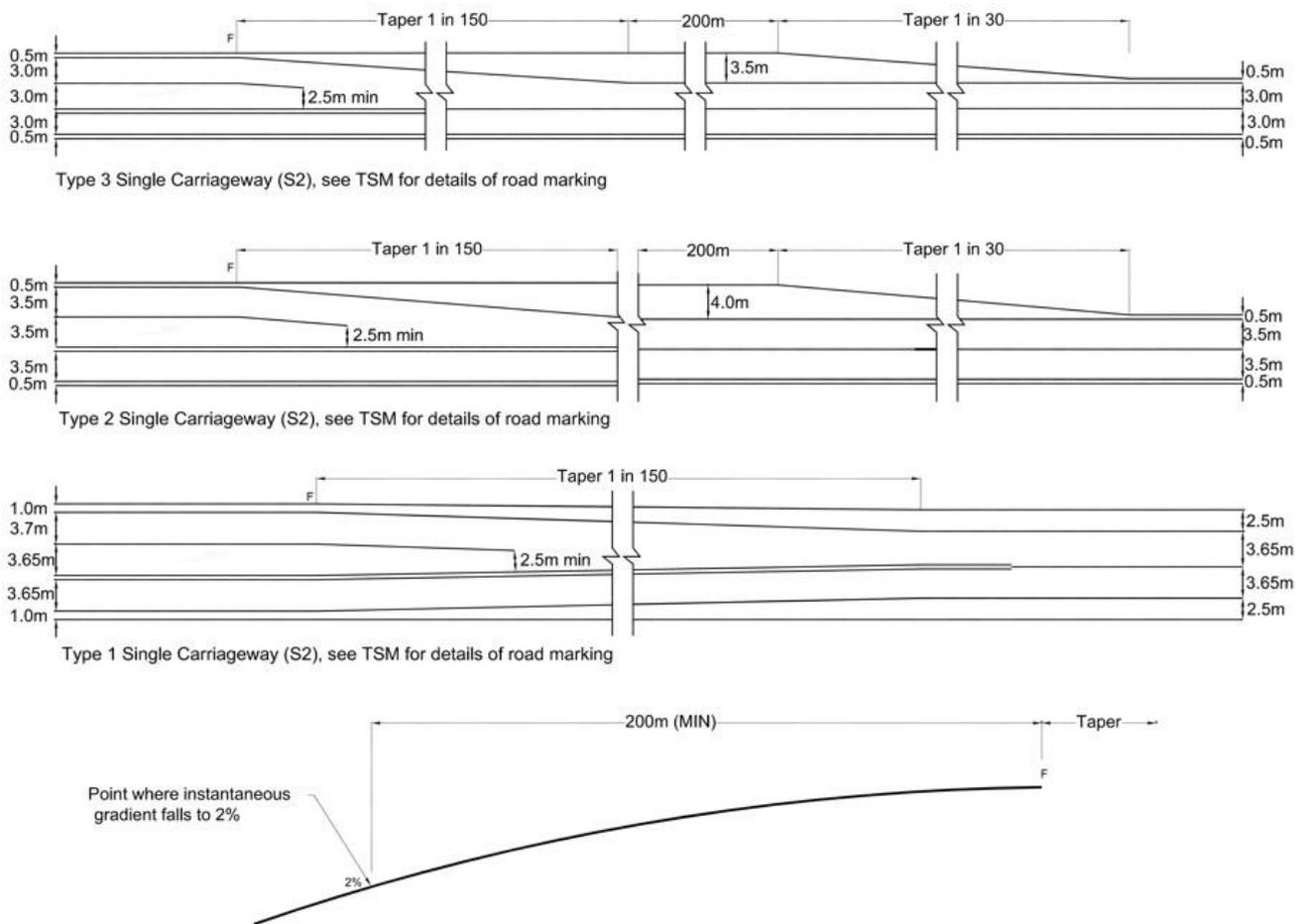
Where the climbing lane is extended the taper arrangement at the end of the lane shall be as shown in Figure 5.5.

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 shall be continued to the roundabout.

5.3.4 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

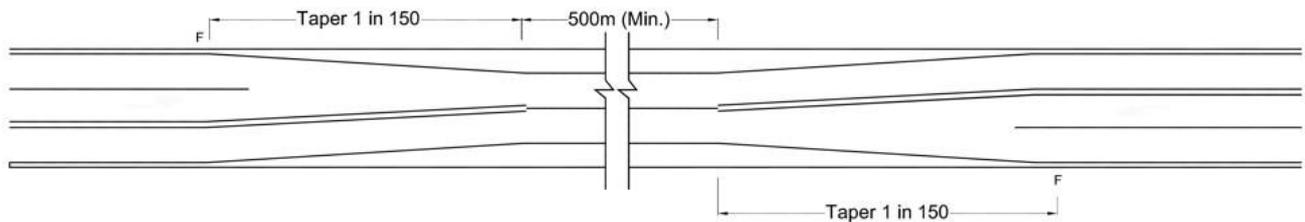


NOTE: (1) F: Finish point of Climbing Lane

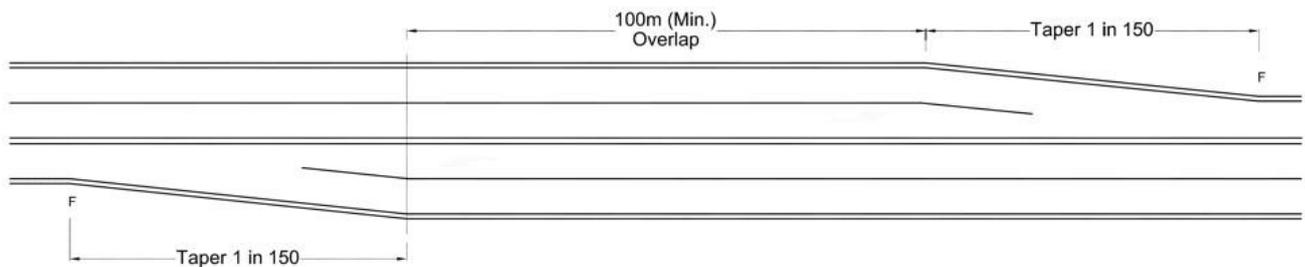
5.3.5 Layout at crests

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 more than 500m in length refer to the layout shown in Figure 5.6 (a). If the length is less than 500m, then 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 5.6 (b). The overlap of the full width climbing lanes shall not be less than 100m. The treatment of lanes, hard shoulders and hard strips shall follow Figures 5.3, 5.4 and 5.5 for the appropriate carriageway standard.

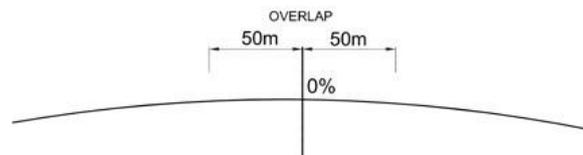
Figure 5.6: Crest with Two Climbing Lanes



(a) Crest Curve Between Separated Climbing Lanes - See TSM for details of road marking



(b): Crest Curve With Overlapping Climbing Lane - See TSM for details of road marking



NOTE: (1) F: Finish point of Climbing Lane

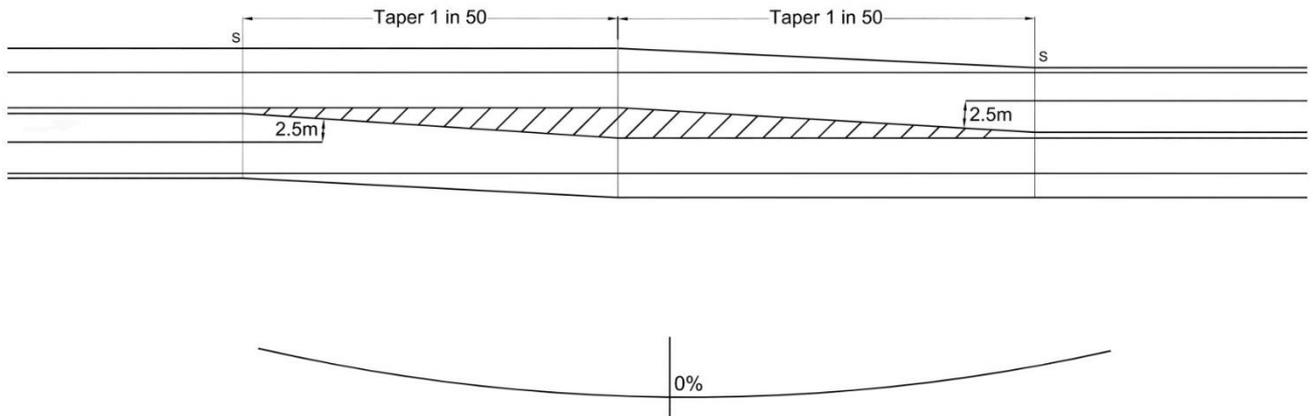
5.3.6 Layout at Sags

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 shall follow Figures 5.3, 5.4 and 5.5 for the appropriate carriageway standard.

5.3.7 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 Desirable Minimum K value.

Figure 5.7: Sag between Two Climbing Lanes



NOTES: (1) S: Start point of Climbing Lane
(2) See TSM for road marking

5.3.8 Marking of Climbing Lanes

Climbing lanes should be marked in accordance with the Traffic Signs Manual. In general, a three-lane hill is marked with a lane line separating the two uphill lanes and a double white line system separating the uphill lanes from the downhill lane. The double white line system will feature a continuous white line for uphill traffic in all cases and the downhill traffic line should be designed in accordance with the Traffic Signs Manual.

5.4 Type 1 and 2 Dual Carriageways and Motorways

Climbing lanes are generally not required on rural Type 1 and 2 Dual Carriageway roads and Motorways as vehicles have more opportunities to overtake. Climbing lanes should only be provided on these type of roads in agreement with TII.

5.5 Type 3 Dual Carriageways

5.5.1 Criteria for Provision and Lane Widths

On Type 3 Dual Carriageways, a climbing lane consists of the provision of a two-lane 'passing lane' section over the requisite length of road. Thus, the road is arranged such that the uphill carriageway is the side with two lanes. On Type 3 Dual Carriageway roads, on hills with gradients ($G = 100H/L$) greater than 2% and longer (L) than 500m a climbing lane will normally be justified if the height risen (H) is greater or equal to the value shown in Table 5.1 for the relevant traffic flow.

Table 5.1: Justification for Climbing Lane on Type 3 Dual Carriageway

Design Year Traffic Flow Two-Way (AADT)	Height Risen (H)
8,000 – 11,000	20m
> 11,000	15m

5.5.2 Layout at Start and End of Climbing Lane

Where the above criteria are met, a two-lane uphill section should be provided over the relevant length of the hill between points 'S' and 'F' as described in this chapter. The general principles of the climbing lane should be in accordance with the requirements for single carriageway roads above, but the cross-section, road markings and the geometric layout at each end shall be in accordance with the requirements for Type 3 Dual Carriageways. The alignment at the end of a two-lane section (including at a climbing lane) on a Type 3 Dual Carriageway, shall place the onus on the driver in the right hand lane to re-join the continuing lane.

5.5.3 Length of Climbing Lanes

Where the length of the climbing lane on a Type 3 Dual Carriageway is such that the one-lane downhill section would be longer than 3km, a section of two-lane carriageway should also be provided for downhill traffic. This will result in a length with the cross-section of a Type 2 Dual Carriageway. The two-lane downhill section needs to be long enough to provide a reasonable overtaking opportunity.

5.5.4 Co-ordination with Vertical Alignment

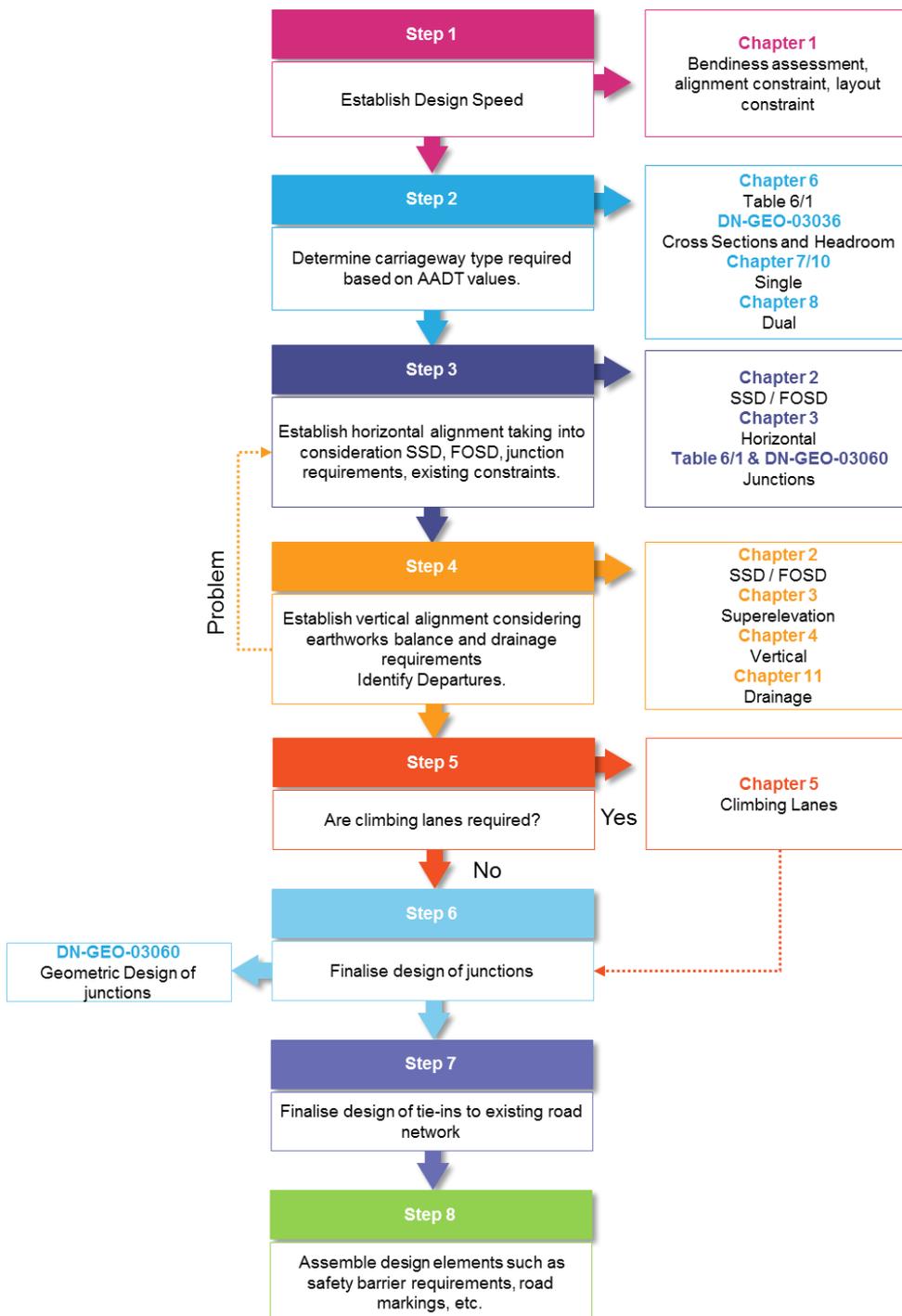
Even if the criterion for climbing lane provision on Type 3 Dual Carriageways are not met, the vertical alignment design should be coordinated so that the two-lane sections function as climbing lanes. Wherever practicable therefore, two-lane sections should be arranged to coincide with up gradients to allow more vehicles to overtake in a given length and hence reduce driver frustration.

6. Introduction to Coordinated Link Design

6.1 General

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 and sustainability effects. Single carriageway design is given particular emphasis due to the provision for overtaking. Figure 6.1 describes the general steps to be taken in coordinating the various road design elements.

Figure 6.1: Coordinated link design



6.2 Rural Roads

A general guide to the layout features appropriate for various types of road is given in Table 6.1. 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 DN-GEO-03036 and the relevant TII Publications Standard Construction Details. Junctions shall be designed in accordance with DN-GEO-03060.

The vehicle flows (in terms of AADT given in Table 6.1) represent the approximate two-way flows corresponding to Level of Service D in reasonably level terrain. At Level of Service D speeds begin to decline slightly with slight increase of flows and density begins to increase somewhat more quickly. Freedom to manoeuvre within the traffic stream is more noticeably limited, and the driver experiences reduced comfort levels.

