

Safety Barriers
(including Erratum No. 1, dated June 2013, and
Amendment No. 1, dated February 2014)

March 2013

Summary:

This Standard gives the requirements for roadside Safety Barriers and their Terminals and Transitions.

**VOLUME 2 HIGHWAY
STRUCTURES:**

**DESIGN (SUBSTRUCTURES AND
SPECIAL STRUCTURES) MATERIALS**

SECTION 2 SPECIAL STRUCTURES

PART 8A

NRA TD 19/13

SAFETY BARRIERS

**(including Erratum No. 1, dated June 2013,
and Amendment No. 1, dated February 2014)**

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1. INTRODUCTION

General

- 1.1** This Standard gives the design requirements for roadside Safety Barriers on National Roads. The design requirements set out in Chapters 1 to 7 shall be applicable for all schemes. A risk assessment procedure shall be undertaken on schemes involving online realignment as described in Chapter 8 of this standard to establish the need for a safety barrier.
- 1.2** The Standard supersedes NRA TD 19/09. The principle changes from the previous Standard are:
- Prioritisation of hazard mitigation measures to ensure safety barriers are only installed if mitigation is not possible.
 - Addition of obstructions within the Clear Zone which should be considered as hazards requiring mitigation in Chapter 3.
 - Update to IS EN 1317 performance classes in Chapter 5.
 - Update to options for terminating barriers in Chapter 6
 - Introduction of a new Chapter 8 to include a risk assessment procedure for schemes involving online realignment on National Roads.
- 1.3** The Standard adopts the performance requirements of:
- IS EN 1317-1, Road Restraint Systems - Part 1: Terminology and General Criteria for Test Methods;
 - IS EN 1317-2, Road Restraint Systems - Part 2: Performance Classes, Impact Test Acceptance Criteria and Test Methods for Safety Barriers;
 - IS ENV 1317-4, Road Restraint Systems - Part 4: Performance Classes, Impact Test Acceptance Criteria and Test Methods for Terminals and Transitions of Safety Barriers.
 - IS EN 1317-5, Road Restraint Systems – Part 5: Product Requirements, Durability and Evaluation of Conformity.

Scope

- 1.4** This Standard details the performance requirements of Safety Barriers in common situations in the verge and central reserve of roads. The requirements for exceptional circumstances which are not encompassed by this Standard shall be agreed with the National Roads Authority in each case.
- 1.5** The Standard also provides guidance on the positioning and detailing of Safety Barriers.
- 1.6** This Standard is concerned only with the requirements for roadside safety barrier systems and their terminals and transitions, but excluding vehicle parapets and crash cushions. Parapets on bridges and retaining walls shall be designed in accordance with NRA BD 52. Crash cushions are not currently covered by NRA Standards.

Implementation

- 1.7** This Standard should be used forthwith for the construction and improvement of all National Road schemes. For schemes involving online realignment, the risk assessment procedure described in chapter 8 should be followed. For minor improvement schemes the Designer shall comply with the requirements of NRA TA 85.

- 1.8** If this Standard is to be used for the design of regional and local road schemes or roads which are improved or diverted as part of a National Road Scheme, the Designer should follow the risk assessment procedure described in Chapter 8.
- 1.9** In situations of exceptional difficulty, it may be necessary to apply for a Departure from Standards in respect of the provisions of this Standard. Proposals to adopt Departures from Standards must be submitted to the National Roads Authority for approval before incorporation into a design layout to ensure that safety is not significantly reduced.

2. DEFINITIONS

General

2.1 For clarification, and for the purposes of this Standard, the following terms defined in IS EN 1317-1 apply:

- a) road restraint system
- b) vehicle restraint system
- c) safety barrier
- d) permanent safety barrier
- e) temporary safety barrier
- f) deformable safety barrier
- g) rigid safety barrier
- h) single-sided safety barrier
- i) double sided safety barrier
- j) terminal
- k) leading terminal
- l) trailing terminal
- m) transition
- n) Vehicle parapet.

2.2 In other parts of the NRA Design Manual for Roads and Bridges and in the NRA Manual of Contract Documents for Road Works, the term ‘safety fence’ is used to describe a deformable safety barrier other than a vehicle parapet. Similarly, the term ‘safety barrier’ is used to describe a rigid safety barrier other than a vehicle parapet. It should, however, be noted that this Standard follows the terminology of EN 1317, whereby the term ‘safety barrier’ is used to describe both deformable and rigid barriers as well as vehicle parapets. Nevertheless, as noted above, vehicle parapets are not covered within this Standard.

Safety Barrier System

2.3 A safety barrier system is defined as the complete installation of a length of safety barrier at any location and includes terminals, transitions, support posts, foundations, beams, brackets, bolts and the like.

Hazard

2.4 A hazard is any physical obstruction which may, in the event of an errant vehicle leaving the carriageway, result in significant injury to the occupants of the vehicle. See Chapter 3 for information on hazards and their mitigation.

Summary of EN 1317 Performance Classes

- 2.5** EN 1317 defines various performance parameters for Safety Barriers, Terminals and Transitions as outlined below. These parameters are described in more detail in the following chapters:

Safety Barriers and Transitions

Containment Level (N1, N2, etc.)
Impact Severity Level (A, B or C)
Working width, (W1, W2, etc.)
Vehicle Intrusion (VI1, VI2 etc.)

Terminals

Performance Class
Impact Severity Level
Permanent Lateral Displacement Class
Exit Box Class

- 2.6** The performance parameters for a particular design of safety barrier, transition and terminal are established empirically by full-scale testing of representative samples. Details of the tests are specified in IS EN 1317-2, and IS ENV 1317-4.

Set-back

- 2.7** The Set-back is the dimension between the traffic face of the safety barrier and the edge of the road pavement (see Paragraphs 5.17 to 5.20).

Clear Zone

- 2.8** The Clear Zone is the total width of traversable land on the nearside or offside, within the road boundary, which is to be kept clear of unprotected hazards. This width is available for use by errant vehicles. The zone is measured from the nearest edge of the trafficked lane: i.e. the hard shoulder or hard strip forms part of the Clear Zone (see Chapter 4).

Length of Need

- 2.9** The Length of Need is the length of a barrier which provides the full level of protection required for a particular hazard. An additional length will normally be required between the start of the Length of Need and the terminal in order for the barrier to reach full performance (see Paragraphs 5.30 to 5.42).

3. HAZARD MITIGATION

General

- 3.1** Generally, the provision of safety barriers is warranted if the consequences of the vehicle striking the barrier are considered to be less serious than those which would result if the vehicle were to remain unchecked by the barrier.
- 3.2** Safety barriers may be located in the verge or central reserve depending on the purpose for which they are provided.
- 3.3** However, safety barriers themselves may be a hazard to traffic and their use should be avoided wherever practicable. In many circumstances, a hazard can be relocated sufficiently far from the road that the protection of a safety barrier is not warranted. Designers should also consider re-designing the hazard such that it is no longer a risk to road users.
- 3.4** The three main reasons for installing a safety barrier are:
- a) To minimise injuries to the occupants of vehicles which leave the carriageway;
 - b) To provide protection to third parties who may otherwise be adversely affected by errant vehicles;
 - c) To protect property, damage to which would result in the instability of a structure.
- 3.5** This Standard details the requirements and guidance for the provision of safety barriers which will normally satisfy items a) and b) above. In circumstances where item c) is considered to be relevant, a risk assessment shall be undertaken by the Designer and the provision of a safety barrier shall be agreed with the National Roads Authority.

Categories of Hazard

- 3.6** The general categories of hazards include: side slopes, fixed objects, water and railways etc. In addition, several other conditions require special consideration:
- a) Locations with high collision histories;
 - b) Locations with pedestrian and bicycle usage;
 - c) Playgrounds, monuments, and other locations with high social or economic value;
 - d) Central reserves.
- 3.7** The following paragraphs provide guidance for determining when the main categories of hazard present a significant risk to an errant vehicle. Use of a safety barrier for obstacles other than those described below will require the approval of the National Roads Authority.

Mitigation of Hazards

- 3.8** Mitigation of hazards is only required if obstructions are within the area which is likely to be traversed by an errant vehicle. This area is termed the Clear Zone and its width is defined in Chapter 4. The Clear Zone does not extend beyond the road boundary and should not be considered as the full extent of travel of an errant vehicle. Therefore in some high risk situations, it may therefore be necessary to provide a safety barrier to protect a hazard outside the Clear Zone. In such cases, details shall be agreed with the National Roads Authority.

- 3.9** Hazard mitigation measures shall be considered by the Designer prior to designing a safety barrier. A safety barrier shall only be introduced if the hazard cannot be mitigated. The mitigation measures for hazards within the Clear Zone are listed below in order of preference:
- a) Remove;
 - b) Relocate;
 - c) Re-design the hazard to reduce the risk to road users e.g. introducing a passively safe sign post;
 - d) Revise the road layout or cross-section to lower the risk, e.g. increase the width of the hard shoulder, improve the road alignment, etc.;
 - e) Reduce impact severity (e.g. by using a breakaway feature or by setting a culvert flush with the existing ground);
 - f) Provide a suitable safety barrier.