6.3 Rural Cycle/Pedestrian Facilities

The required cycle/pedestrian facilities associated with each road type are also shown in Table 6.1. The provision or non-provision of cycle/pedestrian facilities shall be based upon the requirements outlined in Table 6.1 and shall not dictate the cross-section type of the carriageway. A Type 1 Single Carriageway shall only be provided where required based on the projected traffic flows and to maintain route consistency.

Cycle/pedestrian facilities incorporated within the verge of rural roads shall be designed in accordance with DN-GEO-03036. Rural Cycleways remote from the road shall be designed in accordance with DN-GEO-03047.

Table 6.1: Recommended Rural Road Layouts

Type of Road 1.	Capacity ² (AADT) for Level of Service D	Edge Treatment	Access Treatment	Junction Treatment at Minor Road	Junction Treatment at Major Road
Type 3 Single (6.0m) Carriageway (National Secondary Roads Only)	5,000	0.5m hard strip. Cycle Facilities Footways	Minimise number of accesses to avoid standing vehicles and concentrate turning movements.	Simple Priority Junctions ⁵	Priority junctions, with ghost islands where necessary ⁵ or roundabouts.
Type 2 Single (7.0m) Carriageway	8,600	0.5m hard strips. Cycle Facilities Footways	Minimise number of accesses to avoid standing vehicles and concentrate turning movements.	Priority junctions, with ghost islands where necessary ⁵ .	Priority junctions, with ghost islands ⁵ roundabouts ³ , compact grade separation where necessary.
Type 1 Single ⁴ (7.3m) Carriageway	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 ⁵ .	Ghost islands ⁵ or roundabouts or, compact grade separation where necessary
Type 3 Dual ^{3,4} (7.0m + 3.5m) Divided 2+1 lanes Primarily for retro fit projects	14,000	0.5m hard strips. Cycle Facilities Footways where required.	Minimise the number of accesses to avoid standing vehicles and concentrate turning movements.	Restricted number of left in/left out or ghost island priority junctions. ^{5,7}	Priority junctions ^{5,7} , u-turn facility with right turn ⁵ , at-grade roundabouts, compact grade separation
Type 2 Dual ^{3,4} Divided 2 +2 Lanes (2x7.0m) Carriageways.	20,000	0.5m hard strips Cycle Facilities Footways	No gaps in the central reserve. Left in / Left out	No gaps in the central reserve. Left in / Left out	At-grade roundabouts and compact grade separation
Type 1 Dual ⁴ Divided 2+2 Lanes ⁶ (2x7.0m) Carriageways	42,000	2.5m hard shoulders	No gaps in the central reserve. Left in / Left out	No gaps in the central reserve. Left in / Left out	At-grade roundabouts and full-or compact grade separation.
Motorway Divided 2 +2 Lane ⁶ (2X7.0m)	52,000	2.5m hard shoulders	Motorway Regulations	No gaps in the central reserve.	Motorway standards Full-grade separation.
Wide Motorway Divided 2+2 Lane (2X7.5m)	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 DN-GEO-03036 and the relevant TII Publications Standard Construction Details.
2. Capacity figures are indicative for general guidance. The appropriate cross section shall be selected with reference to the TII Project Appraisal Guidelines.
3. The Type 3 Dual Carriageway cross-section shall only be considered where an existing road is to be upgraded on-line. The Type 2 Dual Carriageway cross-section shall be utilised for offline alignments.
4. This road type may be used as an Express Road with the following conditions - access and junction control.
5. This junction type is not permitted on Express Roads.
6. Should the traffic assessment indicate that more than 2 lanes are required in each direction for a Standard Motorway or Type 1 Dual Carriageway, the additional lanes shall be a minimum width of 3.5m subject to curve widening.
7. Right turns off the Major Road only permitted at priority junctions located at single lane sections of Type 3 Dual Carriageways, right turns onto the Major Road are not permitted (see DN-GEO-03060).

7. Two-Way Single Carriageway Roads

7.1 General Principles

Chapter 7 shall be used for the design of two-way single carriageway roads up to 7.3m wide (carriageway width) with the objectives of safety and uncongested flow in mind. Other aspects that should be considered by the designer include:

- a) Continuous flowing alignments, (Section 7.7, Horizontal Curve Design);
- b) Treatment of grade separation on single carriageways (Section 7.10, Junction Strategy);
- c) Single carriageway alternating with Dual Carriageway (Section 7.2.4, Dual Overtaking Sections and Section 7.11, Changes in Carriageway Width);
- d) Staged construction (Section 7.14, Staged Construction).

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.

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. Clearly identifiable Overtaking Sections, including climbing lanes, interspersed with clearly non-overtaking sections, will frequently result in a more cost effective design. The trade-off between the construction and user costs, including collisions, should be tested for alternative alignments by cost/benefit analyses.

In the coordination of vertical and horizontal alignments, many of the general principles contained in Chapter 8 for 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.

7.2 Overtaking Sections

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 comprise of:

- 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 as defined later in this Chapter, to define the method by which the lengths of Overtaking Sections are assessed, and the method of measurement for each category of Overtaking Section as described in the following paragraphs. In general,

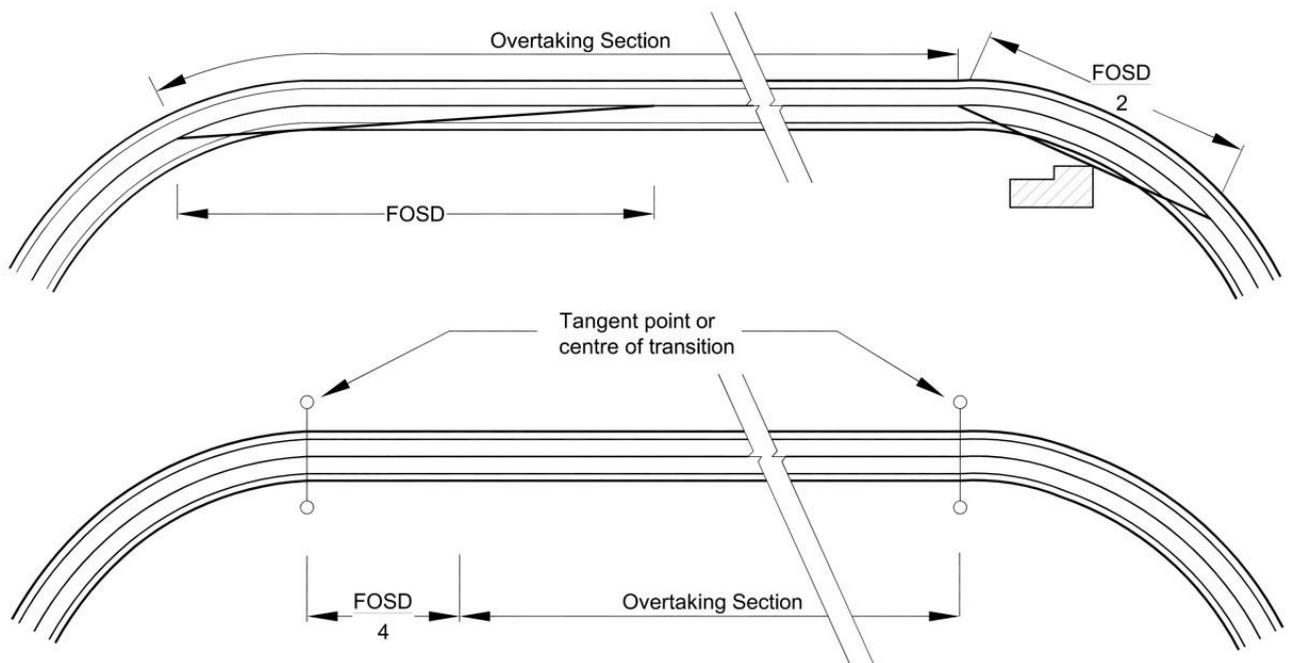
Overtaking Sections will commence whenever either FOSD on a straight (or nearly straight) or right hand curve is achieved, or the width provision is sufficient for overtaking without crossing the dividing line between opposing lanes. They will terminate either at a point where sight distance reduces 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 is as described in sub-section 7.2.3).

The method of measurement described in the following paragraphs is based upon curvature/visibility relationships for Type 1 Single Carriageway roads. The decreased road width of a Type 2 and 3 Single Carriageway provides reduced flexibility for overtaking; however the following design rules should still be used to achieve an optimal overtaking design. It should be noted that the method of measurement of the Overtaking Value differs from the methodology adopted within the Traffic Signs Manual (TSM) for the provision of solid, warning and broken white lines. For the requirements for road markings refer to the TSM.

7.2.1 Two-lane Overtaking Sections

Two-lane Overtaking Sections are sections of single two lane carriageways 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 7.1) and right hand curves, the commencement of which are provided with at least FOSD. The Two-lane Overtaking Section, which is shown in Figure 7.1, is measured as follows:

Figure 7.1: Two-lane Overtaking Sections



Refer to the TSM for details of Road Markings

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.

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 Section 7.4).

Table 7.1: Minimum Radii for Two-lane Overtaking Sections

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

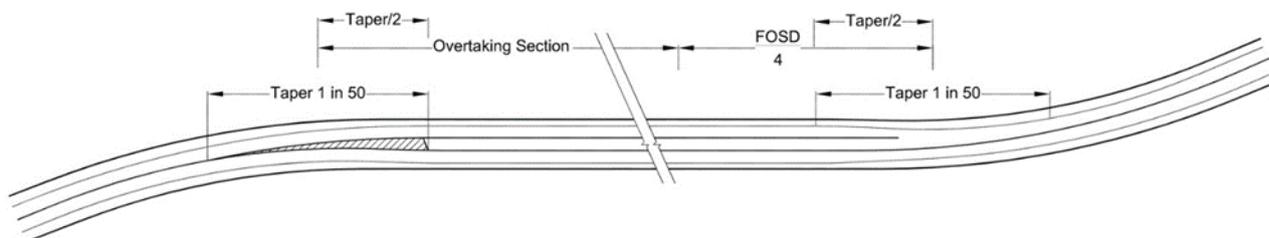
7.2.2 Climbing Lane Overtaking Sections

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 system (either double continuous or continuous/broken). The Climbing Lane Overtaking Section, which is shown in Figure 7.2, is measured as follows:

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

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 7.2: Climbing Lane Overtaking Sections



Note: see TSM for details of road markings

7.2.3 Downhill Overtaking Sections at Climbing Lanes

Downhill Overtaking Sections at Climbing Lanes are sections of a single downhill lane, opposite a climbing lane. They consist of straight or nearly straight sections, and right hand curves with radii greater than those shown in Table 7.2. Downhill Overtaking Sections at Climbing Lanes are 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.

Table 7.2: Minimum Radii of Right Hand Curves for Downhill Overtaking Sections at Climbing Lanes

Design Speed km/h	100	85	70
Minimum Radius m	2880	2040	1440

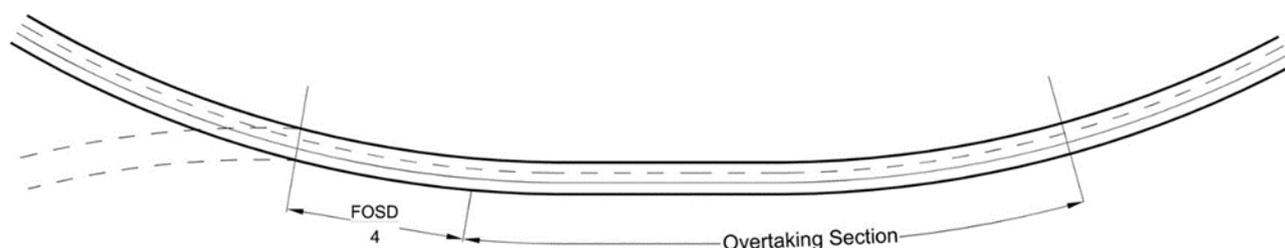
The sight distance naturally occurring within the normal road boundaries at the radii shown in Table 7.2 will be sufficient for downhill overtaking, and thus, for Downhill Overtaking Sections at Climbing Lanes. Verges shall not be widened to give FOSD. However, these sections should only be considered 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 1.3 for FOSD Overtaking Crest K Value.

The Downhill Overtaking Section at a Climbing Lane, which is shown in Figure 7.3, is measured as follows:

Commencement: The point where the right hand curve radius achieves the requisite value from Table 7.2.

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 earlier.

Figure 7.3: Downhill Overtaking Sections at Climbing Lanes



7.2.4 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 overtaking sections described earlier. Single 4-lane Overtaking Sections (where space is limited) should be considered equivalent to Dual Overtaking Sections in terms of assessment of overtaking.

7.3 Non-overtaking Sections

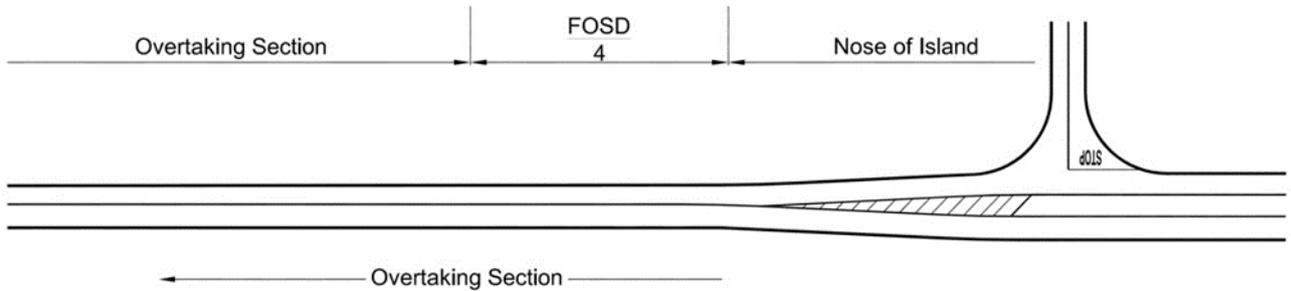
Non-overtaking Sections are all lengths of single carriageway roads that do not conform with the requirements of Section 7.2. These are generally left or right hand curves on two-lane sections, single downhill lanes opposite climbing lanes, or approaches to junctions (see also Non-overtaking crests section later in this Chapter).

7.4 Obstructions to Overtaking

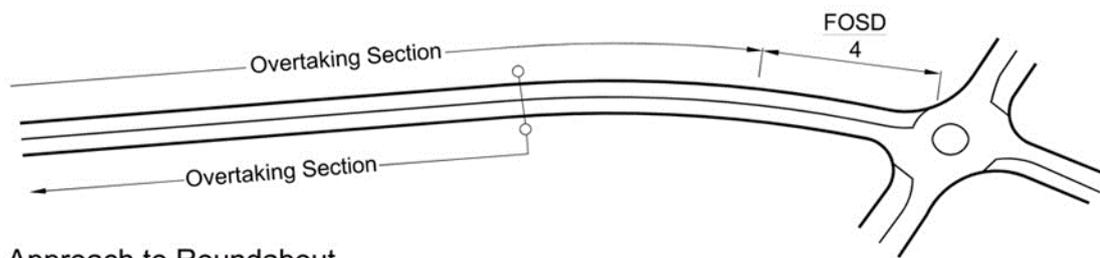
Priority junctions with ghost islands (with mandatory or non-regulatory hatch markings as per the Traffic Signs Manual) and roundabouts shall be considered as obstructions to overtaking if they are sited within an otherwise Overtaking Section. The Overtaking Section shall terminate at a distance of FOSD/4 prior to the nose of the ghost or physical island, or the roundabout Yield line, as shown in Figure 7.4. 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 described earlier in this Chapter.

On schemes involving online realignment, simple junctions and accesses with no central ghost or physical islands can be ignored for the purpose of determining Overtaking Sections. For new offline schemes however, these shall be included in the determination.

Figure 7.4: Obstructions to Overtaking: At Grade Junctions



(a) Approach to Priority junction (with Ghost or Solid Island)

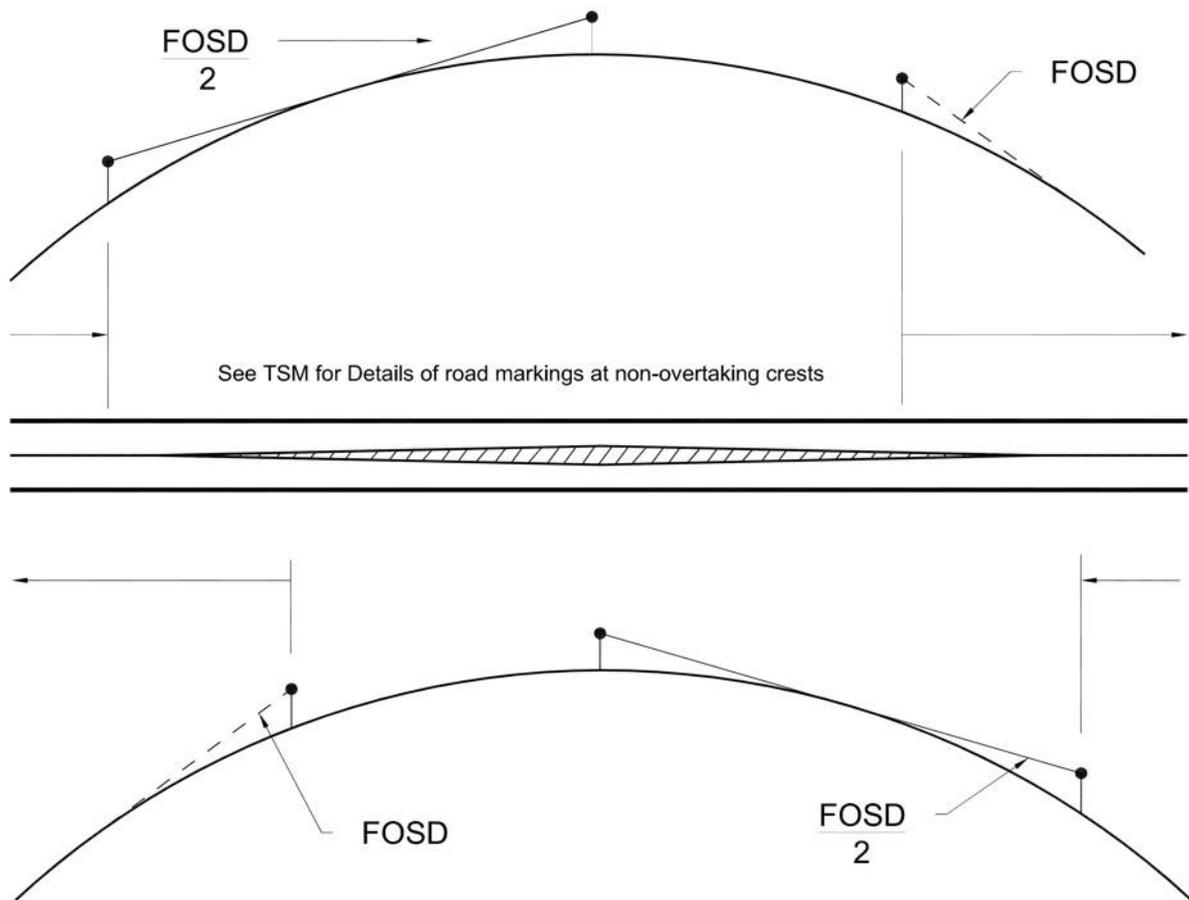


(b) Approach to Roundabout

7.5 Non-overtaking Crests

A crest with a K value less than that shown in Table 1.3 for FOSD Overtaking Crest K Value shall be considered as a Non-overtaking crest. The Overtaking Section within which it occurs shall be considered to terminate at the point at which sight distance has reduced to $FOSD/2$, as shown in Figure 7.5. 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. Where Desirable Minimum crest K values are introduced on single carriageway roads, designers shall ensure that the road markings selected for the alignment do not encourage unsafe overtaking. As outlined in the Road Markings section later in this Chapter, the methods for determining overtaking sections outlined in this Standard differ from the methods outlined in the TSM and designers are required to assess the impact of desirable minimum crest K values on their road marking design, with particular consideration given to the overtaking visibility available either side of the crest curve. The road markings chosen by the designer should not encourage dubious overtaking activities. 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 Section 7.8, Vertical Curve Design), 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 in relation to Relaxations that are NOT permitted on the immediate approaches to junctions as outlined in Chapter 1 take precedence.

Figure 7.5: Non-overtaking Crest



7.6 Overtaking Value

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 are given in Table 7.3.

Overtaking sections shall be distributed along a length of road such that no non-overtaking section exceeds 3km.

Table 7.3: Overtaking Value

Rural Road Type	Online Improvement >2km	New Build Overtaking Value
Type 2 and 3 Single	15%	50%
Type 1 Single	30%	50%

Table 7.3 applies to new construction and online Improvement schemes exceeding 2km. 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 Sections 7.2 to 7.5, 7.8 and 7.12).

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.

The Overtaking Sections along a scheme, which may comprise combinations of the various types shown in Section 7.2, 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.

The Overtaking Values shown shall be regarded as a minimum level of provision. Where a preliminary design is further developed prior to construction such as a Specimen Design for a Design and Build scheme, the Overtaking Value achieved in the preliminary design shall be considered the minimum value to be achieved in the Detailed Design. Detailed guidance in relation to means of improving the overtaking value is provided later in this Section. 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 collision 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.

7.6.1 Schemes Less Than 2km In Length

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.

7.6.2 Means of Improving Overtaking Value

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; or
- e) 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.

7.7 Horizontal Curve Design

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 7.6 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.

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 ($V^2/R < 1.25$).

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 7.1); and
- b) On single lane downhill sections opposite climbing lanes (see Figure 7.3).

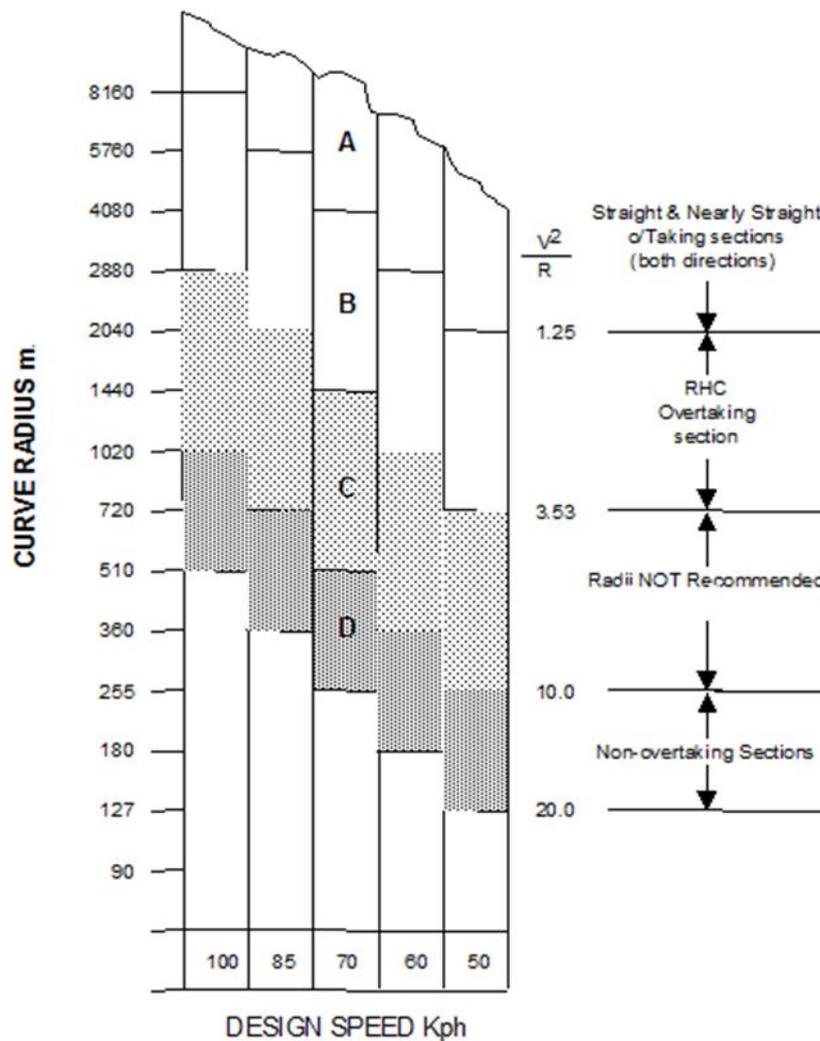
The lower limit of Band B ($V^2/R = 3.53$) shown for RHC Overtaking Sections shall be considered as the minimum radius for use in designing Overtaking Sections. At this level a maximum verge width of 8.45m (plus the 2.5m hard shoulder) would be required on a Type 1 Single Carriageway to maintain FOSD within the road cross-section for RHC traffic. Left hand curves with radii in Band B shall not be considered to be part of Two-Lane Overtaking Sections or Downhill Overtaking Sections at climbing lanes.

The use of radii in Band C ($3.53 > V^2/R < 10$) is a Departure from standard, as they, in common with Band B, provide long sections with dubious overtaking conditions for Left Hand Curve (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 shall concentrate only on Bands A and B for clear Overtaking Sections, and Band D for clear Non-overtaking Sections.

On online improvements to existing roads the use of Band C curves is also regarded as a Departure from standard.

Non-overtaking Sections shall 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 super-elevation.

Figure 7.6: Horizontal Curve Design



7.8 Vertical Curve Design

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 Section 2.2. However, for Non-overtaking Sections (refer to Figure 7.5 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 7.6, 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 Non-overtaking Crests). 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 shall not be greater than Desirable Minimum;
- b) 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 potentially dubious crest visibility, and reducing the length of clear Overtaking Sections that could otherwise be achieved;

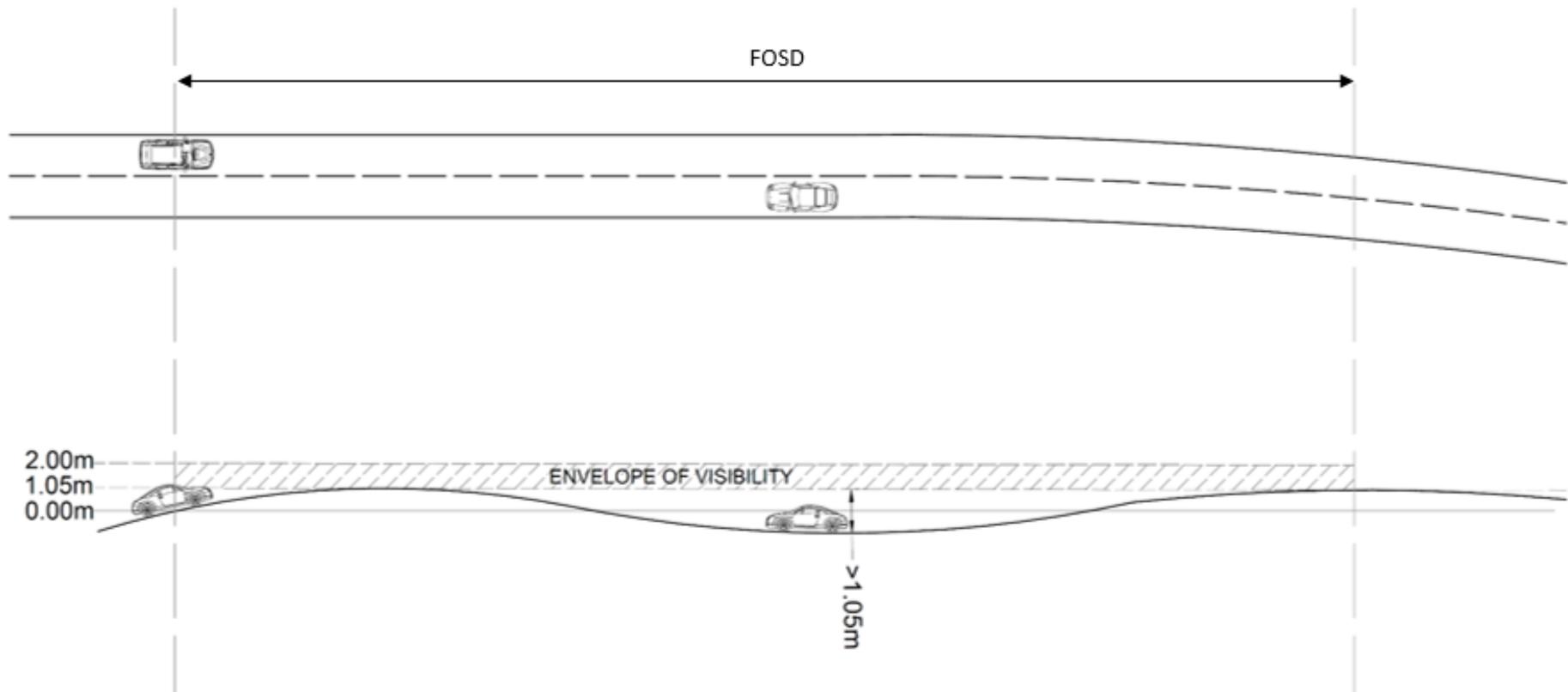
- c) The crest curve K value on the immediate approaches to junctions shall be not less than the Desirable Minimum, in accordance with the requirements for Relaxations that are not permitted on the immediate approaches to junctions outlined in Chapter 1.

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.

7.9 Hidden Dips

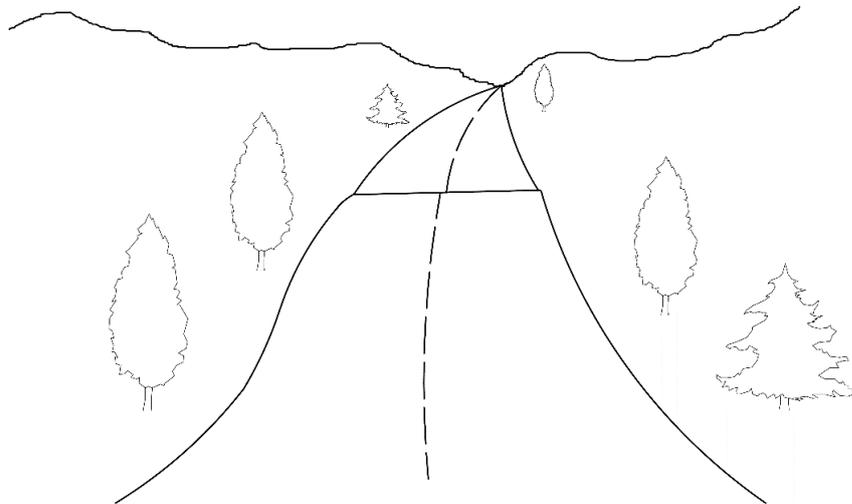
Care must be taken to avoid the creation of 'blind spots'. These occur when the road disappears from view over a crest or around a bend and reappears in view again further on. Vertical blind spots, or Hidden Dips, occur where there is a sag between two crests on a straight road; horizontal blind spots 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 collisions, FOSD must be provided both horizontally and vertically in each direction of travel on these sections of road in accordance with the requirements of Chapter 2.

Figure 7.7 (a) Vertical blind spot or Hidden Dip



Problem: Vertical height between the underside of 1.05m sight line and the road surface too great to provide FOSD in the vertical plane.

Figure 7.7 (b) Illustration of Hidden Dip



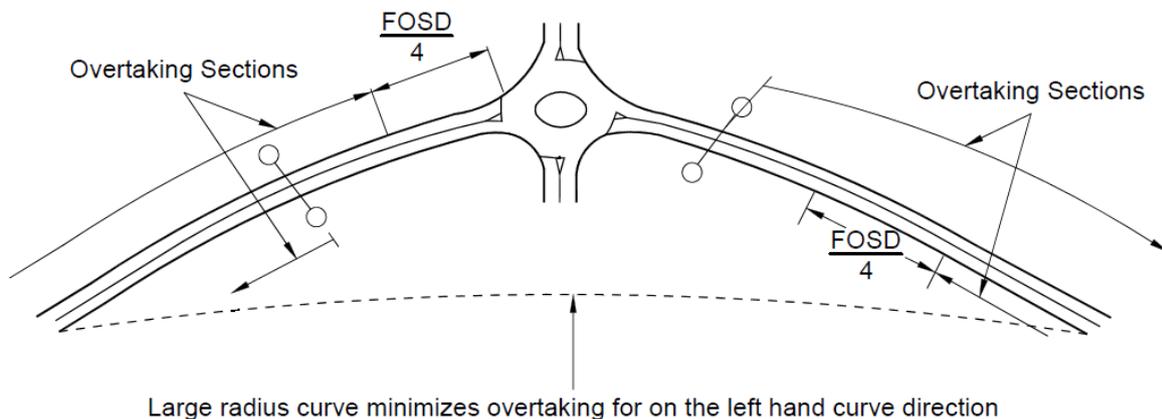
7.10 Junction Strategy

The aim should be to provide drivers with layouts that have consistent standards and are not likely to confuse them. On lengths of rural road, sequences of junctions should not therefore involve many different layout types. For example, a length of route containing roundabouts, ghost islands, simple priority junctions and grade separation would inevitably create confusion and uncertainty for drivers and cause collisions on that account.