Side Slopes

Embankment Slopes

- 3.10** Embankment slopes can present a hazard to an errant vehicle with the degree of severity dependent upon the slope and height of the embankment. Providing embankment slopes that are 1:5 or flatter can mitigate this hazard. If flattening the slope is not feasible or cost effective the installation of a barrier may be appropriate. In all cases, the tops and toes of earthworks slopes should be rounded to a minimum radius of 4m.
- 3.11** Table 5/5 in Chapter 5 identifies where safety barriers are required. However, even where Table 5/5 does not require a safety barrier, obstacles on the slope may compound the hazard and thus warrant the provision of a barrier or some other safety feature.

Cut Slopes

- 3.12** A cut slope is usually less of a hazard than a safety barrier provided the toe is rounded to a minimum radius of 4m. The exceptions are a slope steeper than 1:2 or a rock cut with a rough face that could cause vehicle snagging rather than providing relatively smooth redirection. The Designer should consider the potential risks and benefits to the motorist of treatment of rough rock cuts located within the Clear Zone. A cost-effectiveness analysis that considers the consequences of doing nothing, removal or smoothing of the cut slope and all other viable options to reduce the severity of the hazard can be used to determine the appropriate treatment. Some potential options are:
- a) Redirectional land form (e.g. a grass cut slope at the foot of the rock cut);
 - b) Flexible barrier;
 - c) More rigid barrier.
- 3.13** Individual investigations should be conducted for each rock cut or group of rock cuts and the most cost-effective treatment selected.

Combinations of Slopes

- 3.14** Where combinations of side slopes occur, for example due to berms, bunding or large ditches, changes in slope shall be rounded to a minimum of 4m radius. Each component shall be considered independently and shall be treated as a hazard if that component, on its own, would require protection in accordance with Table 5/5. The embankment heights defined in Table 5/5 shall be the total height from the highest point to the lowest point within the Clear Zone.

Central Reserves

- 3.15** The Designer shall give consideration to the installation of safety barriers in central reserves to protect against errant vehicles crossing into the opposing flow of traffic. Such consideration should take due account of:
- a) the design speed for the road;
 - b) the volume of traffic using the road (each carriageway);
 - c) the type of traffic using the road (percentage HCVs);
 - d) the width of the central reserve;
 - e) the vertical alignment and super-elevation of each carriageway; and
 - f) the existence of lighting columns, traffic signs and other potential obstructions.

Fixed Objects

- 3.16** Structures tested and passed as passively safe for the appropriate speed class in accordance with IS EN 12767, Passive Safety of Support Structures for Road Equipment – Requirements and Test Methods, are not considered a hazard.
- 3.17** The following obstructions within the Clear Zone should be considered as hazards requiring mitigation unless they comply with the above requirements:
- a) wooden poles or posts with cross sectional area greater than 25,000mm² that do not have breakaway features;
 - b) ¹all fences (including timber post and rail fences) if not being used as a road boundary²;
 - c) tubular steel posts or supports greater than 89mm diameter tube by 3.2mm thick, or equivalent strength;
 - d) lighting columns;
 - e) trees having a girth of 175mm or more measured at 1m above the ground;
 - f) substantial fixed obstacles extending above the ground by more than 150mm;
 - g) concrete posts with cross sectional area greater than 15,000mm²;
 - h) Drainage items, such as culvert headwalls and transverse ditches that are not detailed to be traversed safely.

¹ Amended as per Erratum No. 1, item 1

² Amended as per Erratum No. 1, item 2

Trees

- 3.18** When evaluating new plantings or existing trees, the maximum allowable girth should be 175mm measured at 1m above the ground when the tree has matured. When removing trees within the Clear Zone, complete removal of stumps is preferred. However, to avoid significant disturbance of the roadside vegetation, larger stumps may be mitigated by grinding or cutting them flush to the ground and grading around them.

Culvert Ends

- 3.19** A traversable end treatment should be provided when the culvert end section or opening is on the roadway side slope and within the Clear Zone. This can be accomplished for small culverts by bevelling the end to match the side slope, with a maximum of 150mm extending out of the side slope. Larger culverts exceeding the following criteria will require protection using a Safety Barrier.
- a) A single cross culvert opening exceeding 1000mm measured parallel to the direction of travel;
 - b) Multiple cross culvert openings exceeding 750mm each, measured parallel to the direction of travel; or
 - c) A culvert approximately parallel to the roadway that has an opening exceeding 600mm measured perpendicular to the direction of travel.

Sign Posts

- 3.20** Whenever possible, sign supports should be located behind safety barrier installations that have been provided for other purposes. This will eliminate the need for breakaway supports. Sign posts with cross sectional areas greater than the sizes outlined in Paragraph 3.17 that are within the Clear Zone and not located behind a barrier must have breakaway features.

Water

- 3.21** Water with a likely depth of 0.6 m or more and located with a likelihood of encroachment by an errant vehicle must always be considered a hazard. If the water feature forms part of the design (e.g. a balancing pond), consideration should be given to relocation. In most cases however, it is likely that the feature is existing or cannot be moved and a safety barrier will need to be provided.
- 3.22** Interceptor ditches offset from the toe of the earthworks in accordance with the NRA Road Construction Details and not more than 1.2m deep need not be regarded as a hazard in normal circumstances, provided they run nominally parallel to the road.

Linear Hazards (e.g. Roads and Railways)

- 3.23** Particular difficulties can be experienced at locations where the road crosses or runs alongside a linear hazard such as a road or railway. In these cases, users of the other road or railway as well as the occupants of an errant vehicle need to be protected. The rules and guidance concerning Clear Zones and Length of Need may not provide sufficient protection to the hazard beneath. Therefore the Designer should undertake a risk assessment to identify the extent and type of safety barrier to be used. The outcome of the risk assessment must be agreed with the National Roads Authority.

3.24 The recommended procedure for linear hazards is:

- a) Prepare an initial layout using Clear Zone, Length of Need, etc.
- b) Select the appropriate barrier as a minimum from Table 5/5;
- c) Consider whether the physical layout of the safety barrier will adequately prevent vehicles from reaching the hazard. (Note: This stage is purely to determine the layout and it should therefore be assumed that vehicles will be arrested by the selected barrier if this is hit.);
- d) Undertake a risk assessment to decide whether the layout determined in c) above should be adopted and whether the Containment Level should be increased. Consideration should be given, inter alia, to the types and numbers of vehicles using the road, the road geometry, Design Speed and the frequency of use of the linear feature;
- e) Agree the proposals with the National Roads Authority

4. CLEAR ZONE

General

- 4.1** A primary consideration when designing a road is to minimise the hazards to which the motorist is exposed. As described in Chapter 3 this can largely be achieved by removing the hazards from the immediate roadside through careful design. The width of land which should be kept clear of hazards so as to be available for use by errant vehicles is termed the Clear Zone. Where hazard mitigation is not reasonably practicable, safety barriers will be required.
- 4.2** The Clear Zone is the total width of traversable land on the nearside or offside, within the road boundary, which is to be kept clear of unprotected hazards. The zone is measured from the nearest edge of the trafficked lane: i.e. the hard shoulder or hard strip forms part of the Clear Zone. The zone does not normally include the boundary fence nor areas of land beyond the road boundary. However, in some circumstances, it may be necessary to consider hazards on or beyond the road boundary.

Zone Width

- 4.3** Several factors influence the path of a vehicle which leaves the carriageway. The most notable of these are the vehicle speed, the horizontal curvature of the road and the terrain over which the vehicle passes. Table 4/1 indicates the required Clear Zone width for various design speeds and curvatures. However, where the road boundary is closer to the trafficked lane than the relevant width from Table 4/1, the Clear Zone is curtailed at the road Boundary.
- 4.4** Figures 4/1 and 4/2 indicate the Clear Zone width available with different classes of terrain. Where the ground is reasonably flat (Terrain Class 1), the width of the embankment or cutting slope can be included in the available Clear Zone. Where there is a medium embankment slope (Terrain Class 2), it is considered that a vehicle can cross the slope without overturning but cannot slow down. In such terrain, therefore, the available Clear Zone does not include the width of the slope. Where the slope is steep enough to form a hazard in itself (Terrain Class 3), the available Clear Zone does not extend onto or across the slope.
- 4.5** Where the required Clear Zone (from Table 4/1 or the width to the road boundary, whichever is the lesser) is not available and clear of hazards, a safety barrier will normally be required.

Terrain Classes

- 4.6** The Terrain Classes are defined as:

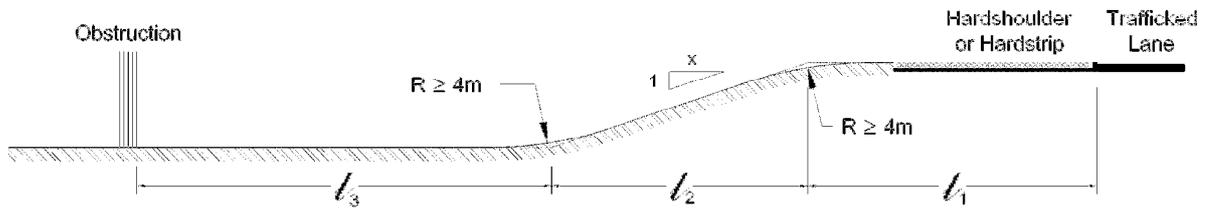
- Class 1:** Slope is equal to or less steep than 1:5 (falling) or 1:2 (rising).
The area is considered as level terrain.
If the total change in level is less than 0.5m the area can be judged as level terrain regardless of the angle of the slope.
- Class 2:** Slope is between 1:3 and 1:5 (falling).
It is possible to drive on such a slope without overturning, provided the transition to the slope is rounded off, but vehicles cannot decelerate on the slope. The slope width can be part of the Clear Zone, but cannot be included in the determination of the necessary width of the Clear Zone.

Class 3: Slope rises sharply (steeper than 1:2) or falls sharply (steeper than 1:3). These inclinations present a danger of overturning or sudden halting of the vehicle. These areas are considered hazards if it is not possible to remove the risk in some way. On falling ground, the width of level ground beyond a slope between 1:3 and 1:2 and which is less than 2m high may be included in the computation of Clear Zone Width. See Class 3a in Figure 4/1.

4.7 A fundamental feature of the concept is to round the top and bottom of the slope such that vehicles do not become unstable as they traverse the embankment or cutting. The slope rounding should generally have a radius of at least 4m.

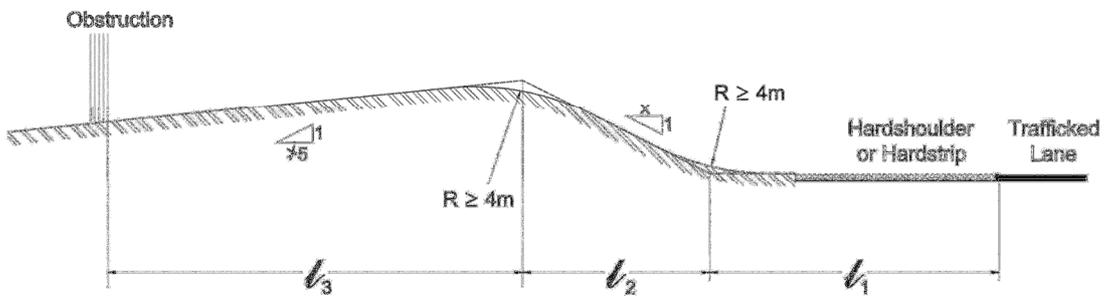
	Design Speed (km/h)		
	85	100	120
Horizontal radius (m)	Required Width of Clear Zone (m)		
Inside of bend or Straight	6.5	8.0	10.0
Outside of bend $\geq 1,000\text{m}$	6.5	8.0	10.0
“ 900m	7.1	8.8	12.4
“ 800m	7.7	9.6	14.9
“ 700m	8.3	10.4	17.5
“ 600m	8.8	11.2	20.0
“ 500m	9.4	12.0	
“ 400m	10.0	12.8	
“ 300m	10.6		

Table 4/1: Required Clear Zone Width



Embankment or Falling Terrain	Terrain Class	Clear Zone Width
Slope flatter or equal to 1:5	1	$l_1 + l_2 + l_3$
Slope between 1:5 and 1:3	2	$l_1 + l_3$
Slope between 1:3 and 1:2 and <2m high	3a	$l_1 + l_3$
All other slopes between 1:3 and 1:2	3b	l_1
Slope steeper than 1:2	3c	l_1

Figure 4/1: Land Included in Clear Zone: Embankments



Cutting or Rising Terrain	Terrain Class	Clear Zone Width
Slope shallower or equal to 1:2	1	$l_1 + l_2 + l_3$
Slope steeper than 1:2	3	l_1

Figure 4/2: Land Included in Clear Zone: Cuttings

5. PERMANENT SAFETY BARRIERS

General

- 5.1** Safety Barriers should be considered an integral part of the road alignment design since their position may affect the stopping sight distance and clearance to structures etc. In particular, it will be necessary to ensure that the visibility requirements of NRA TD 9 (NRA DMRB 6.1.1) are not compromised by the presence of safety barriers.
- 5.2** The introduction of a safety barrier adjacent to the carriageway should only be considered where the elimination of all hazards within the Clear Zone is not reasonably practicable. The mitigation steps outlined in section 3.9 should be followed by the Designer prior to designing a safety barrier. In cases where removal or relocation of the hazard is not practicable, the provision of a safety barrier is mandatory, except on schemes involving online realignment.
- 5.3** The ideal position of a safety barrier in relation to the edge of the road will depend, inter alia, on the type of device being considered and on the number of hazards being protected. In general, the designer should provide the maximum width of level verge or central reserve in front of the system as possible. This will optimise the opportunity for an errant vehicle to regain control without striking the safety barrier.

EN 1317 Performance Classes

- 5.4** IS EN 1317-2 defines various performance parameters for Safety Barriers as outlined in Tables 5/1 to 5/4 and Figure 5/1.

Containment Level

- 5.5** Containment level is an indication of the severity of impact – type, weight and speed of vehicle – which the safety barrier is designed to contain. The standard levels stipulated in IS EN 1317-2 are as shown in Table 5/1.

Containment Level	Vehicle Impact Test				
	Test	Impact Speed (km/h)	Impact Angle (degrees)	Vehicle Mass (t)	Vehicle Type
Normal Containment N1 N2	TB 31	80	20	1.5	Car
	TB 32	110	20	1.5	Car
Higher Containment H1 L1 L1 H2 L2 L2 H3 L3 L3	TB 42	70	15	10.0	Rigid HCV
	TB 42	70	15	10.0	Rigid HCV
	TB 32	110	20	1.5	Car
	TB 51	70	20	13.0	Bus
	TB 51	70	20	13.0	Bus
	TB 32	110	20	1.5	Car
	TB 61	80	20	16.0	Rigid HCV
	TB 61	80	20	16.0	Rigid HCV
	TB 32	110	20	1.5	Car
Very High Containment H4a H4b L4a L4a L4b L4b	TB 71	65	20	30.0	Rigid HCV
	TB 81	65	20	38.0	Articulated HCV
	TB 71	65	20	30.0	Rigid HCV
	TB 32	110	20	1.5	Car
	TB 81	65	20	38.0	Articulated HCV
	TB 32	110	20	1.5	Car

Note: Barriers with a Containment Level of N2 or higher shall also be subjected to Test TB 11, using a light vehicle (900kg), in order to verify that satisfactory attainment of the maximum level is also compatible for a light vehicle. (Source: IS EN 1317-2)

Table 5/1: IS EN 1317 Containment Level Tests

Impact Severity Level		
	ASI	THIV
A	≤ 1.0	≤ 33 km/h
B	≤ 1.4	≤ 33 km/h
C	≤ 1.9	≤ 33 km/h

(Source IS EN 1317-2)