Priority junctions with ghost islands 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.

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 7.8.

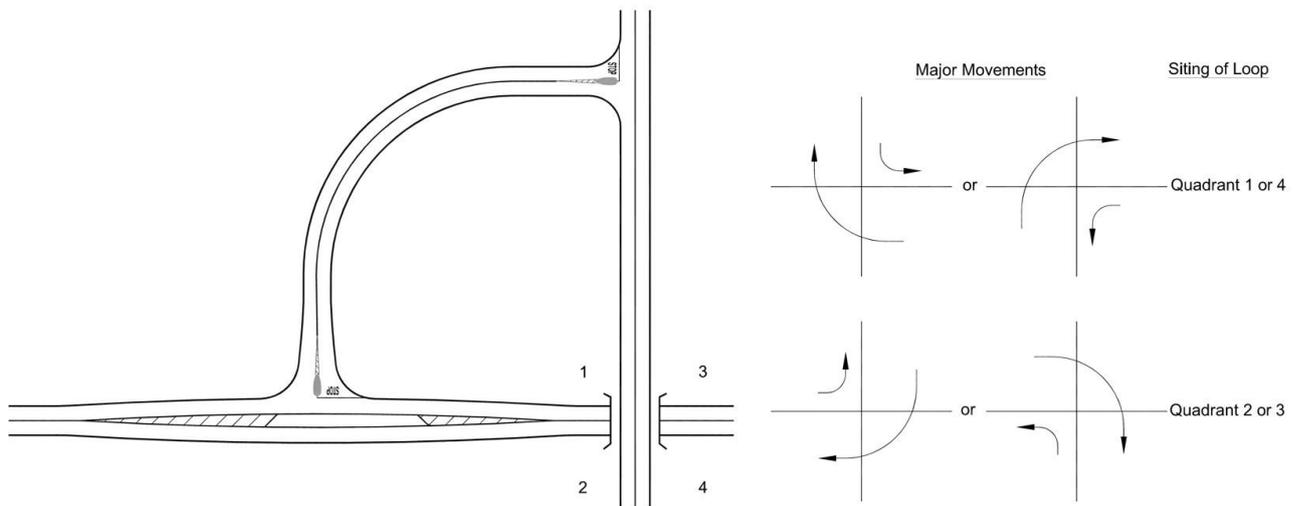
Figure 7.8: Use of Roundabout to Change Alignment



7.10.1 Grade Separation of Single Carriageway Roads

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 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, a compact grade separated junction as per DN-GEO-03060 may be considered. The single quadrant link layout with a conventional ghost island junction, as shown in Figure 7.9, 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.

Figure 7.9: Single Quadrant Link



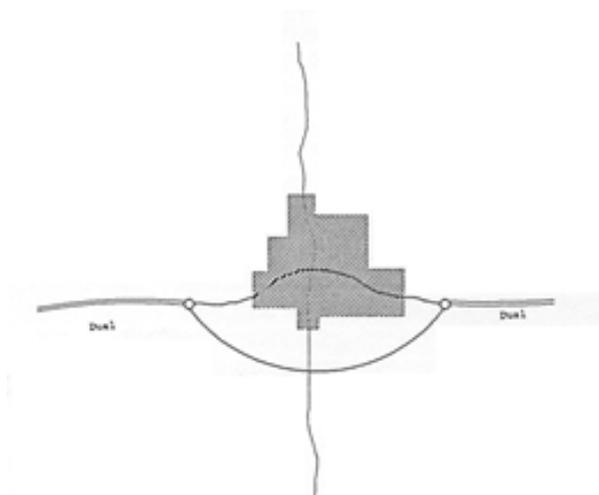
7.11 Changes in Carriageway Width

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.

Where it is necessary to change from dual to single carriageway, careful consideration shall 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 in accordance with the Traffic Signs Manual.

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 7.11 and the preceding paragraphs).

Figure 7.11: Provision of Terminal Junctions



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.

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 priority junctions shall be avoided within 1 kilometre of the end of the central reserve on either type of carriageway.

7.12 Road Markings

At non-overtaking horizontal curves and crests as described earlier, continuous line markings should be provided where the visibility (measured in the same way as for FOSS) is less than the relevant distance stated in the Traffic Signs Manual.

Refer to Chapter 7 of the Traffic Signs Manual for the road marking requirements for single carriageways. It should be noted that the method of measurement of the Overtaking Value differs from the methodology adopted within the Traffic Signs Manual for the provision of solid, warning and broken white lines.

The methodology for determining overtaking sections included in this standard is intended to provide reasonable overtaking opportunities for drivers operating at the 85thile design speed, while the TSM thresholds are based on observed times required to complete overtaking manoeuvres of slow moving vehicles. Designers shall take care to ensure that the use of Centre Line Warning Markings do not introduce sections of road with potentially dubious overtaking potential.

7.13 Existing Single Carriageway Road Improvements

The design standards contained in the preceding Sections 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 roads, the need for improvements will frequently be dictated by evident dangerous bends, junctions, narrow sections, hills, etc. For such improvements the application of DN-GEO-03030, or alternative standards such as TII Interim Technical Advice, more appropriate to minor improvement works, shall be agreed with TII. Where 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 Section 7.6. One of the most economic methods of improving Overtaking Value is the provision of climbing lanes 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.

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 shall 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.

7.14 Staged Construction

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 earlier 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 generous planting can reduce the overall impression of space.

The overriding requirements for clear Overtaking Sections in the first stage design means that the flowing alignment requirements for Dual Carriageways as described in Chapter 8 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

8.1 General Principles

All-purpose Dual Carriageways and Motorways shall be designed to permit light vehicles to maintain the Design Speed. For all-purpose Dual Carriageways and Motorways 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. The coordination of all-purpose Dual Carriageway and Motorway design elements mainly involves the design and optimisation of aesthetic alignments.

In the coordination of vertical and horizontal alignments, the following principles are generally desirable for all dual carriageway and Motorway designs.

- a) Short horizontal curves and short straights shall not be used. Such elements should be reasonably long to avoid a disjointed appearance. Adjacent curves should be similar in length.
- b) Small changes of direction should not be made, as they give the perspective of the road ahead a disjointed appearance.
- c) 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 extend the transition curves to a common point between curves of the opposite sense. Curves of the same sense connected together with a transition curve or a short straight shall be avoided.
- d) Changes in horizontal and vertical alignment should be phased to coincide where possible. This is very important with horizontal curves sharper than 2,000m radius and vertical curves of less than 15,000m radius.
- e) At the start of horizontal curves superelevation must not create flat areas on which water would stand and must not create kinks in the vertical alignment (refer to Chapter 11).
- f) 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. The view of the road ahead should not appear distorted by sharp horizontal curvature introduced near the low point of a sag curve.

8.2 Motorways

The high standard of Motorway design allows for high vehicle speeds. This is achieved by complete elimination of access other than at interchanges and service areas, prohibition of usage by pedestrians and certain vehicle types, and a generous flowing alignment for the traffic flows indicated in Table 6.1.

Motorway design shall follow the relevant alignment standards in Chapters 2 to 5 and the principles in the preceding paragraph. Additionally:

- a) Horizontal and vertical curves should be as generous as possible throughout.
- b) Long sections should be aligned to give a view of some prominent feature ahead. This relieves the monotony of driving on a road with extensive forward visibility.

8.3 Type 1 Dual Carriageways

Type 1 Dual Carriageway is the highest category all-purpose Dual Carriageway. It shall accommodate the traffic flows indicated in Table 6.1 and all intersections, both major and minor (other than left in/left out minor junctions and accesses), shall be grade separated, and accesses should be avoided wherever possible.

8.4 Type 2 Dual Carriageways

Type 2 Dual Carriageway is the next category of all-purpose dual carriageway. Type 2 Dual Carriageway shall accommodate the traffic flows indicated in Table 6.1 and shall be used primarily for new off-line alignments, with careful use for retrofit projects.

The vertical alignment of a Type 2 Dual Carriageways should follow the topography closely, with the horizontal alignment phased to match. The principles outlined in paragraph 8.1 for alignment design shall be followed.

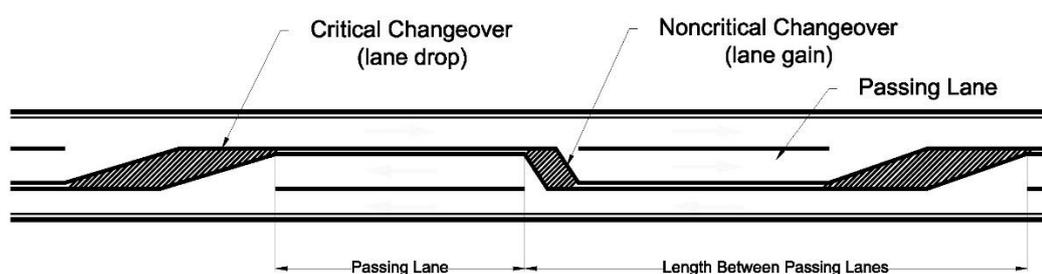
8.5 Type 3 Dual Carriageway

Type 3 Dual Carriageway is the lowest category of all-purpose Dual Carriageway. Type 3 Dual Carriageway shall accommodate the traffic flows indicated in Table 6.1 and shall be used primarily for online upgrading of existing single carriageway roads (or retrofit projects).

This cross-section can be used as an alternative to a single carriageway road where high speeds are expected due to a shortage of accesses and junctions or where a short link is being provided from a Motorway.

The Type 3 Dual Carriageway consists of two lanes in one direction of travel and one in the other. The two lane section, which provides the overtaking opportunity shall alternate with the one lane section at intervals of between 1 and 2km. This is illustrated schematically in Figure 8.1.

Figure 8.1: Schematic Layout of a Type 3 Dual Carriageway



Note: Road markings are to be designed in accordance with the TSM

8.5.1 Application

Type 3 Dual Carriageways should be designed with the objectives of safety and uncongested flow in mind. This requires appropriate design of horizontal and vertical alignments, and careful attention to the arrangement of two-lane sections and the location of junctions.

Type 3 Dual Carriageway shall not be used for urban areas or where junctions, accesses or pedestrian activity are frequent.

Existing standard or wide single carriageway roads can be improved by retrofitting a Type 3 Dual Carriageway.

8.5.2 Passing Lane Lengths

In order for a Type 3 Dual Carriageway to be effective, the traffic in both directions needs to be given opportunities to overtake. Thus, the side of the carriageway with two lanes (the passing lane) needs to change over at intervals. The length of an individual two-lane section is a compromise between allowing a length long enough to enable a platoon of traffic to overtake a slower vehicle on the two-lane side and short enough to avoid causing delay and frustration to traffic on the one-lane side. Lengths will also be determined by other items such as the road geometry and the location of junctions.

Passing lanes shall have a full width length of between 1,000m and 2,000m. A full width length of between 800m and 1,000m is allowed as a Relaxation, while a full width length less than 800m would be a Departure from Standard.

Long single lane lengths should be avoided on Type 3 Dual Carriageways. A length between full width passing lanes in the range from 2,500m to 3,000m is a Relaxation. A length between passing lanes that is greater than 3,000m requires a Departure from Standard.

8.5.3 Changeovers

Changeovers are locations where the passing lane changes from one direction of travel to the other. There are two principal types of changeover:

- a) Critical changeover: is immediately downstream of a lane drop (see Figure 8.2). At critical changeovers vehicles in the middle lane are heading towards one another, so a substantial buffer is needed.
- b) Non-critical changeover: is immediately upstream of a lane gain (See Figure 8.3). This is non-critical as vehicles in the middle lane are heading away from one another.

Changeovers should be sited at junctions where practicable (see DN-GEO-03060). However, where changeovers occur away from junctions they shall be in accordance with the layouts shown in Figures 8.2 and 8.3. Critical changeovers shall not be permitted where the curve radius is Band D or below.

Figure 8.2: Dimensions of Critical Changeover (Lane Drop)

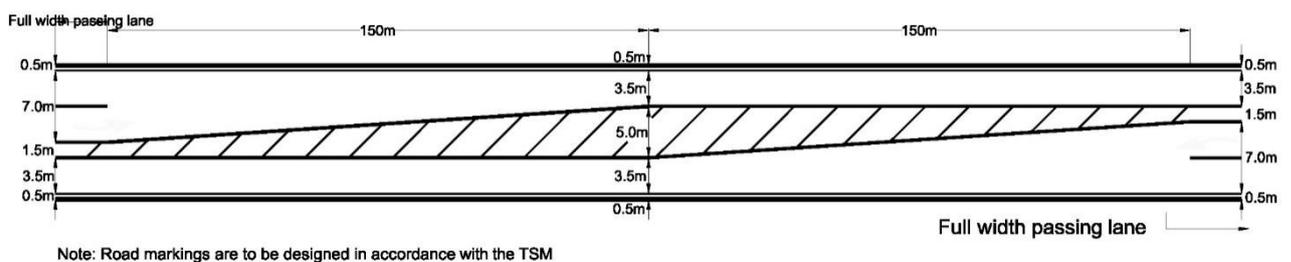
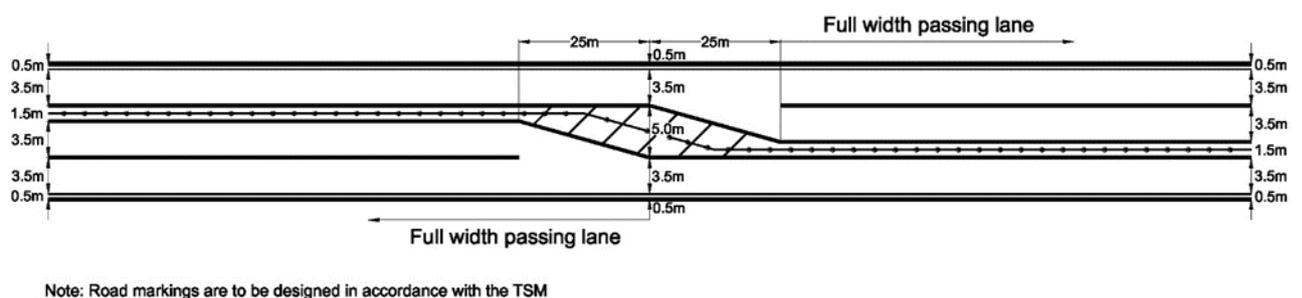


Figure 8.3: Dimensions of Non-critical Changeover (Lane Gain)



8.5.4 Pinch Points

At restricted locations, for example on a long viaduct or at a difficult pinch point, the cross-section may be reduced to omit the passing lane. The resulting cross-section shall have two 3.5m wide 1 lane sections side by side separated by a central reserve in accordance with the Type 3 Dual Carriageway requirements in DN-GEO-03036.

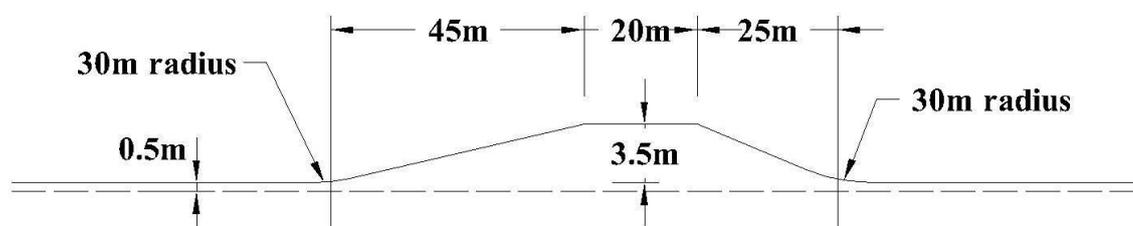
8.5.5 Overlapping Passing Lanes

In some instances, it may be appropriate to provide two overlapping two-lane sections, thus forming a Type 3 Dual Carriageway with overlapping passing lanes. This is most likely to occur on long hills where the uphill two-lane section functions as a climbing lane (see Chapter 5). The cross-section at such locations should be the same as for a Type 2 Dual Carriageway (see DN-GEO-03036).