Table 5/2: EN 1317 Impact Severity Levels

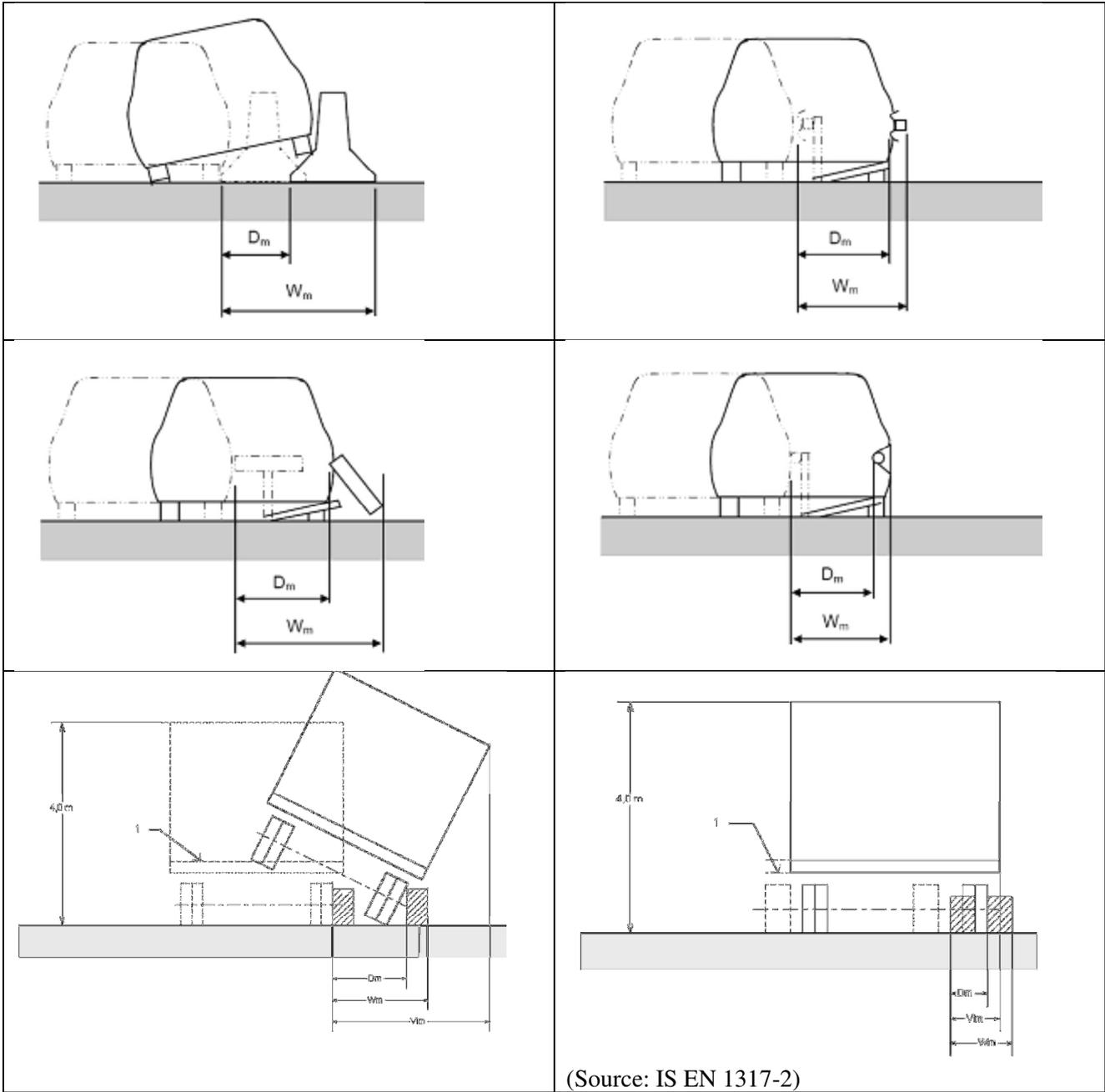


Figure 5/1 Part 1: Dynamic Deflection (D_m), Working Width (W_m) and Vehicle Intrusion (V_{Im}) Measured Values

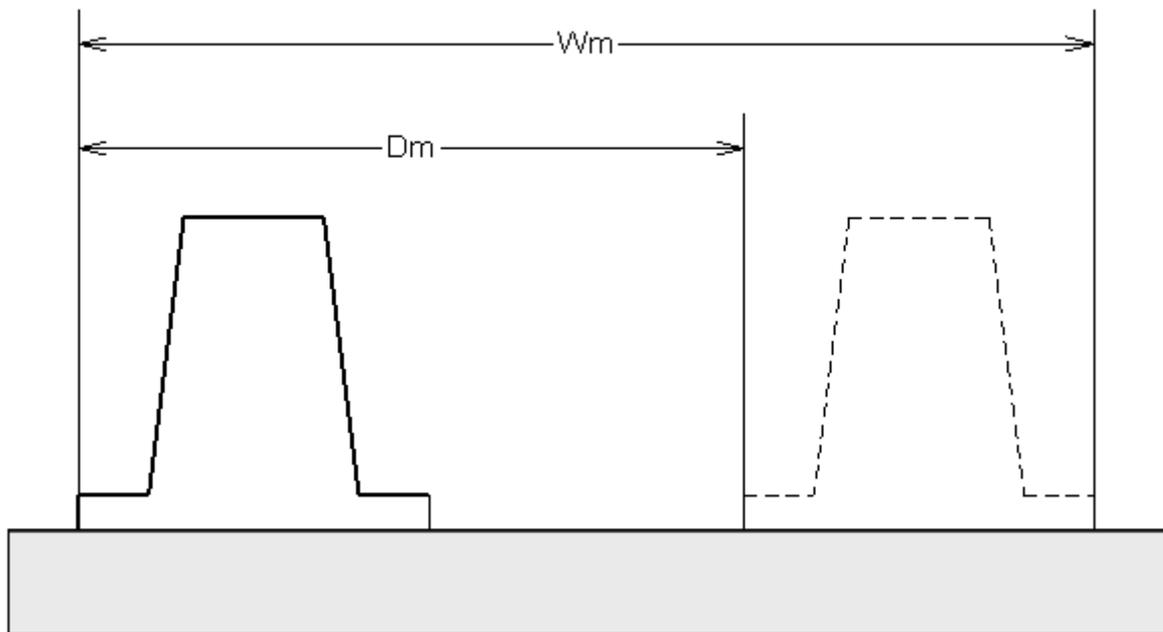


Figure 5/1 Part 2: Dynamic Deflection (D_m), Working Width (W_m) and Vehicle Intrusion (V_{Im}) Measured Values

Impact Severity Level

- 5.6** Impact Severity Level is measured as a function of the Acceleration Severity Index (ASI) and the Theoretical Head Impact Velocity (THIV). IS EN 1317-2 defines these terms and describes how they should be measured. The three levels given in the Standard are shown in Table 5/2.
- 5.7** Impact Severity Level A affords a greater level of comfort for vehicle occupants than Level B and Level C (see Paragraph 5.14).

Working Width and Vehicle Intrusion

- 5.8** The working width (W_m) is the maximum lateral distance between any part of the barrier on the undeformed traffic side and the maximum dynamic position of any part of the barrier. If the vehicle body deforms around the road vehicle restraint system so that the latter cannot be used for the purpose of measuring the working width, the maximum lateral position of any part of the vehicle shall be taken as an alternative. Examples of Working Width are illustrated in Figure 5/1.

5.9 Working Width is specified as one of the classes listed in Table 5/3.

Class of Working Width	Level of Working Width
W1	≤ 0.6 m
W2	≤ 0.8 m
W3	≤ 1.0 m
W4	≤ 1.3 m
W5	≤ 1.7 m
W6	≤ 2.1 m
W7	≤ 2.5 m
W8	≤ 3.5 m

(Source: IS EN 1317-2)

Table 5/3: Working Width Classes

5.10 The vehicle intrusion (VI_m) of the Heavy Goods Vehicle (HGV) is its maximum dynamic lateral position from the undeformed traffic side of the barrier; it shall be evaluated from high speed photographic or video recordings, in consideration of a notional load having the width and length of the vehicle platform and a total height of 4 m. The VI_m shall be evaluated by measuring the position and angle of the vehicle platform and assuming the notional load stays undeformed and rectangular to the vehicle platform or by using test vehicles with the notional load. Examples of Vehicle Intrusion are illustrated in Figure 5/1.

5.11 Vehicle Intrusion is specified as one of the classes listed in Table 5/4.

Class of Vehicle Intrusion	Level of Vehicle Intrusion
VI1	≤ 0.6 m
VI2	≤ 0.8 m
VI3	≤ 1.0 m
VI4	≤ 1.3 m
VI5	≤ 1.7 m
VI6	≤ 2.1 m
VI7	≤ 2.5 m
VI8	≤ 3.5 m
VI9	>3.5m

Table 5/4 Vehicle Intrusion Classes

Provision Criteria

5.12 A safety barrier shall be provided in central reserves and where there is a hazard within the Clear Zone. At the locations described in Table 5/5, the barrier shall have at least the Containment Level indicated.

5.13 On motorways and Type 1 dual carriageways barriers on central reserves shall be constructed from concrete.

- 5.14** Barriers on verges should have Impact Severity Level A and barriers on central reserves should have an Impact Severity Level no worse than B. However, on central reserves wider than 7.5m, provision of Impact Severity Level A is preferred. The use of Impact Severity Level B on verges or on central reserves wider than 7.5m shall constitute a Relaxation, for which justification will be required.
- 5.15** The Designer shall agree the provision of safety barriers with the National Roads Authority where there are exceptional local hazards or conditions which are not identified in Table 5/5 or which are considered to warrant an increase in the containment level. Account shall be taken, for example, of an unusually high percentage of Heavy Commercial Vehicles in deciding whether to increase the containment level of the safety barrier at any particular location.
- 5.16** Where several hazards are in close proximity, the highest required Containment Level shall be provided throughout the safety barrier length.

Set-back

- 5.17** The Set-back is the dimension between the traffic face of the safety barrier and the edge of the road pavement. It should be noted that the road pavement includes any hard shoulder or hard strip.

Location	Containment Level	
1. Within the Clear Zone:		
Embankments:		
<u>Slope Angle</u>	<u>Slope Height</u>	
Steeper than 1:2 (see Note 3)	≥0.5	N2
Between 1:2 and 1:3 (inclusive)	>2m	N2
From 1:3 and up to 1:5	≥6m	N2
Cuttings:		
At steep sided cuttings or earth bunds (steeper than 1:2) within the Clear Zone		N2
Verges and Central Reserves:		
a) At individual hazards such as bridge piers or abutments, sign posts, gantry legs and trees, etc. (see Chapter 3) (see Note 4)		N2
b) At lighting columns that are not passively safe		N2
c) At substantial obstructions such as retaining walls which extend more than 150mm above the carriageway level (See Note 7).		N2
d) At underbridges or at retaining walls >0.5m high supporting the road, where a vehicle parapet or vehicle/pedestrian parapet of the required performance class is not provided		N2
Central Reserves:		
a) At central reserves up to 7.5m wide		H2
b) At central reserves greater than 7.5m wide		N2
c) Where the difference in adjacent carriageway channel levels exceeds 1.0m and the slope across the reserve exceeds 1:4		H2
Parapets (see BD 52):		
For a minimum of 30m in advance of the approach end and 15m after the departure end of a vehicle parapet or vehicle/pedestrian parapet (see Note 5).		N2
For a minimum of 30m in advance of the approach end and 15m after the departure end of a vehicle parapet or vehicle/pedestrian parapet over a railway. (see Note 5)		H2
2. Within or Beyond the Clear Zone		
Verges:		
a) At locations where an errant vehicle may encroach onto an adjacent road (but see Note 6) or impact another significant hazard		H2
b) At locations where an errant vehicle may encroach onto an adjacent railway		H2
c) At hazardous topographical features beyond the road boundary, but within the width defined in Table 4/1		N2

Notes:

- This Table provides minimum Containment Levels for particular situations. Higher Containment Levels may be justified in some situations.
- Where there is more than one reason for a safety barrier (e.g. at a central reserve 6m wide with lighting columns that are not passively safe), the highest of the required Containment Levels shall be provided.
- The use of 4m radius slope rounding will prevent the development of slopes steeper than 1:2 until the embankment height is greater than 0.85m.
- Where the hazard is not designed to withstand collision loads and where impact may result in injuries to people other than those in the errant vehicle, a higher Containment Level may be required.
- The Containment Level on the approach shall be equal to that of the parapet or the adjacent safety barrier, whichever is the greater.
- A safety barrier is not required (unless there is another reason) where the adjacent road joins the road under consideration, e.g. at slip roads and junctions.
- Retaining walls may incorporate a concrete barrier of the profile shown in the NRA Road Construction Details rather than require a separate barrier, provided the surface of the wall presents a smooth traffic face for at least 1.5m above the carriageway level.
- For roads with a Design Speed of 85km/h or less, containment level N1 may be substituted for N2 in the table above.

Table 5/5: Minimum Containment Level

- 5.18** The minimum Set-back on a verge shall be 1.2m. This may be reduced to 0.6m if a hard strip with a width of 1m or more or hard shoulder is present or where the road Design Speed is 85km/h or less.
- 5.19** At central reserves the minimum Set-back shall be 0m (zero) where a hardstrip of width 0.6m or greater is present. If there is no hardstrip present, the minimum Set-back shall be 0.6m.
- 5.20** The performance of the safety barrier system must not be compromised by the presence of a filter drain, cables or the like close to the barrier foundations. The clear distance required between the barrier and any feature which may affect the safety barrier performance shall be ascertained. Alterations to the Set-back may be required in some circumstances although the minimum Set-back shall never be compromised.

Lateral Positioning

- 5.21** For normal containment barriers, the Working Width should be **W6** where space is available. However, the Set-back should also be as large as practicable in order to provide the maximum width in which errant vehicles can regain control. Within the limited verge or central reserve widths available with many road cross-sections, it will be necessary to provide a reasonable compromise between a large Working Width and a generous Set-back. It must also be ensured that the detailing of the drainage and services within the verge does not restrict the selection of safety barrier unduly.
- 5.22** Design decisions regarding the lateral position of the barrier and its Working Width are further complicated by factors such as the barrier Set-back required to achieve the required stopping sight distance. In some cases, additional verge width may need to be provided in order to accommodate a higher Working Width barrier or a larger Set-back.
- 5.23** For isolated hazards, the safety barrier should be placed as close to the obstruction as possible and hence a small Working Width (normally **W2** to **W4**) should be selected. This provides the maximum available Set-back and maximises the space available for the errant vehicle to be brought under control.
- 5.24** For high containment barriers with small Working Widths, it is considered preferable to keep the Set-back distance as small as possible (subject to compliance with 5.19 above) as this will minimise the angle of impact and consequently reduce the severity of impact on the occupants of the errant vehicle.
- 5.25** Where combinations of hazards are to be protected by a single length of safety barrier, the Set-back of the barrier should be established by assessing the obstruction nearest to the road as if this was an isolated hazard. This Set-back should be retained for the remaining obstructions although the Working Width can be varied to suit each obstruction. Changes in Working Width, however, along the length of a barrier are subject to suitable transitions being available.
- 5.26** With the exception bridge and sign gantry supports in central reserves containing in-situ concrete barriers, where objects are being protected, the Working Width of the safety barrier must be such that under design conditions the hazard is not impacted. There must also be full headroom for the impact vehicle in its position of maximum lateral displacement.
- 5.27** On verges, the Working Width of the safety barrier shall not allow the traffic face of the barrier, when deflected to the full Working Width, to extend beyond the intersection of the embankment or cut slope and the verge.

- 5.28** On central reserves, the safety barrier position and Working Width shall be such that under design impact conditions no part will deflect into the opposing traffic lane. On wide central reserves with anti-dazzle hedges, the centre of the safety barrier should, where practicable, be at least 2.4m from the centre of the hedge.

Examples of Safety Barrier Requirements

- 5.29** Examples of the parameters of safety barriers in typical situations – in terms of Containment Level, Impact Severity Level, Working Width and Set-back – are indicated in Appendix A.

Length of Need (LoN)

- 5.30** The length of safety barrier shall be derived from a detailed consideration of each location. The total length of barrier will normally comprise the Length of Need plus, at each end, the length of the terminal and an intermediate length over which the barrier attains full performance.
- 5.31** The Length of Need consists of the Approach Length, the length of the hazard and the Departure Length. It is dependent on the location and geometry of the hazard, direction(s) of traffic, design speed, traffic volume, and type and location of safety barrier.
- 5.32** Gaps of 100m or less between barrier lengths should be avoided. However, short gaps are acceptable when the barriers are terminated in a cut slope. If the end of the Length of Need is near the end of another barrier, it is recommended that the barriers be connected to form a continuous barrier. Maintenance access should be considered when determining whether to connect barriers.

Approach Length

- 5.33** The calculation of the Approach Length is based on the premise that the errant vehicle should not be able to leave the carriageway and get behind the barrier and thereby hit the obstacle. The calculations are based on an impact angle of about 8° (1:7).

Embankments and Level or Falling Ground

- 5.34** Where the ground behind the barrier is level or falling away from the road (e.g. road on embankment), the Approach Length (AL) shall be at least 30m and not less than:

$$AL = 7xD_E$$

where D_E = distance from traffic face of the safety barrier either to the rear of the hazard or to the edge of the Clear Zone, whichever is the less.

A typical example is illustrated in Figure 5/2.

- 5.35** Where the hazard is the embankment slope itself, the Length of Need begins and ends at the points where the hazard starts and finishes. There is no need for Approach and Departure Lengths.

Cuttings and Environmental Bunds

- 5.36** Where the ground behind the barrier rises (i.e. road in cutting or by an environmental bund), an errant vehicle may pass around the end of the barrier and alter direction towards the obstacle or hazard. At such locations, the Approach Length shall be at least 30m and not less than:

$$AL = 7xD_C$$

where D_C = distance from traffic face of the safety barrier to the edge of the Clear Zone.

- 5.37** Additional protection of the obstacle could be provided by the use of dense vegetation or gravel beds behind the barrier to provide a deceleration force on the vehicle. Terminals should be returned to the cutting face wherever practicable, as this will minimise the risk of end impact by an errant vehicle.

- 5.38** For obstacles which are only a hazard due to a face parallel to the road, such as a rock cutting or a retaining wall with buried ends, both Approach and Departure Lengths shall be at least 10m and not less than:

$$AL = 7xD_F$$

where D_F = distance from traffic face of the safety barrier to the face of the hazard.

Horizontal Curvature

- 5.39** The equations given in Paragraphs 5.34, 5.36 and 5.38 are applicable to all normal road curvatures. For particularly onerous circumstances, the Designer should discuss the provision of a safety barrier with the National Roads Authority.

Departure Length

- 5.40** The length of barrier beyond the hazard is termed the Departure Length. For two-way carriageways, it shall generally be determined using the same equations as for the Approach Length, but shall be at least 15m long on non-overtaking sections and 30m long on overtaking sections (except where Paragraph 5.38 applies). The Clear Zone for the Departure Length commences at the divide between opposing traffic flows; this will normally result in a Departure Length considerably shorter than the Approach Length (see Figure 5/2).

- 5.41** For dual carriageways and motorways, the Departure Length shall be at least 15m long (except where Paragraph 5.38 applies).