8.6 Type 2 and 3 Dual Carriageway Parking Bays

To allow for breakdowns and to facilitate maintenance, a parking bay as per Figure 8.4 shall be provided on both sides of a Type 2 and Type 3 Dual Carriageway every 1km to 1.5km dependant on site constraints. The parking bays shall be sited so that opposing parking bays either side of the road are staggered. Wherever practicable, parking bays should not be sited on the inside of bends or near junctions or signing. Where a single carriageway road is being upgraded to a Type 3 Dual Carriageway, the parking bay can also function as a bus bay. The designer must consider pedestrian access in such scenarios, ideally bus stops should be sited where there is grade separated pedestrian access. Bus stops should generally be avoided on Type 2 Dual Carriageways. Stops should remain on the existing alternative routes. In exceptional circumstances where a bus stop is required, a bus lay-by must be provided and should be located where grade separated pedestrian access is available. Care should be taken to avoid creating conflicting traffic movements at junctions.

Figure 8.4: Parking Bay



8.7 Type 2 and 3 Dual Carriageway - Changes in Carriageway Type

The change of cross-section between Type 2 and Type 3 Dual Carriageway shall be provided by means of critical or non-critical changeovers.

Short isolated lengths of Type 2 or 3 Dual Carriageway shall not be provided on single or Type 1 Dual Carriageway roads. If lengths of Type 2 or Type 3 Dual Carriageway are unavoidable, they shall be at least 5km long and preferably 10km. Junctions should be located at the change in road cross-section to mark the change in road type.

Where there is a change from a Type 2 or Type 3 Dual Carriageway to a single carriageway the use of a roundabout is strongly recommended as a terminal junction. A roundabout slows all traffic and helps to indicate the change of cross section.

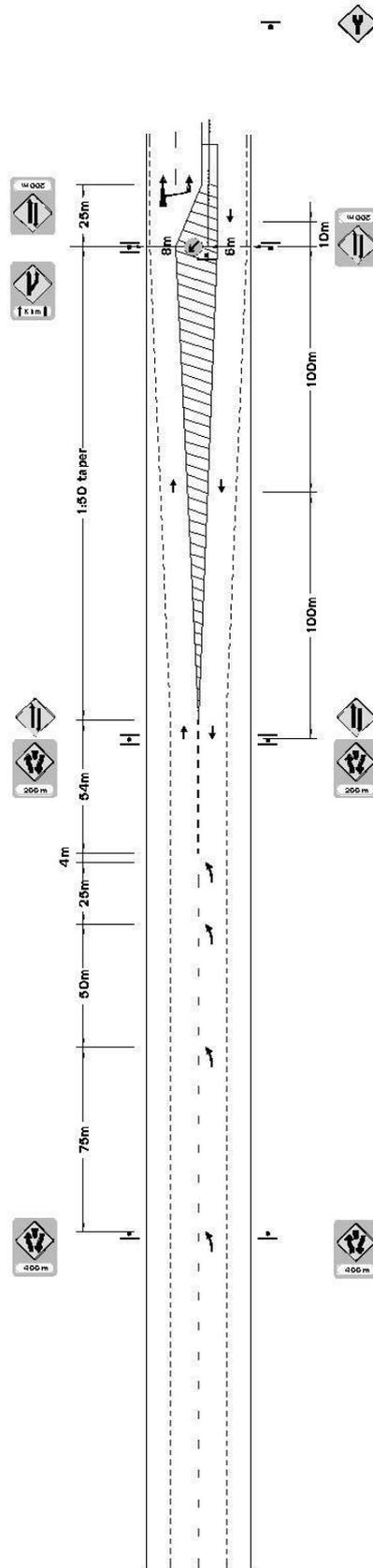
Where the road type changes between a Type 2 Dual Carriageway and another type of carriageway, other than at a roundabout, the layout shall provide a smooth transition. Wherever possible, the changes in width should be developed by using the road curvature to provide the transition. Where widths are narrowing, a taper of approximately 1 in 70 should be used for the lane or edge marking which has the greatest lateral shift. Where widths are increasing, a taper of approximately 1 in 40 should be used for the lane or edge marking which has the greatest lateral shift.

Where there is a change between a Type 3 Dual Carriageway and a single carriageway, other than at a roundabout, the preferred arrangement is for traffic leaving the Type 3 Dual Carriageway to be on a one lane length and traffic entering the Type 3 Dual Carriageway to join a two-lane length. The start of the Type 3 Dual Carriageway shall be preceded by a taper of 1 in 50, as shown in Figure 8.5. If traffic leaving the Type 3 Dual Carriageway is on a two-lane length, it will be necessary to reduce that side of the carriageway to a single lane section in a manner similar to a critical changeover.

For these specific instances the tapers outlined above take precedence over the values in Table 3.3.

Where a change in carriageway cross-section from a Type 1 Dual Carriageway or Motorway to a Type 2 Dual Carriageway is necessary due to traffic entering or exiting the major road, the junction shall be designed to the standards of the higher classification of road.

Figure 8.5: Change between Standard Single and Type 3 Dual Carriageway



8.8 Central Reserve Widening

Where the central reserve varies in width, (e.g. localised widening in advance of bridge piers or gantries) the change of road cross section shall take place over the taper lengths included in Table 3.3. The length of barrier bifurcation shall ensure a maximum and minimum set back to the median barrier of 1.5m and 1.0m respectively, unless a wider set-back is required for sight visibility reasons. For further details see Chapter 3 of DN-GEO-03036.

8.9 Provision of Emergency Accesses

This section describes the requirements to provide emergency access and egress from Motorways and Type 1 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.

On Motorway or Type 1 Dual Carriageway National Roads emergency access facilities shall be provided to the minimum frequency shown in Table 8.1. Emergency access must be provided either as:

- a) A break in the central reserve barrier as an Emergency Crossing Point (ECP) ; or
- b) An Emergency Access Link (EAL) to connect the Motorway/Dual Carriageway in both directions to the side road network in the vicinity of a side road crossing.

Proposals to change the frequency or omit ECPs or EALs must be submitted as a Departure Application to Transport Infrastructure Ireland.

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 shall be incorporated as part of the overall emergency access provision.

ECPs and EALs shall be provided to facilitate route specific emergency access and egress procedures in accordance with the requirements of this Chapter.

For Type 2 or 3 Dual Carriageways, ECPs or EALs are not required, although EALs may be provided if there are suitable locations.

Table 8.1: Minimum Frequency for Emergency Access Provision

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

8.10 Emergency Crossing Points

Central reserve openings to facilitate ECPs must be secured with a section of vehicle restraint that is easily removed and replaced, and is in line with the requirements outlined below.

The ECP 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 8.7.

The ECP 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.

Solutions must comply with the requirements of DN-REQ-03034.

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.

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

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

- a) The minimum level of containment must be N2 or the equivalent standard of the adjacent barrier, whichever is greater;
- b) The equipment to remove the central reserve barrier must be lightweight and suitable to be transported in a standard Traffic Corp Gardaí or emergency services vehicle;
- c) The opening of the crossing point shall only necessitate a closure of the outside lane in the secondary carriageway;
- d) 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.

8.11 Network Operation

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 8.6 indicates possible operational modes.

8.12 Siting

Where possible an ECP 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 (ETA) shall be no more than 500m downstream of a central reserve crossing point. An indicative operation of an ETA is given in Figure 8.6 and Figure 8.7. Where lay-bys are to be constructed consideration should be given to their location to facilitate an ETA as part of the route emergency access strategy. Layby Types A, B or C as per DN-GEO-03046 may be utilised as an ETA although this will require long vehicles to cross the raised island. This is facilitated by the use of 45 degree splayed kerbs. Conversely an ETA may be utilised in lieu of a Maintenance Layby as per DN-GEO-03046 but not visa-versa.

An ECP may be located where the central reserve is of sufficient width to accommodate turning vehicles. Any hardened areas shall be suitable for being trafficked without damage.

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

ECPs shall be sited no closer than 2km apart on any given link to ensure they serve the purpose of traffic management without compromising the safety of the road users.

Figure 8.6: Potential Modes of Operation for an Emergency Turnaround Area (ETA)

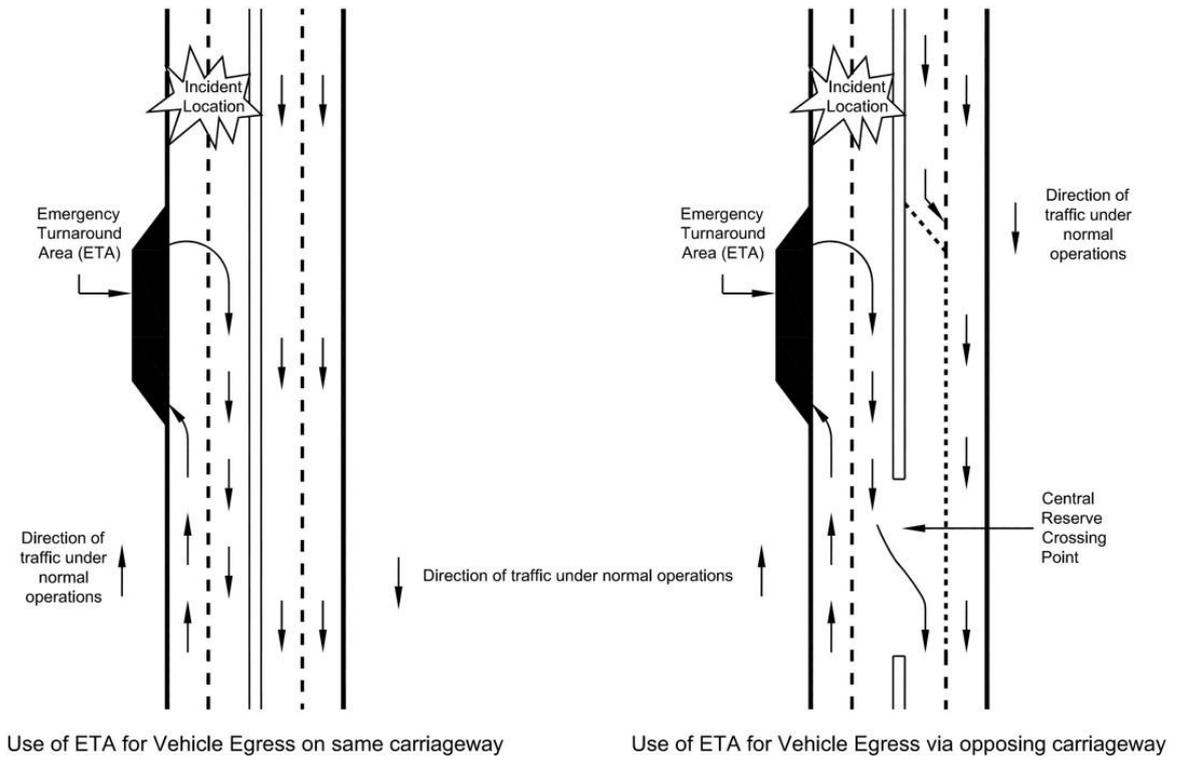
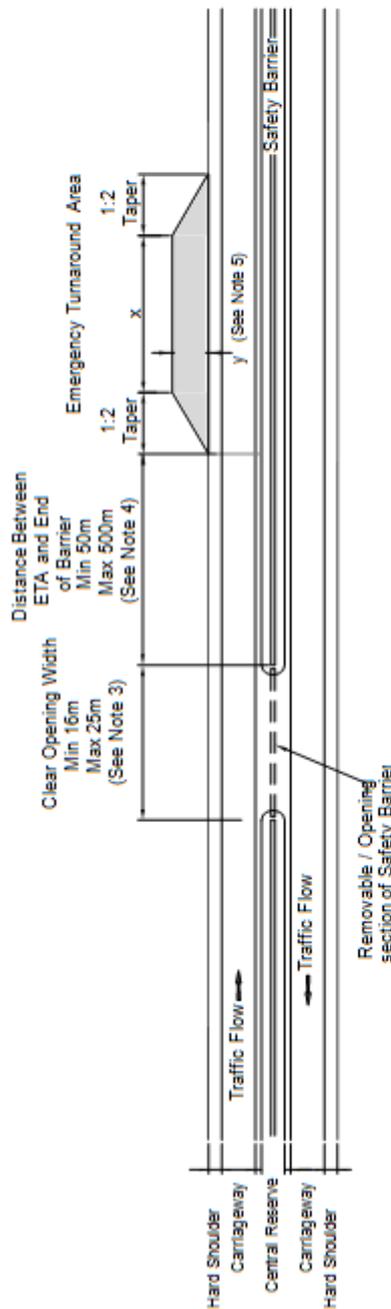


Figure 8.7: Central Reserve Crossing Point and Emergency Turnaround Area (ETA)



KEY:

- Cellular grass paving system or similar.

NOTES:

- Exact dimensions to be determined during local design including swept path analysis. Designers should note the dimensions are minimums, and as such several vehicles including large rigid HGVs and coaches may have difficulty turning in the space provided depending on site conditions. The minimum dimensions may need to be increased if rigid HGV or coach numbers are high.
- The 25m safety barrier opening has a design speed of 20km/h. A slower operational speed should be considered during design if a smaller opening is to be used.
- It is recommended that the length of removable / opening safety barrier is restricted to 25m to ensure ease of operation and reduce speeds during operation.
- Offset between end of barrier and start of ETA to be determined on basis of preferred mode of egress operation.

SUGGESTED MINIMUM ETA DIMENSIONS (SINGLE U TURN MANOEUVRE OF ARTICULATED VEHICLE)

ROAD TYPE	x	y
2 Lane	15m	7m
3 Lane	15m	5m

(See note 1)

8.13 Routine Maintenance

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.

8.14 Emergency Access Links

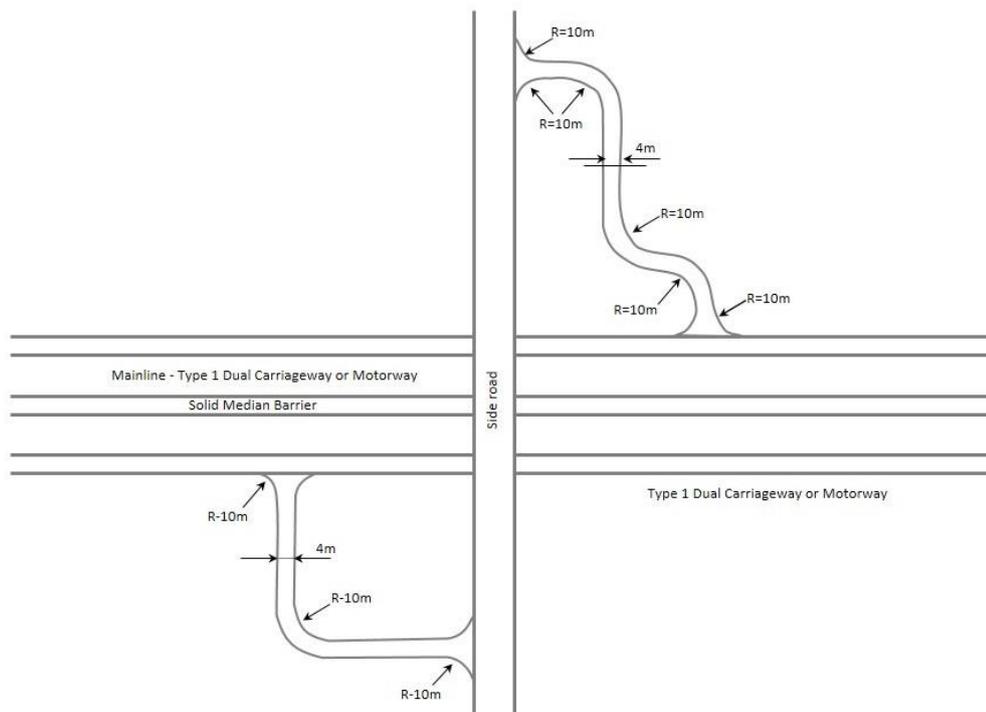
EALs provide emergency access between a side road and the main line. Ideally EALs should be provided at the mid-point between interchanges and should be located on both sides of the Motorway/Dual Carriageway. If a choice of locations exists the higher classification / standard of side road should be selected.

The designer must consider the length of need of any VRS that may be required at an overbridge location when siting the EAL junction with the mainline. It may be preferable to site the EAL junction downstream of the overbridge; the VRS would need to be considered when assessing the visibility requirements of the EAL junction.

EALs shall be constructed with junctions at right angles to the roads to which they connect as shown in Figure 8.8. EALs shall be provided with a lockable barrier adjacent to both the mainline and side road. Galvanised heavy duty chains (minimum section 5mm) shall be provided at the top and bottom of the EAL to prevent use by the general public.