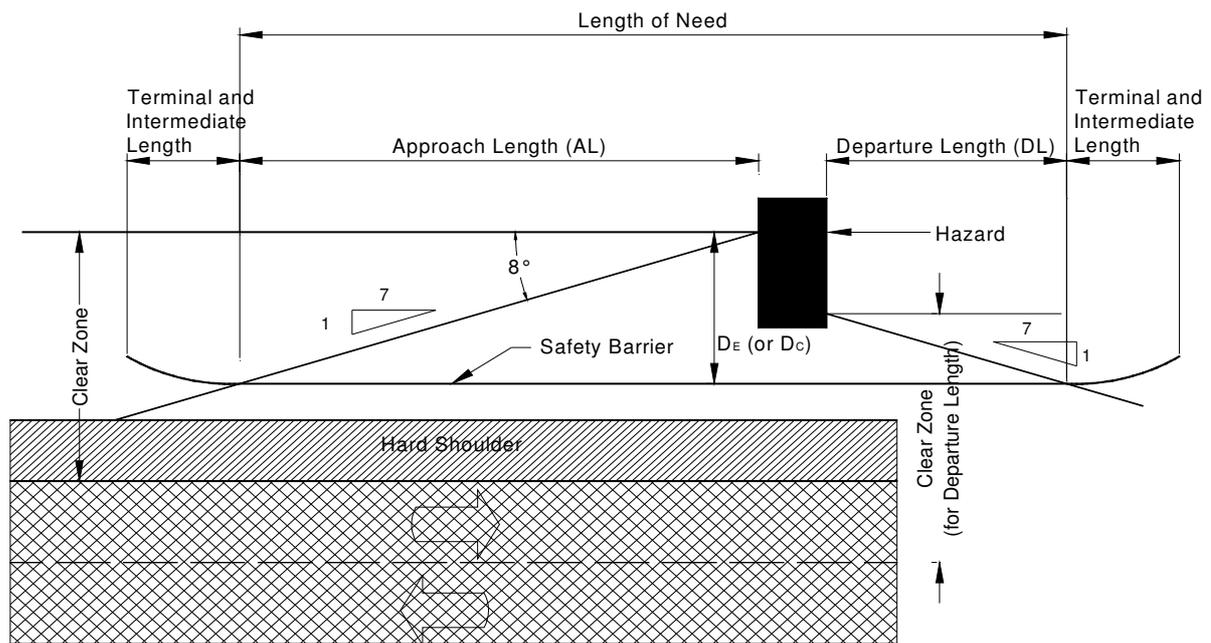


Figure 5/2: Example of Approach and Departure Lengths

Minimum Length

5.42 An appropriate system must be provided whose minimum length is equal to or less than the length of barrier to be installed, thus ensuring effective operation in service.

Height of Safety Barrier

5.43 Safety barriers shall be set at the height specified for the system, within the specified tolerances. Particular care shall be taken to ensure that the barrier is at the correct height following resurfacing or overlay works.

5.44 Where the Set-back is less than 1.5m, the height of the barriers shall be related to the edge of the road pavement. Elsewhere, the height shall be measured from the general ground level in close proximity to the front of the barrier.

Kerbs

5.45 Kerbs in front of a safety barrier can contribute to the vehicle overturning or ascending the safety barrier. If kerbs in front of the safety barrier cannot be avoided on roads with a Design Speed of 85 km/h or more, the kerbs should be splayed over the full height by at least 45° to the vertical and not higher than 80 mm.

Flare

5.46 Safety barriers should be installed in accordance with the manufacturer's requirements. Where these allow and wherever practicable, the ends of barriers should be flared. There are three functions of the flare:

- To locate the barrier and its terminal as far from the carriageway as is feasible;
- To minimise a driver's reaction to the introduction of an object near the carriageway;
- To reduce the Length of Need.

However flaring may not be appropriate at full height terminals.

5.47 It has been shown that an object (or barrier) close to the carriageway may cause a driver to shift laterally, slow down, or both. The flare reduces this reaction by gradually introducing the barrier so that the driver does not perceive the barrier as a hazard. However, a flare increases the angle at which a vehicle will impact the barrier. A compromise between flare and impact angle is needed. Flare rates steeper than 1:20 should, therefore, not be used.

5.48 The following general principles apply:

- Vehicles should not be able to pass easily behind the approach flare;
- Anchorages and concrete ramps on central reserves should not be located so they protrude into the deflection space of the opposite fence.

5.49 Where parts of the Approach and/or Departure Lengths are flared, these lengths may be calculated in accordance with Appendix B. In some circumstances this will lead to shorter barriers.

5.50 Flare rates of up to 1:20 may also be used:

- if to do so does not conflict with the manufacturer's requirements, and
- if it is necessary to change the Set-back of a barrier (e.g. at the approaches to bridge piers in the central reserve).

Ground Conditions

5.51 Most safety barrier systems rely on certain ground conditions in order to function satisfactorily. Where this is the case, a test regime, as described in the Series 400 clauses of the NRA Specification for Road Works, shall be established to ensure that the system performs as intended.

In-Situ Concrete Barrier

5.52 The diagrams detailing the In-situ Concrete Barrier are contained in the 400 Series of the NRA Road Construction Details. This barrier design is 900mm in height with a small step 250mm above road surface level. It requires a hardened foundation into which the barrier is rebated.

5.53 This barrier has been approved by the National Roads Authority for use in situations which require an H2 Containment Level, an Impact Severity Level B. In general this barrier requires a Working Width of W2. However where the barrier transforms to provide a vertical face in line with a bridge or gantry support in a central reserve, as shown in the 400 Series of the NRA Road Construction Details, a working width of zero may be assumed.

Emergency Crossovers

5.54 Emergency crossovers shall be provided in accordance with NRA TD9

Safety Barriers at Junctions

- 5.55** At junctions, safety barrier layouts should be adjusted to suit the requirements of both roads. Consideration should be given to any hazard close to the junction which lies within the Clear Zone of the main road. It may be appropriate to provide a safety barrier in front of such a hazard, even though the barrier will follow the line of the adjacent edge of pavement and may not be parallel to the main road.
- 5.56** Care should be taken to avoid positioning barriers at greater than 20 degrees maximum to the likely approach direction of an errant vehicle. In particular barriers should not be turned through sharp radii such that they could be hit head on and create a greater hazard than the unprotected situation (e.g. at T-junctions and accesses).
- 5.57** Safety Barriers are not an appropriate solution to potential hazards at diverge junction nosings. Alternative arrangements should be made to create a passively safe environment.

6. TERMINALS

Definitions

- 6.1** A Terminal is the treatment of the beginning and/or end of a safety barrier. In addition, it can provide an anchorage for the barrier system.
- 6.2** A Transition is an interface between two safety barriers of different cross-section or different stiffness. The requirements for transitions are described in Chapter 7.

Options for Terminating Barriers

- 6.3** All safety barriers shall be terminated such that the risk of injury to the occupants of errant vehicles is minimised.
- 6.4** Options for terminating barriers in order of preference include:
- a) Returning the barrier such that the end is buried in a cutting face or bund.
 - b) Ramping the barrier down to ground level, where the terminal is not in the direct line of traffic.
 - c) Terminating at a full height terminal of Performance Class P4 where the terminal is in the direct line of traffic.

Terminating barriers described in sections (a) and (b) above shall have a flare of 1:20 away from the road.

Direct connections to vehicle parapets shall be considered as transitions (see Chapter 7).

- 6.5** Upstream terminals shall comply with the requirements of IS ENV 1317-4 for the performance criteria detailed in paragraphs 6.7 to 6.20 below.
- 6.6** Downstream terminals may be of types a) b) or c) as described in paragraph 6.4 above. If a full height terminal is used, this shall comply with the requirements of IS ENV 1317-4 for the performance criteria detailed in paragraphs 6.7 to 6.20 below.

Performance Class

- 6.7** For roads with a design speed of 100km/h or greater upstream terminals shall be of Performance Class P4, where the terminal is in the direct line of traffic. For lower design speeds upstream terminals shall be of minimum Performance Class P1.
- 6.8** Downstream full height terminals shall be of minimum Performance Class P1.

Impact Severity Level

- 6.9** The impact severity level of the terminal should be consistent with the barrier to which the terminal is attached.

Permanent Lateral Displacement Class

- 6.10** The Permanent Lateral Displacement Class is a measure of the maximum permissible displacement of a terminal in the event of an impact, as defined in IS ENV 1317-4.

- 6.11** D_a is the maximum permissible deflection in front of the original front face line of the connecting safety barrier. D_d is the maximum permissible deflection behind the original front face line of the connecting safety barrier.
- 6.12** If the safety barrier is to be flared to maintain setback to the end terminal, this should be included in the measurement of D_d .
- 6.13** The Permanent Lateral Displacement Class shall be specified as one of the classes listed in Table 6/1. (e.g. x2/y2).

Class Code		Displacement (m)	
x	1	D _a	0.5
	2		1.5
	3		3.0
y	1	D _d	1.0
	2		2.0
	3		3.5
	4		>3.5

(Source: IS EN 1317-4)

Table 6/1: Permanent Lateral Displacement of Terminals

- 6.14** The Permanent Lateral Displacement Class shall be specified to ensure that the deflected terminal does not encroach onto the traffic lanes, but may be permitted to encroach onto a hard shoulder or hard strip.

Exit Box Class

- 6.15** The Exit Box Class is a measure of the vehicle redirection following an impact with a terminal, as defined in IS ENV 1317-4.
- 6.16** Z_a is the maximum vehicle redirection in front of the original front face line of the connecting safety barrier. Z_d is the maximum vehicle redirection behind the original front face line of the connecting safety barrier.
- 6.17** The Exit Box Class shall be specified as one of the classes listed in Table 6/2.

Classes of Z	Approach Side Z _a (m)	Departure Side Z _d (m)
Z ₁	4	4
Z ₂	6	6
Z ₃	4	No limit
Z ₄	6	No limit

(Source: IS EN 1317-4)

Table 6/2: Exit Box Dimensions

- 6.18** Terminals with Exit Box Classes Z3 and Z4 should be used with caution due to the unlimited dimension of the Exit Box on the departure side.
- 6.19** The Exit Box Class should be defined to ensure that an errant vehicle does not encroach beyond the first traffic lane adjacent to the barrier, and in the case of a central reserve, beyond the hard strip of opposite carriageway.

Compatibility

- 6.20** It must be ensured that the terminal can function adequately in combination with the type of safety barrier it is attached to. The contractor must check with the Safety Barrier manufacturer(s) and ensure that the proposed Safety Barrier and Terminal will act together and meet the Performance Class criteria and the other requirements specified.

7. TRANSITIONS

General

- 7.1** Transitions are necessary between safety barriers with different Working Widths or Containment Levels. They may also be required between barriers and bridge parapets.
- 7.2** A Transition is an interface between two safety barriers of different cross section or different lateral stiffness, where the containment is to be continuous. The purpose of a transition is to provide a gradual change from the first to the second barrier, to prevent the hazard of an abrupt variation. A transition is designed to connect two specified barriers.
- 7.3** The junction between two barriers having the same cross section and the same material, and differing in the Working Width by no more than one Class, shall not be considered a transition.
- 7.4** Direct connections between a safety barrier and a vehicle parapet shall be considered as transitions. So too shall expansion joint assemblies.

Transition Between Types of Safety Barrier

- 7.5** The definitions for Transitions of the Containment Level, Severity Index Level and Working Width are the same as specified in IS EN 1317-2 for safety barriers (see Chapter 5). The Containment Level for the transition shall not be lower than the lower Containment Level, nor higher than the higher, of the two connected barriers. Its Working Width shall not be larger than the larger Working Width of the two connected barriers.
- 7.6** The design of transitions should be such that changes in Working Width and Containment Level are introduced gradually and evenly along the length of the transition. Additionally the length of the transition should be sufficient to ensure that no significant changes in the dynamic deflection occur over short lengths: a length of at least 10 to 12 times the change in Working Width should normally be provided. Where a transition is made to an immovable barrier, the working width should be assumed to be zero for the purpose of this calculation.
- 7.7** All transitions shall comply with the requirements of the impact assessment test criteria specified in IS EN 1317-2 for safety barriers and the critical impact requirements in Paragraphs 7.8 to 7.11. Evidence of compliance shall be submitted to the National Roads Authority in the form of a full test report.

Critical Impact Requirements for Transition to EN 1317

- 7.8** In order that a transition can be approved for use based on its compliance with Paragraph 7.7, it must pass two tests, as specified in IS EN 1317-2 for safety barriers, one with a light vehicle for impact severity and another with a heavy vehicle for maximum containment.
- 7.9** The direction of impact as well as the impact point shall be chosen as the most critical for each test. In general the most critical direction of impact is from the softer to the stiffer barrier. Therefore, the impact direction shall be from the lower containment barrier toward the higher containment barrier, provided the latter has demonstrated the smaller dynamic deflection in the high containment test. If the dynamic deflection of the higher containment barrier is higher than the dynamic deflection of the lower containment barrier, the impact direction for each test shall be chosen by the technical officer responsible for the Test Laboratory, and the justification for such choices shall be recorded in the test report. If the two connected barriers have the same containment class, the impact direction shall be from the higher dynamic deflection to the lower.

- 7.10** In general the impact point for the light vehicle shall be at a distance of $\frac{3}{4}$ of the length of the transition from the beginning of the transition, in the direction of impact. The impact point for the heavy vehicle shall be the midpoint of the transition. In special cases different choices of the critical impact point can be made by the technical officer responsible for the Test Laboratory, and recorded with justification in the test report.
- 7.11** All the impact test acceptance criteria for transitions are the same as those specified in IS EN 1317-2 for safety barriers.

Removable Barrier Sections

- 7.12** A Removable Barrier Section not longer than 40m shall be considered a special transition connecting two pieces of the same barrier, installed to allow quick removal and reinstallation. It shall be tested as a single transition.
- 7.13** A Removable Barrier Section longer than 40m shall be considered a different barrier, connected to the normal barrier by two transitions. The barrier must have passed the two tests specified in IS EN 1317-2 relative to its class. The transition shall be tested as specified in Paragraphs 7.8 to 7.11.
- 7.14** If the Removable Barrier Section is longer than 40m but shorter than 70m, the barriers shall be tested in the Removable Barrier Section configuration, i.e. with the two transitions installed, and the impact point shall be $\frac{1}{3}$ of the Removable Barrier Section length. In this case, the test with a light car (Test TB11 of IS EN 1317-2) on this impact point can be omitted.

8. RISK ASSESSMENT PROCEDURE¹

General

8.1 To assess the need for a safety barrier on a scheme involving online realignment, a risk assessment procedure shall be undertaken by the Designer as described in sections 8.2 to 8.17 below. The designers' professional judgment is required in the risk assessment and in the inclusion or omission of barriers².

Risk Assessment Procedure

8.2 As part of the risk assessment procedure the Designer shall complete a risk assessment sheet at the preliminary design stage using the layout included in Appendix C and include it in the preliminary design report. This risk assessment procedure shall also be completed at the detailed design stage.

8.3 The Designer shall undertake the following procedure for all hazards and record it in the risk assessment sheet:

- a) Establish if the hazard is within the clear zone and if it can be mitigated;
- b) Rank the hazard as per Appendix D;
- c) Calculate the sinuosity of that section of road;
- d) Assess the collision rate threshold for that section of road;
- e) Assess the risk of a vehicle leaving the road based on sinuosity ranking and collision rate ranking;
- f) Assess the overall risk rating;
- g) Undertake a site survey to confirm the need for a safety barrier.

8.4 The risk assessment stages described above are explained in more detail in sections 8.5 to 8.17 below.

Hazard Location and Ranking

8.5 The Designer shall establish if the hazard is located within the clear zone in accordance with Chapter 4.

8.6 Where possible hazards shall be mitigated as described in paragraph 3.9.

8.7 If the hazard cannot be mitigated the Designer shall assess if the hazard ranking is high, medium or low record it in the risk assessment sheet (Appendix D contains a non-exhaustive list of hazards to assist the Designer with the ranking)³.

¹ Amended as per Amendment No. 1, item 1

² Amended as per Amendment No. 1, item 2

³ Amended as per Amendment No. 1, item 3

Sinuosity

8.8 The sinuosity of a road is defined as the actual section length between two points on a road divided by the shortest path between them (see figure 8/1). The sinuosity index shall be calculated by the Designer as follows:

$$\text{Sinuosity Index (SI)} = \frac{\text{Actual section length between A and B}}{\text{Shortest path between A and B}}$$

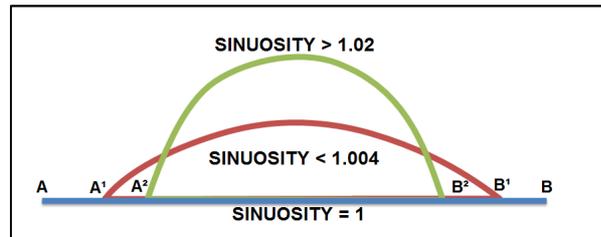


Figure 8/1 Sinuosity Index

8.9 The sinuosity index shall be calculated by the Designer on the approach to a hazard as set out below (in all cases the minimum approach length to the hazard considered shall be 200m):

- 1) Where the hazard is located within or at the end of a horizontal curve the sinuosity index shall be calculated by the Designer over the full length of that curve on the approach to the hazard (see figure 8/2).

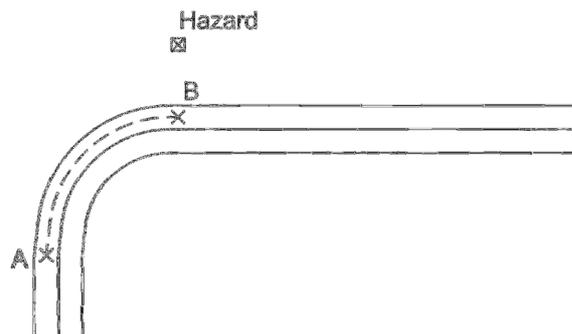


Figure 8/2

- 2) Where the hazard is located on a straight or nearly straight section of road beyond a horizontal curve but within the Desirable Minimum Stopping Sight Distance (SSD) length for the Design Speed of that road measured from the end of the curve, the sinuosity index shall be calculated by the Designer over the full length of the curve and the straight or nearly straight section of road up to the hazard location (see figure 8/3).

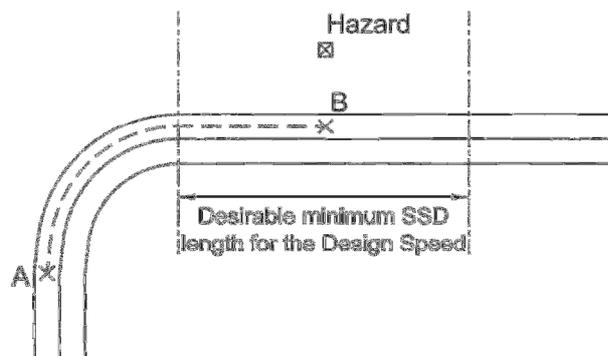


Figure 8/3

- 3) Consideration of the entire horizontal curve length need not be included in the sinuosity index calculation where the hazard is located on a straight or nearly straight section of road beyond the horizontal curve and beyond the Desirable Minimum SSD length for the Design Speed of that road measured from the end of the curve. The Designer shall consider the curve length which lies within the 200m minimum length on the approach to the hazard only (see figure 8/4).