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

Figure 8.8: Typical Layouts for Emergency Access Links



8.15 Geometry

Design standards for EALs are shown in Table 8.2. The design shall ensure that forward visibility along the EAL on approach to the stop line within the EAL junctions shall be at least equal to the Stopping Sight Distance shown in Table 8.2.

The connecting junctions at both ends of EALs shall be designed in accordance with the design principles contained within DN-GEO-03060. The visibility “x” distance to be used at the ends of the EAL shall be 2.4m. The Stopping Sight Distances on the mainline and the side road on approach to the EAL junctions shall be appropriate for the Design Speed of these roads. If the Design Speed is not available, then an assessment shall be undertaken to establish a Design Speed in the vicinity of the EAL junctions. The need for additional signing identifying the EAL should be considered.

A minimum 5.0m length dwell area with a maximum gradient of plus or minus 3% shall be provided immediately adjacent to the connecting road either end of the EAL.

Table 8.2: Design Standards for Emergency Access Links

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

8.16 Typical Cross Section

The EAL carriageway shall have a minimum cross-section width of 4.0m with 1.0m soft verges on either side, compatible with Standard Construction Detail CC-SCD-00706.

Design of the EALs shall require analysis of the swept path of the design vehicle (8m rigid vehicle) to ensure widening of the EAL is provided where necessary.

8.17 Maintenance Access to Attenuation Ponds

Where maintenance access to attenuation ponds and pollution control areas are directly off the mainline the access arrangement shall comply with the requirements for a Direct Access Layout 1 in accordance with DN-GEO-03060 or a Maintenance Layby in accordance with DN-GEO-03046 as appropriate to the terrain.

9. Express Roads

9.1 General Principles

An Express Road is a category of road that shall be a Type 1 Single or Type 1 or 2 Dual Carriageway road type incorporating access control as outlined in Section 9.2.

Where facilities for non-motorised users are required as per Table 6.1, provision shall be made beyond the fence line of the Express Road cross-section. Where a roundabout junction is used on an Express Road, non-motorised user facilities may cross the Express Road while passing through the junction on the intersecting road subject to the requirements of DN-GEO-03060.

An Express Road shall not cross at grade with any railway or tramway track.

9.2 Junction Strategy

An Express Road shall be designed so as to minimise the number of junctions and to provide drivers with straightforward junction layouts which shall be controlled. Only the following junction types are permitted for use on Express Roads.

- a) Roundabouts;
- b) Grade Separated Junctions (including Compact Grade Separated Junctions);
- c) Left-in/Left-out Junctions.

10. Two-Way Single Carriageway Rural Roads – Regional and Local Roads

10.1 Introduction

This Chapter shall be used for the design of two-way single carriageway Regional and Local Roads which are constructed or improved as part of a National Road scheme.

The principles of design given within this Chapter allow lower Design Speeds for Regional and Local Roads.

Due to the amount of frontage activity and also where physical restrictions on the alignment make it impractical to achieve geometry relative to a higher Design Speed, lower Design Speeds may be required when designing Regional or Local Roads as part of a National Road scheme.

10.2 Selection of Design Speed

10.2.1 Regional and Local Roads greater than 2km long:

Where the new or improved length of a Regional and Local Road is over 2km in length, the speed of traffic will depend on the design standards selected. The Design Speed should be not greater than the value indicated in Table 9.1 for the stated mandatory speed limit.

Table 9.1: Design Speeds for Mandatory Speed Limits

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

10.2.2 Regional and Local Rural Roads less than 2km long:

Where the improved length of Regional or 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. Where a new length of local link road is to be constructed and the length of the new link is less than 300m (e.g. short link roads and cul-de-sacs) an appropriate Design Speed shall be chosen to correspond to the anticipated speed.

10.2.3 Alignment Constraint

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

$$Ac = 12 - VISI/60 + 2B/45$$

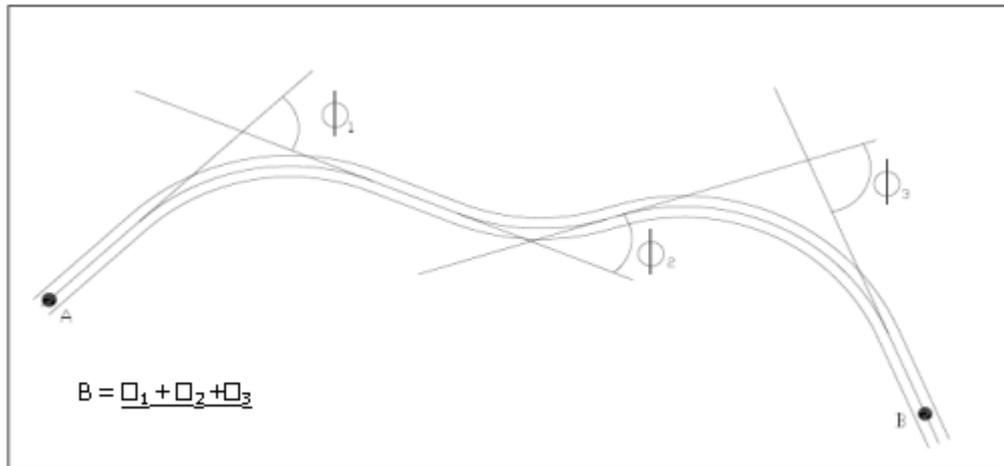
Where:

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

VISI = Harmonic Mean Visibility, m (see Appendix A)

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 9.1) and that Bendiness must be calculated as the average value over the section to be improved and 1km both sides of the proposed scheme. The bendiness should be calculated using 1:2500 scale OS digital mapping (refer to Appendix A).

Figure 9.1: Bendiness



10.2.4 Layout Constraint

Layout Constraint (Lc) measures the degree of constraint imposed by the road cross-section, verge width and frequency of junctions and accesses. Table 9.2 shows the values of Lc for Regional and Local Roads relative to cross section features and density of access per km (see DN-GEO-03060), over a distance of 2km, where:

M = Medium Access numbering 6 to 8 per km;

H = High Access numbering 9 or more per km.

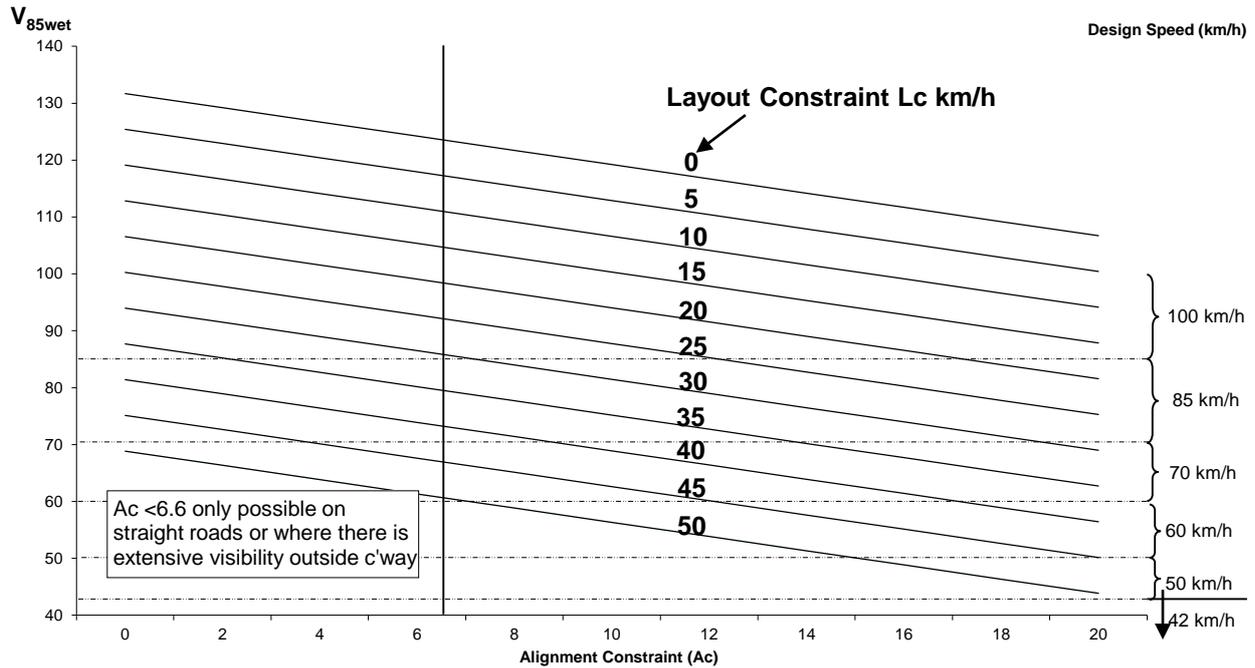
Table 9.2: Layout Constraint, Lc km/h

Carriageway width (ex. Hard strips)	3.0m		4.0m		5.0m		6.0m	
	H	M	H	M	H	M	H	M
Degree of access and junctions								
With 3m verge	47*							
35*	39*	32*	33*	29*	29	26		
With 1.5m verge	49*	37*	41*	34*	35*	31*	31	28
With 0.5m verge	51*	39*	43*	36*	37*	33*	33	30
No verge	53*	41*	45*	38*	39*	35*	35*	32*

*These values were interpolated from Table 1.1 of this Standard

The Design Speed is then derived from the ensuing Ac and Lc values using Figure 9.2 below. The strategy for the continuous section of road however must be considered when determining Ac and the cross-sectional design.

Figure 9.2: Selection of Design Speed for Regional and Local Roads



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

10.3 Design Speed Related Parameters

For Design Speeds on Regional and Local Roads the geometric parameters stated in Table 9.3 of this Standard shall apply.

10.4 Overtaking Sight Distance

For safety reasons overtaking is discouraged for Regional and Local Roads with a design speed ≤ 50 km/h. accordingly, allowable Overtaking Sight Distances are not included in Table 9.3 and any design should not seek to provide for overtaking manoeuvres where the design speed is ≤ 50 km/h.

10.5 Gradients

The parameters stated in Section 4.1 for maximum allowable vertical gradients shall apply to Regional and Local Roads.

Table 9.3: Design Speed Related Parameters

REGIONAL AND LOCAL ROAD DESIGN SPEED (km/h)	85	70	60	50	42	V2/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
Three Steps below Desirable Min R with Superelevation of 7%	180	127**	90**	65*	44*	40
Four Steps below Desirable Min R with Superelevation of 7%	127	90**	65**	44*	34*	56.56
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 Regional and Local Roads of design speeds 50km/h and less, a maximum superelevation of 3.5% shall apply.

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

*** Missing FOSD parameters - refer to Section 10.2.5 below.

+ Not to be used in the design of single carriageway Regional and Local Roads where the design speed is > 60km/h (see Horizontal Curve Design and Vertical Curve Design in Chapter 7).

10.6 Relaxations and Departures

In general the policy with regard to Relaxations and Departures shall be that adopted for National Roads as set out in this Standard. Section 10.7 below sets out exceptions to the Relaxations and Departures that will apply to Regional and 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.

10.7 Exceptions

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, this requires a Relaxation. This arrangement is permitted and will not require a Departure from Standards when applied on a Regional or Local Road, except on the approaches to junctions, where Desirable Minimum Stopping Sight Distance is required.

Where site-specific circumstances dictate, transitions may be omitted from the design of the new realigned section of a Regional or Local Road at low design speeds ($\leq 60\text{km/h}$). This is permitted and is not considered to be a Relaxation.

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 Section 3.10.2 Application of Superelevation). On new and existing roads without transitions, between $\frac{1}{2}$ and $\frac{2}{3}$ of the superelevation shall be introduced on the approach straight and the remainder at the beginning of the curve. The use of a 'q' value of 0.6 on Regional and Local Roads is permitted and is not considered to be a Relaxation.

In the circumstances described in Section 1.8 for Relaxations;

- a) Relaxations below the Desirable Minimum Radius values, R, may be made at the discretion of the Designer. The number of Design Speed steps permitted below the Desirable Minimum for Regional and Local Roads is 4 steps.

10.8 Rate of Change of Cross-Section Width

Changes in cross-sections may be required either for the development and elimination of additional lanes on Regional or Local Roads. The transition tapers shall be developed and eliminated at a rate in accordance with Table 9.4 below. Where Table 9.4 is used, the transition tapers should correspond with the higher Design Speed of the two adjoining links under consideration.

Table 9.4: Rate of Change of Width

Design Speed km/h	Transition taper
50	1:25
60	1:30
70	1:35
85	1:45

10.9 Passing Bays

Where a scheme involves the design of a two-way Regional or Local Road with an existing carriageway width of 5.3m or less, it may be appropriate to provide passing bays instead of full carriageway widening along the length of the relevant design. This will allow narrow roads with low traffic volumes to be improved in a sustainable manner at a reasonable cost. Where passing bays are required, they shall be designed in accordance with the requirements set out in DN-GEO-03030.

10.10 Road Camber

For narrow local roads a superelevation between the edges of the road is allowable as a Relaxation.

10.11 Band C Curves

On local and regional roads the use of Band C curves is regarded as a Relaxation from standard.

11. Geometric Design to Enhance Surface Drainage of Carriageways

11.1 General

This Chapter describes the occurrence of aquaplaning and effects of excess surface water on a carriageway. This Chapter provides the technique for assessing the water film depth on a drainage path and methods for reducing the aquaplaning potential of a design.

11.2 Effects of Surface Water on the Carriageway

11.2.1 Aquaplaning

Aquaplaning occurs when the vehicle's tyres are partially or fully separated from the road surface by a film of water which results in loss of control of the vehicle. If the combination of water depth on the road surface, vehicle speed and tyre condition exceeds the point where water can be dispersed, the thickness of the water film in front of the tyre builds up and begins to penetrate the tyre contact patch.

The degree to which water is displaced is largely governed by the speed of the vehicle, and the capacity of the pavement macrotexture and tyre tread grooves to provide the necessary drainage paths. The provision of appropriate road drainage in conjunction with suitable transverse superelevations and longitudinal pavement gradients ensures that there is a minimal depth of surface water on the carriageway to be displaced.

Full aquaplaning is unlikely to occur when vehicles operate within the speed limits with tyres maintained and in good condition. Partial aquaplaning is more likely to occur resulting in loss of control during wet conditions.

Aquaplaning potential of a design can be assessed from the following two stage process:

Determine the expected water film depth for a given drainage path across the carriageway;

Check estimated water depths against acceptable design limits.

It should be noted that although the assessment process provided in this Chapter concentrates on the prediction of surface water depths, road collisions are typically multi-factored incidents that usually cannot be attributed to one single cause. Therefore a reduction in skid resistance arising from wet weather conditions may be a contributory factor but it would not necessarily be the only causal factor in road collisions. Other factors such as driver behaviour, vehicle condition, road geometry and climatic conditions, including extreme rainfall events, may be involved to varying degrees.

11.2.2 Aquaplaning versus Skidding

Skidding occurs with no separation between the tyre and the road, while aquaplaning arises from a reduced or absent contact patch between tyre and pavement. Skidding typically occurs as a consequence of vehicle manoeuvres involving excessive acceleration or braking, and is generally experienced on bends and at junctions. A partial aquaplaning incident is a combination of aquaplaning and skidding.

11.2.3 Factors Influencing Aquaplaning Potential

It is important for the designer to gain an appreciation for the factors influencing the occurrence of aquaplaning and in doing so, recognise that only certain factors are within the designer's control. Key contributory factors to aquaplaning are:

- a) Road geometry;
- b) Drainage design and maintenance regimes;
- c) Surface characteristics;
- d) Design / Operating speed;
- e) Rainfall intensity;
- f) Water film depth;
- g) Vehicle characteristics (tyre tread depth, tyre pressure etc.); and
- h) Driver behaviour.

Rainfall intensity, driver behaviour and poor vehicle maintenance (inadequate tyre tread depth or pressure etc.) represent significant influences that are beyond the designer's control and are indicative of the difficulty in defining strict rules for design.

11.2.4 Maintenance of Drainage Systems

Effective carriageway drainage in conjunction with applied geometric parameters is critical to ensure the expeditious removal of surface water runoff during and after a rainfall event. This is very important where the road cross-section changes from camber (normal crossfall) to superelevation, particularly when combined with a flat longitudinal gradient.

It is imperative that maintenance regimes are put in place in order to ensure that the removal of water from the road surface is not hindered as a result of blocked gullies, build-up of debris or verge grass growth. This is of particular importance at changes in superelevation where carriageway crossfall is low. Further guidance is contained in DN-DNG-03022.

11.2.5 Drainage Path

The drainage path is the route taken by rainfall runoff from the point at which it falls on the carriageway surface to the carriageway edge. The drainage path follows the steepest gradient to the carriageway edge and is dictated by the combination of longitudinal gradient and superelevation, which in turn vary on the horizontal and vertical geometry of the road.

On a carriageway with minimal longitudinal gradient, drainage path lengths are predominantly influenced by superelevation, resulting in short drainage paths and the expeditious removal of surface water. As longitudinal gradients increase, the drainage path becomes more influenced by the longitudinal grade than the superelevation; this can significantly increase the length of the drainage path. Longer drainage paths produce greater water depths, which in turn increase the risk of aquaplaning.

While drainage path lengths and gradients can be easily determined on sections of consistent route geometry, any areas of varying width and geometry require careful consideration by the designer. On the approach to horizontal curves, the standard two way superelevation may transition to a one way crossfall (superelevation) giving rise to localised low crossfalls and a rapid increase in drainage path lengths. The determination of drainage path lengths at superelevation rollovers is most effectively assessed by the designer using contoured plans of the carriageway surface.

11.2.6 Minimum Design Gradients

Most roads are designed to maintain a minimum longitudinal gradient of 0.5% wherever possible to allow for adequate water flow along the roadside edge channel. It should be noted however that on wider carriageways, the most direct drainage path, and therefore the shortest drainage path lengths occur at zero longitudinal gradient. Low longitudinal gradients can therefore be acceptable (and potentially more effective in removing surface water) provided that standard crossfalls are maintained and a continuous drainage system is utilised in accordance with DN-DNG-03022.

In areas of superelevation development, designers should aim to increase the longitudinal gradient along the road centreline to ensure a sufficient gradient is maintained along the carriageway edge.

11.2.7 Length of Superelevation Development

Refer to Chapter 3 of this document for details on the length of superelevation development.

11.2.8 Surface Characteristics

Adequate pavement macrotexture provides drainage paths for surface water to escape and reduce the potential for aquaplaning. The importance of good surface macrotexture becomes increasingly critical as vehicle speeds increase, as even a relatively thin layer of surface water could be problematic if combined with low texture depth and 'smooth' tyres. The most significant characteristic becomes the water depth at texture levels above the mean level.

Adequate pavement surface microtexture shall be provided by the designer to enable the tip of the aggregate to penetrate any remaining water film and establish direct contact between the tyre and road surface. Microtexture influences wet and dry skid resistance at all speeds, interacting with the vehicle's tyres to generate the adhesive friction forces. The degree of friction provided in wet conditions is dependent on the extent to which the microtexture can penetrate the surface water film.

It should be noted that pavement surface characteristics cannot be specified to compensate for extreme rainfall events, driver speed, vehicle maintenance or deficiencies in the geometric design.

11.2.9 Effect of Carriageway Edge Markings

Carriageway surface drainage can be affected by continuous edge markings, particularly where raised rib markings are used. Where continuous edge lines are used drainage gaps shall be included to prevent surface water ponding and the risk of localised ice formation.

The spacing of drainage gaps shall be adjusted in conjunction with the vertical gradient with a 2m maximum spacing to be provided at lower gradients and superelevation rollovers. For further guidance on dimensions and spacing of drainage gaps in road markings, refer to the Traffic Signs Manual.

11.3 Geometric Design Methodology to Enhance Surface Drainage

11.3.1 Introduction

The importance of considering drainage as a fundamental part of highway design is noted in DN-DNG-03022. The information, assessment methodology and criteria presented in this section have been developed for geometric road designers to allow them to identify and minimise aquaplaning potential.

Consideration of surface drainage (by minimising the build-up of water on the carriageway) must be viewed by the designer as an equivalent constraint to horizontal and vertical alignment design as other elementary considerations such as sight distance and limiting curvature.

11.3.2 Assessment Process

The designer shall use the method developed by Gallaway et al (1979) to calculate the expected surface water film depth. This method provides an empirical relationship relating average pavement texture depth, drainage path length, rainfall intensity and slope of drainage path to the expected water film depth on the carriageway surface.

The metric version of the Gallaway formula is given below:

$$D = \frac{0.103 \times T^{0.11} \times L^{0.43} \times I^{0.59}}{S^{0.42}} - T$$

Where,

D	=	Water film depth above the top of pavement texture (mm)
T	=	Average pavement texture depth (mm)
L	=	Length of drainage path (m)
I	=	Rainfall intensity (mm/hour)
S	=	Slope of drainage path (%)

Average Pavement Texture Depth

Average pavement texture depth is an average measure of the depth of macrotexture.

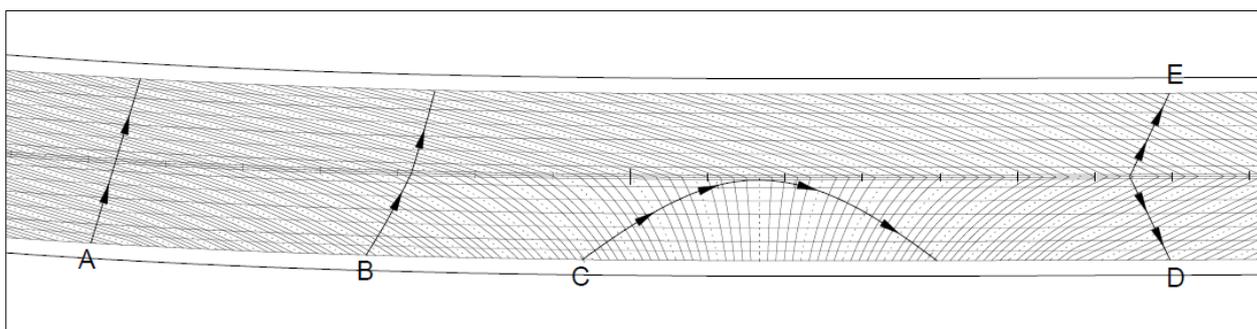
To take account of reduced average pavement texture depths due to pavement deterioration, a design check shall be carried out by the designer assuming a value of 0.4mm for the surface texture depth.

Length of Drainage Path

The designer shall determine the drainage path length by plotting and assessing the contours on the proposed road surface. The longest drainage path (or the critical drainage path) is identified and assessed using the Gallaway formula.

- a) Figure 11.1 illustrates a typical example of drainage paths based on road surface contours at a superelevation rollover at the exit from a left hand curve.
- b) Path A represents the drainage path when the carriageway is in full superelevation along the curve, with a constant slope applied across the full width of the road pavement.
- c) At Path B, the superelevation begins to roll down on the exit from the curve resulting in a gradual change in the drainage path direction and a wider contour spacing.
- d) Path C is of particular interest where the drainage path begins to cross the road and then, due to the superelevation rotation, returns back to the same edge of carriageway. This situation frequently results in long drainage paths with a flat section in the middle, as indicated by the wider spacing of the contours.
- e) Paths D and E represent shorter drainage paths where the carriageway has returned to a normal crossfall situation.

Figure 11.1: Example of Drainage Paths



Path C represents the critical drainage path in respect of road surface water flows. Assessment of this path using the Gallaway formula must be carried out by the designer to check anticipated water film depths against the limits set out in Section 11.6.

The calculation of water film depths using the Gallaway formula must be undertaken by the designer at all locations where superelevation is applied. Other locations considered susceptible to surface drainage problems shall also be assessed by the designer. Such areas may include:

- a) Entry/exit taper on grade separated junctions where pavement widths increase significantly
- b) Steep longitudinal grades resulting in long drainage path lengths along the road surface

Rainfall Intensity

Water film depths shall be calculated by the designer using a minimum rainfall intensity of 50mm/hr.

Slope of Drainage Path

The slope of the drainage path at any location on the carriageway surface is represented by the resultant gradient arising from the combination of superelevation and longitudinal fall of the road. This slope is easily determined in areas of consistent geometry, however the situation becomes more complicated in locations where the surface geometry varies along the length of the drainage path, e.g. superelevation rollovers. In such cases, it is necessary to consider the carriageway in sections with individual drainage sub-paths, each having a different slope and direction.

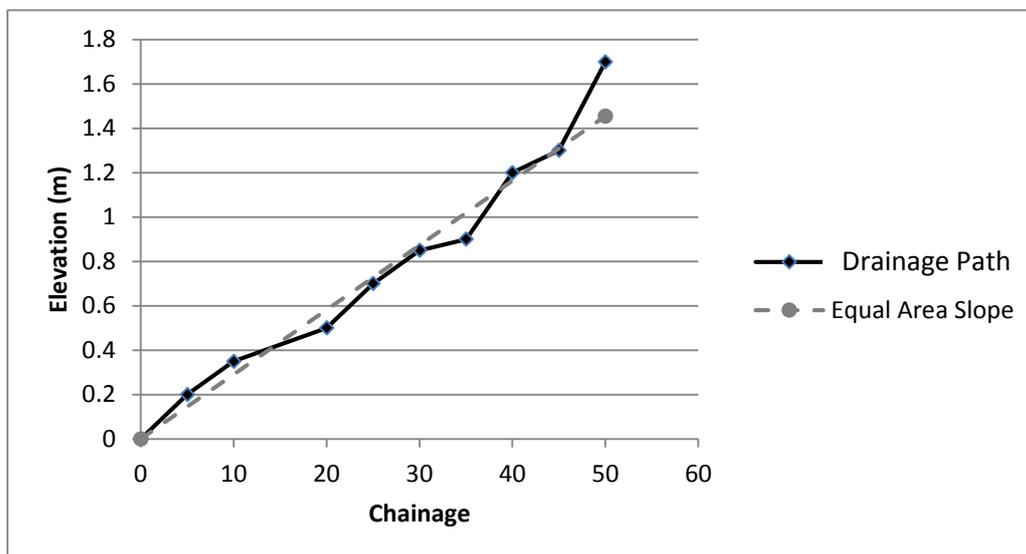
The Equal Area slope is the best 'single slope' representation of the drainage path at any location containing more than one sub-path (see Figure 11.2). If the drainage path is predominantly flat with some steep sub-paths, then the Equal Area Slope will be relatively flat. Alternatively, if the drainage path is predominantly steep with some flat sub-paths, then the Equal Area Slope will be relatively steep. If a water depth is required at the end of, or at any point along the drainage path, then the Equal Area Slope shall be determined by the designer from this point of the analysis back to the start of the drainage path; this value represents the value of 'S' in the Gallaway formula.

The procedure which shall be followed by the designer in determining the Equal Area Slope from a point of analysis back to the start of the drainage path is summarised in the following steps:

- a) Plot the profile of the drainage path (long section);
- b) Working in metres, calculate the total area under the profile;
- c) Divide the area by the length of the profile, and then multiply by 2. This calculates the vertical ordinate of the equal area triangle;

- d) Plot this new ordinate (at highest point on drainage path) and join back to point of analysis;
- e) Now calculate the slope of this line, i.e. the Equal Area Slope, expressed as a percentage (%).

Figure 11.2: Equal Area Slope



11.4 Assessment Criteria

The results of the Gallaway analysis shall comply with the following criteria. Where the design does not comply with these requirements, the aquaplaning potential is considered too high and a redesign is required. The geometric design criteria are as follows:

- a) A maximum water film depth of 3.3mm shall apply to new single carriageway roads.
- b) A maximum water film depth of 3.3mm shall apply on Motorways and Dual Carriageways.
- c) Road surface geometry shall be such that drainage paths are limited to a length of approximately 60m.

11.4.1 Aquaplaning Assessment Report

For new roads, the assessments carried out in accordance with the above design methodology shall be compiled by the designer in a single Aquaplaning Assessment Report for the scheme.

The Aquaplaning Assessment Report shall be submitted by email to TechSubs@tii.ie under the subject heading 'Aquaplaning Assessment Report'. Reports shall be submitted for review as part of the preliminary design process and shall contain the following information as a minimum:

- a) Surface contour drawings at each assessed location. This shall include all superelevation rollover locations and any other areas deemed necessary.
- b) Water film depth calculation at each assessed location in accordance with the Gallaway formula.

11.5 Guidance to Reduce Aquaplaning Potential

If water film depths calculated in accordance with the Gallaway formula exceed the maximum limits, appropriate remedial measures shall be implemented by the designer before the critical drainage path is reassessed. It must be recognised that while surface texture is a contributing factor to the calculated depth, drainage problems will exist irrespective of pavement texture if the combination of superelevation and longitudinal gradient impedes the flow of surface runoff in the first instance. Aquaplaning shall be considered by the designer to be a geometric issue rather than a drainage one. The shape of the road surface has the most direct influence on surface flow and the build-up of storm water runoff, which in turn directly influences the aquaplaning potential.

11.5.1 Methods to Reduce the Water Film Depth

If application of the Gallaway formula results in unacceptable water film depths above the maximum limits, the designer shall consider the following methods of adjusting the drainage path length or gradient to reduce the water depth. Methods to achieve this are as follows, in order of preference:

- a) Alter the horizontal or vertical alignments, or both, to reduce drainage path lengths;
- b) Alter the alignment to locate the rollover on a section with sufficient longitudinal gradient;
- c) Adjust the rate of superelevation development or increase crossfalls to steepen drainage paths.

A camber of 3% may be appropriate as a Relaxation instead of the standard camber of 2.5%, on sections of carriageway with shallow or flat longitudinal gradients and greater than 2 lanes in width, to reduce drainage path lengths. The designer must consider the increased length of transitions required at rollover sections when using a camber of 3%.

Consider introducing additional crown lines (rolling or longitudinal crowns) if other measures are not deemed satisfactory.

Any locations with potential drainage problems must be identified as early as possible in the design process and mitigated through amended geometric design. It is important for the designer to gain an appreciation for the interplay between longitudinal gradient and superelevation to ensure compliance with the limiting water depth criterion. Combinations of superelevation transitions with vertical curves and low gradients must be assessed by contouring the finished road surface and applying the Gallaway formula.

11.5.2 Departures

At difficult locations, such as at junctions and tie in points to existing roads, if water film depths calculated in accordance with the Gallaway formula still exceed the maximum limits following all appropriate remedial measures being implemented by the designer, a Departure from Standard shall be submitted to TII. In addition to the information required within the Aquaplaning Assessment Report, the following information shall be provided within an application for a Departure from Standards at a minimum:

- a) General scheme information:
 - i. whether the scheme is a new scheme or an upgrade of an existing road;
 - ii. carriageway type/cross section and design speed;
 - iii. chainage range under consideration; and
 - iv. the rate of change of pavement edge gradient used for each location assessed.

- b) Drawings indicating the contour lines marked with their respective elevation throughout the carriageway section (combination of the longitudinal gradient and the superelevation).
- c) Drawings shall also show the critical flow path marked with arrows to indicate the runoff direction, the length of the critical flow path, the superelevation pivot point, and the direction of travel.
- d) Supporting documents such as suitable computer generated models and/or drawings.
- e) A 'departure justification' should be provided including all relevant specific constraints (e.g. critical path located near an intersection restricting the possibility of shortening the rollover application and hence the critical path).
- f) As well as stating the WFD achieved, the resultant gradient achieved must also be included to indicate if the required 1% resultant gradient has been achieved.
- g) The WFD profile along the length of the critical flow path to allow assessment of the extent to which WFD thresholds are exceeded.

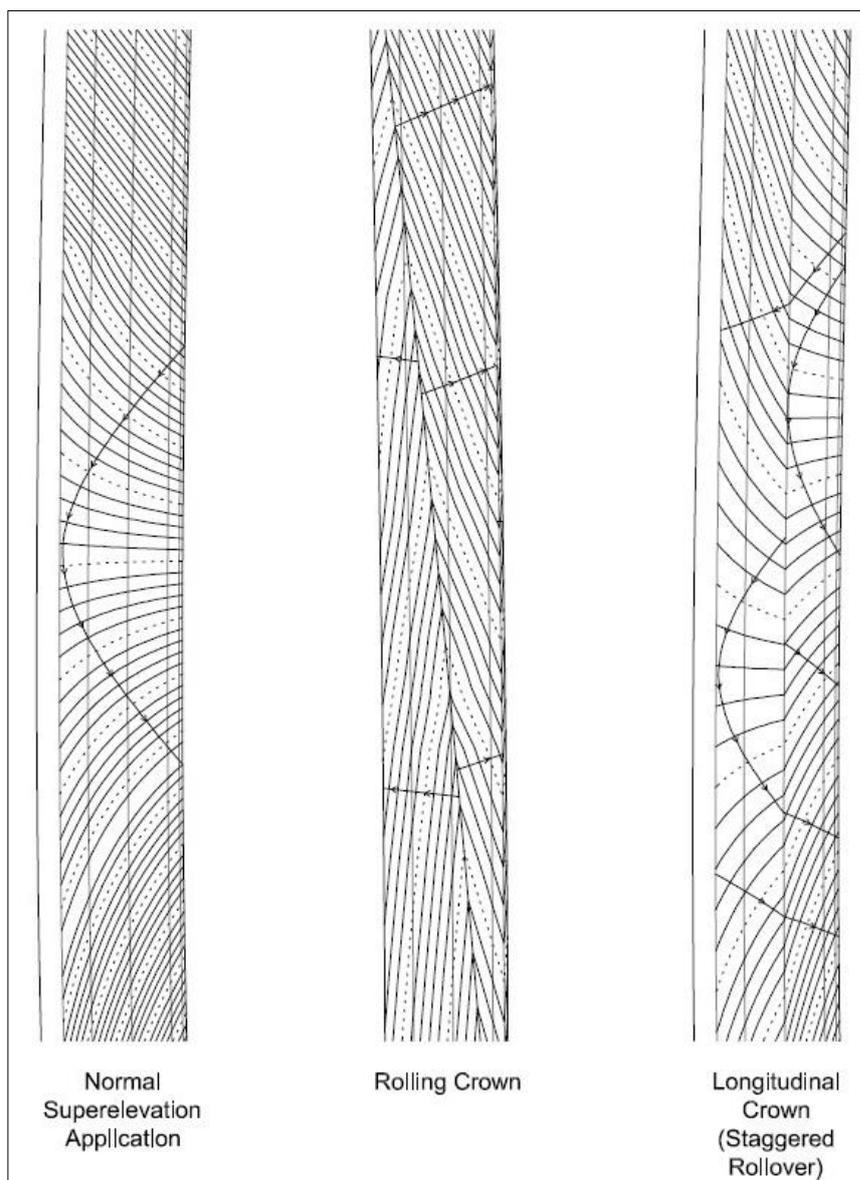
11.6 Alternative Methods for Reducing Water Film Depth

11.6.1 Crown Lines

Where surface drainage problems exist and limiting water depths cannot be achieved by traditional methods, alternative methods can be used by the designer. Two methods are presented which can be very effective in reducing surface water depths at locations of superelevation development, these are:

- a) Rolling crowns (diagonal crowning); and
- b) Longitudinal crowning (independent lane rotation).

Figure 11.3: Alternative Methods of Rollover Application



11.6.2 Rolling Crowns

Rolling crowns (or diagonal crowning) provide an effective hydraulic solution to surface water problems at rollover locations by eliminating the point of zero superelevation and ensuring a superelevation is maintained at all locations along the diagonal rollover. It should be noted however that edge drainage is required on both sides of the carriageway along the length of the crown to remove surface water (refer to DN-DNG-03022 for more details).

All other available methods for alleviating rollover drainage problems shall be exhausted by the designer before rolling crowns are adopted. Construction difficulties in achieving the gradients required and associated ride quality issues generally preclude the inclusion of rolling crowns as an acceptable solution and particular care should be taken in the design, specification and construction of such features.

Where rolling crowns are proposed for use on high speed roads, the prior approval of Transport Infrastructure Ireland shall be sought via the Departures Application procedure.

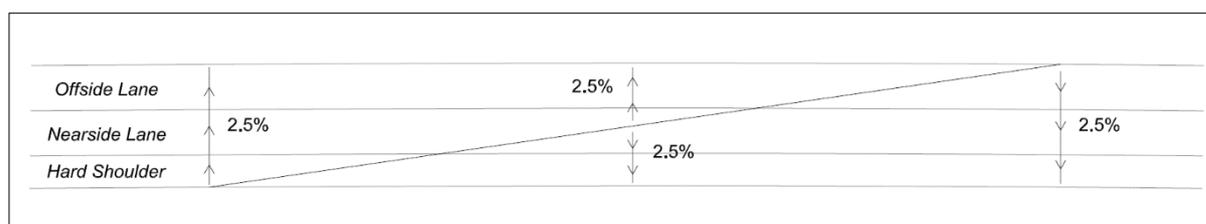
Rolling crowns may be particularly suited to resolving surface drainage problems at superelevation rollovers on existing carriageways. In such cases, the use of rolling crowns may provide an effective, low cost solution to the problem with minimal impact on existing geometrics.

11.6.3 Rolling Crown Design

Rolling crowns can represent an abrupt change to road users on high speed roads and the effects of an instantaneous change in superelevation, particularly on heavy goods vehicles, must be considered. While the design of rolling crowns as a retrofit solution may be influenced by existing site constraints, the following guidance shall be followed by the designer to ensure a smooth application of rollover and satisfactory ride quality.

- a) The pavement superelevation shall be reduced to a maximum of 2.5% either side of the rolling crown to limit the localised change in superelevation over the crown to a maximum of 5% (see Figure 11.4).
- b) The length of the rolling crown should match the length used to apply superelevation in the normal manner. For Motorways and high speed Dual Carriageways, a crown length of about 60m per lane should be sufficient.

Figure 11.4: Application of Rolling Crown



11.6.4 Longitudinal Crowning

Longitudinal crowning (or staggered rollover application) can be used by the designer to apply superelevation using a longitudinal offset between adjacent lanes. The method has the benefit of reducing the overall length of superelevation development across the full width of the carriageway in comparison to normal application. It should be noted that locations of zero superelevation will still exist in each lane; however the drainage path length is reduced significantly.

If longitudinal crowning is proposed for use on high speed roads, the prior approval of Transport Infrastructure Ireland shall be sought via the Departures Application procedure.

11.7 Drainage for Cycle Facilities

11.7.1 Surface Drainage

Surface water runoff from cycle facility is preferably collected from over-the-edge drainage ditches or by direct runoff into combined surface water and ground water filter drains. In some limited areas runoff may be collected by a kerb and gully system, but this should be avoided if possible as it is not really suitable in a rural area.

Where a cycle facility is proposed, as either a new construction or an improvement to an existing road, a surface water collection system should be provided in accordance with DN-GEO-03022.

Where an off-road cycle facility is proposed running parallel to the road, surface water runoff can be collected either within the segregation grassed verge or may be allowed to flow across the cycle facility and into a drainage ditch.

11.7.2 Over-the-Edge Drainage

Over-the-edge drainage is the preferred arrangement for a rural road with a cycle track adjoining. Where over-the-edge drainage is used it is important to ensure that the surface water runoff flows off the cycle track towards the drainage ditch and does not pond. Suitable superelevation of between 1% and 3% should be provided on the cycle track pavement, with a maximum of 5.0% permitted over short sections.

The grassed verge between the carriageway and the cycle track must be constructed with a superelevation of no more than 10% so as not to destabilise an errant cyclist. No minimum superelevation is specified for the grassed verge as water infiltration is desirable to limit and attenuate the overall runoff to the receiving watercourse.

The free pavement edge detail of both the carriageway and cycleway should be higher than the proposed ground level in accordance with CC-SCD-00701 (in order to stop back flow of the surface water runoff from a flat grassed verge).

12. References

12.1 TII Publications (Standards):

- a) DN-REQ-03034 – Safety Barriers.
- b) DN-GEO-03036 – Cross-Sections and Headroom.
- c) DN-DNG-03022 – Drainage Systems for National Roads.
- d) DN-GEO-03035 – Layout of Grade Separated Junctions.
- e) DN-GEO-03046 – The Location and Layout of Lay-bys.
- f) DN-GEO-03042 – Layout of Compact Grade Separated Junctions.
- g) DN-GEO-03060 – Geometric Design of Junctions.

12.2 Other TII Publications

- a) National Roads Authority, 2005. Guidelines on Traffic Calming for Towns and Villages on National Routes Revision B. Transport Infrastructure Ireland, Dublin.
- b) National Roads Authority, 2010. 2010 NRA Project Management Guidelines. Transport Infrastructure Ireland, Dublin.
- c) National Roads Authority, 2011. Project Appraisal Guidelines. Transport Infrastructure Ireland, Dublin. Available at: <http://www.tii.ie/tii-library/strategic-planning>
- d) Department of Transport, 2010. Traffic Signs Manual. Transport Infrastructure Ireland, Dublin.
- e) Road Traffic (Signs) Regulations 1997 to date. The Stationery Office, Dublin.
- f) Department of Transport, Tourism and Sport and Department of Environment, Community and Local Government, 2013. Design Manual for Urban Roads and Streets. Department of Environment, Community and Local Government, Dublin.
- g) Fitzgerald, D.L., 2007. Estimation of Point Rainfall Frequencies, Technical Note 61. Met Éireann, Dublin.

12.3 Other documents

- a) Austroads 2013, Guide to Road Design Part 5A Drainage - Road Surface, Networks, Basins and Subsurface, Publication No. AGRD05A-13. Austroads, Sydney.
- b) Department of Transport and Main Roads, 2015. Manual, Road Drainage. State of Queensland, Brisbane.
- c) Gallaway, B.M, Schiller, R.E. Jr, and Rose, J.G, 1971. The Effects of Rainfall Intensity, Pavement Cross Slope, Surface Texture and Drainage Length on Pavement Water Depths, Research Report 138-5. Texas Transportation Institute, College Station, Texas.

Appendix A: Harmonic Mean Visibility

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.

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

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

Where:

n = number of observations

V1 = sight distance at point 1, etc.

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.

$$\text{Log}_{10} \text{VISI} = 2.46 + \text{VW}/25 - \text{B}/400$$

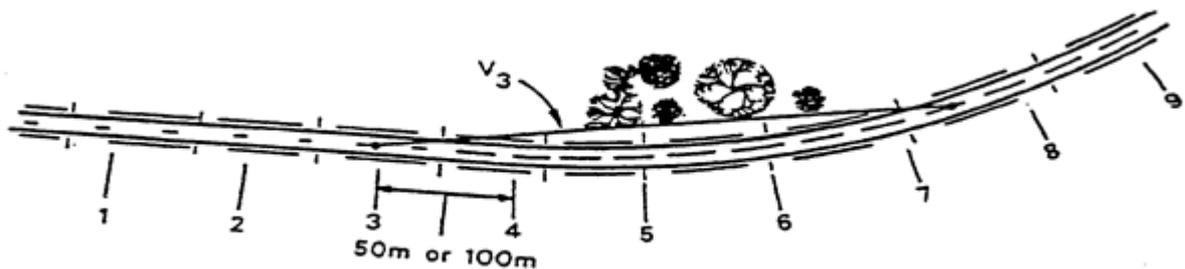
Where:

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



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.

Appendix B:

Worked Example – calculation of
water film depth

Assumptions and Methodology

The following example illustrates the recommended process to be followed by designers in determining the water film depth on a carriageway and assessing the potential for aquaplaning.

In this example, it is required to calculate the water film depth at the end of the critical drainage path on a superelevation rollover section. In order to carry out the analysis, it is first necessary to produce an accurate contour model of the proposed road surface using three dimensional triangulation models.

Assumptions

The following assumptions were required to carry out the assessment.

- a) Standard Motorway cross-section with 120km/h design speed.
- b) Surface texture depth assumed conservatively as 0.4mm.
- c) Rainfall intensity adopted for analysis is 50mm/hr.
- d) Road surface contours are as per figure B1 below.

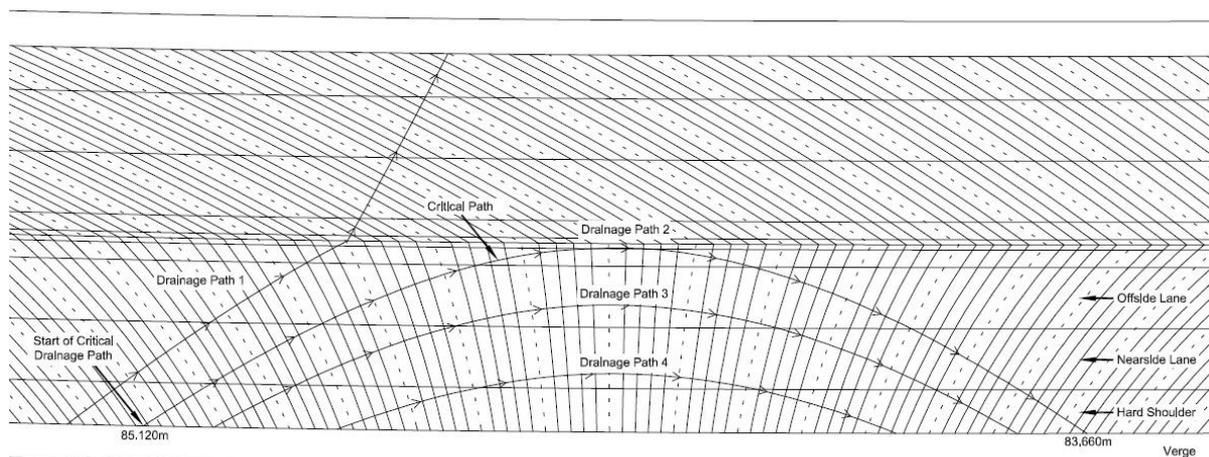
Methodology

Step 1:

Review the contour plan of the proposed road surface and identify the critical drainage path.

- a) Drainage path 1 represents the drainage path with superelevation still applied, with water flowing from one side of the carriageway to the other and is not the critical path.
- b) Drainage paths 2, 3 and 4 all start on one side, travel towards the other side but then turn back (due to the superelevation rotation) and drain off the same side as they started.
- c) The longest path is considered the critical path, therefore drainage path 2 will be assessed to determine the water film depth.

Figure B1: Road Surface Contours



Step 2:

The profile for the critical drainage path is extracted with finished road elevations recorded at regular intervals along the drainage path.

	Distance Chainage (m)	Elevation (m)
Start of Drainage Path	0	85.12
	4	85.00
	8	84.88
	12	84.78
	16	84.68
	20	84.58
	24	84.50
	28	84.42
	32	84.34
	36	84.25
	40	84.17
	44	84.07
	48	83.97
	52	83.86
	56	83.74
End of Drainage Path	58.60	83.66

Step 3:

The water depth film depth (D) for the longest drainage path is calculated using the Gallaway formula.

$$D = \frac{0.103 \times T^{0.11} \times L^{0.43} \times I^{0.59}}{S^{0.42}} - T$$

The rainfall intensity, I, adopted for the analysis is 50mm/hr (refer to Section 11.3.2, Assessment Process).

The texture depth, T, is assumed to be 0.4mm taking into account future degradation of the pavement surface.

For drainage path length L, and drainage path slope S, refer to Chapter 10. The slope to the point of assessment is the calculated 'Equal Area Slope' as per the procedure outlined in Section 11.3.2, Assessment Process. A summary of the calculations is presented in the following table.

Chainage (m)	Elevation (m)	Difference (m)	Slope (%)
0	85.13		
4	85.00	0.13	3.25
8	84.88	0.12	3.06
12	84.78	0.1	2.75
16	84.68	0.1	2.64
20	84.58	0.1	2.59
24	84.50	0.08	2.41
28	84.42	0.08	2.30
32	84.34	0.08	2.23
36	84.25	0.09	2.23
40	84.17	0.08	2.19
44	84.07	0.1	2.24
48	83.97	0.1	2.28
52	83.86	0.11	2.35
56	83.74	0.12	2.44
58.60	83.65	0.09	2.53

Once all the variables have been determined, the Gallaway formula can be applied to determine the water film depth at each point analysed.

At the end of the drainage path;

$$D = \frac{0.103 \times (0.4)^{0.11} \times (58.6)^{0.43} \times (50)^{0.59}}{(2.52)^{0.42}} - 0.4 = 3.258mm$$

A summary of the calculations at each interval along the drainage path is presented below:

Chainage (m)	Elevation (m)	Slope (%)	Water Film Depth (mm)
0	85.13	-	0
4	85.00	3.18	0.65
8	84.88	3.01	1.04
12	84.78	2.84	1.36
16	84.68	2.68	1.64
20	84.58	2.54	1.89
24	84.50	2.41	2.14
28	84.42	2.32	2.36
32	84.34	2.25	2.56
36	84.25	2.21	2.73
40	84.17	2.21	2.88
44	84.07	2.23	3.00
48	83.97	2.29	3.10
52	83.86	2.36	3.17
56	83.74	2.45	3.23
58.60	83.65	2.52	3.26

Step 4:

The calculated water depths must be compared against the assessment criteria described in section 4. It can be seen that the maximum water film depth on the critical drainage path is within the desirable limit of 3.3m for Dual Carriageway roads.

If the water film depth exceeds the maximum limit, a review of the geometrics is required.



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