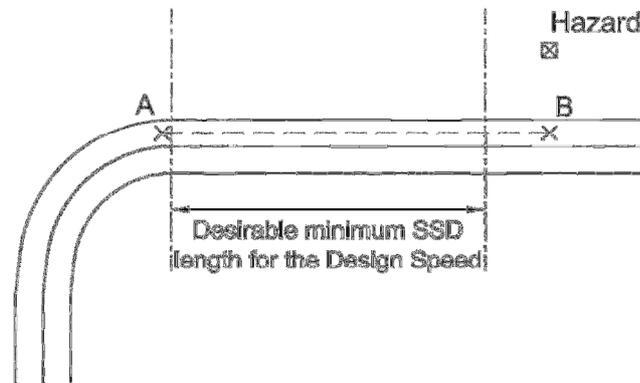


Figure 8/4

The Desirable Minimum SSD length shall be as per Table 1/3 of NRA TD 9 for the particular Design Speed.

Nearly Straight sections shall be as per Figure 7/6 of NRA TD 9.

8.10 Sinuosity is divided into three sinuosity rankings as follows:

- 1) High (H) - Sinuosity Index > 1.02 ;
- 2) Medium (M) – $1.004 \leq \text{Sinuosity Index} \leq 1.02$;
- 3) Low (L) - Sinuosity Index < 1.004

The Designer shall record the calculated Sinuosity Index and Sinuosity Ranking in the risk assessment sheet.

Collision Rate Ranking

8.11 The collision rate thresholds for a particular section of road shall be reviewed by the Designer using data compiled by the NRA.

Collision rates have been calculated by the NRA, and then using the methodology described in HD 15/12, compared with historical rates and the following thresholds established:

- 1) Twice Above Expected Collision Rate
- 2) Above Expected Collision Rate
- 3) Below Expected Collision Rate
- 4) Twice Below Expected Collision Rate

8.12 Collision Rate Thresholds can be requested from the NRA by the Designer at infosafety@NRA.ie and shall be assessed for the section of road under consideration. The Designer shall confirm the accuracy of the information with the client.

8.13 The Designer shall assign a Collision Rate Ranking to the Collision Rate Threshold for the section of road under consideration as follows and record it in the risk assessment sheet:

- 1) High (H) - Twice Above Expected Collision Rate;
- 2) Medium (M) - Above Expected Collision Rate;
- 3) Low (L) - Below Expected Collision Rate and Twice Below Expected Collision Rate.

Risk of a Vehicle Leaving the Road

8.14 The Designer shall take account of both the collision rate ranking and the sinuosity ranking for the section of road being examined and determine the risk of the vehicle leaving the road using the matrix in Table 8/1.

Risk of a Vehicle Leaving the Road	Collision Rate Ranking		
Sinuosity Ranking	<i>H</i>	<i>M</i>	<i>L</i>
<i>H</i>	H	H	M
<i>M</i>	H	M	L
<i>L</i>	M	L	L

*Where *H*=High, *M*=Medium, *L*=Low

Table 8/1 Risk of a vehicle leaving the road

Overall Risk Rating

8.15 The Designer shall compare the risk of a vehicle leaving the road against the Hazard Ranking using the matrix in Table 8/2 below to determine the Overall Risk Rating for the location under consideration.

Overall Risk Rating	Hazard Ranking		
Risk of a vehicle leaving the road	<i>H</i>	<i>M</i>	<i>L</i>
<i>H</i>	H	H	M
<i>M</i>	H	M	L
<i>L</i>	M	L	L

*Where *H*=High, *M*=Medium, *L*=Low

Table 8/2 Overall Risk Rating

8.16 For each hazard location a determination shall be made as follows:

- 1) If the overall risk rating is High, then a safety barrier shall be installed to meet the requirements of this standard or the hazard shall be mitigated.
- 2) If the overall risk rating is Medium, then the designer shall provide a safety barrier or mitigate the hazard if it is within 2m of carriageway edge.

If the hazard is located $\geq 2\text{m}$ from the carriageway edge the Designer shall assess the hazard level and the risk of the vehicle leaving the road on site and determine if a safety barrier is required.

- 3) If the overall risk rating is Low, a safety barrier is not required.

Each determination shall be recorded in the risk assessment sheet along with the reason for providing or not providing the safety barrier.

Site Survey

8.17 A site survey shall be carried out by the Designer as part of the risk assessment procedure to confirm the need or otherwise for a safety barrier at all locations.

9. REFERENCES

Design Manual for Roads and Bridges (DMRB):

NRA BD 52 (DMRB 2.3.3) – The Design of Highway Bridge Parapets.

Irish and European Standards

IS EN 1317-1, Road Restraint Systems – Part 1: Terminology and General Criteria for Test Methods.

IS EN 1317-2, Road Restraint Systems – Part 2: Performance Classes, Impact Test Acceptance Criteria and Test Methods for Safety Barriers.

IS ENV 1317-4, Road Restraint Systems – Part 4: Performance Classes, Impact Test Acceptance Criteria and Test Methods for Terminals and Transitions of Safety Barriers.

IS EN 1317-5, Road Restraint Systems – Part 5: Product Requirements, Durability and Evaluation of Conformity.

IS EN 12767: 2000, Passive Safety of Support Structures for Road Equipment – Requirements and Test Methods.

Other NRA Documents

NRA Manual of Contract Documents for Road Works, Volume 1: Specification for Road Works.

NRA Manual of Contract Documents for Road Works, Volume 4: Road Construction Details.

10. ENQUIRIES

- 10.1** All technical enquiries or comments on this document, or any of the documents listed as forming part of the NRA DMRB, should be sent by e-mail to infoDMRB@nra.ie, addressed to the following:

Head of Network Management, Engineering Standards & Research
National Roads Authority
St Martin's House
Waterloo Road
Dublin 4



.....
Pat Maher
Head of Network Management,
Engineering Standards & Research

National Roads Authority
Design Manual for Roads and Bridges
(NRA DMRB)

**ERRATUM No. 1 (June 2013) to NRA TD 19 – Safety Barriers Dated
March 2013**

NRA TD 19 Dated March 2013 is amended as follows:-

1. Page 7, Paragraph 3.17

Delete the following text as a listed item under this paragraph 'b) timber post and rail fences if not being used as a road boundary'

2. Page 7, Paragraph 3.17

Add the following text as a listed item under this paragraph 'b) all fences (including timber post and rail fences) if not being used as a road boundary'

3. Appendix D, Page D/1

Delete the following text listed as bullet 11 under the medium row 'timber post and rail fences if not being used as a road boundary' and add the following text listed as bullet 11 under the medium row 'all fences (including timber post and rail fences) if not being used as a road boundary'

National Roads Authority

Design Manual for Roads and Bridges (NRA DMRB)

AMENDMENT No. 1 (February 2014) to NRA TD 19 – Safety Barriers Dated March 2013 (Including Erratum No. 1)

NRA TD 19 Dated March 2013 (Including Erratum No. 1) is amended as follows:-

1. Page 30, Chapter Heading
Delete the following text ‘FOR SCHEMES INVOLVING ONLINE REALIGNMENT ON NATIONAL ROADS’
2. Page 30, Paragraph 8.1
Add the following text at the end of the paragraph ‘The designers’ professional judgment is required in the risk assessment and in the inclusion or omission of barriers.’
3. Page 30, Paragraph 8.7
Delete the following text ‘using the suggested hazard ranking system included in Appendix D and’ from the second line, and add the following text ‘(Appendix D contains a non-exhaustive list of hazards to assist the Designer with the ranking)’ to the end of the paragraph.
4. Page D/1, Appendix D Table
Add the following text to the high hazard ranking ‘Steep Embankment Slopes, steeper than 1:2 and $\geq 1.0\text{m}$ height’, delete the following text from the medium hazard ranking ‘Steep Embankment Slopes, steeper than 1:2 and $\geq 0.5\text{m}$ height’, and add the following text to the medium hazard ranking ‘Steep Embankment Slopes, steeper than 1:2 and between $\geq 0.5\text{m}$ and 1.0m height’.

APPENDIX A: EXAMPLES OF SAFETY BARRIER PARAMETERS

A1 The following Tables A/1 and A/2 give examples of the parameters (Containment Level, Impact Severity Level, Working Width and Set-back) which a designer might select in typical situations. The examples illustrate ways in which the requirements of this Standard can be met. In many cases, other parameters could also be chosen to meet the requirements.

Road Type	Grassed Verge Width (m)	Hard Shoulder or 1m min Hard Strip	Set-back (m)	Safety Barrier Criteria			Comments
				Containment Level	Impact Severity Level	Working Width	
1. Top of Embankment (1:2, 2m to 6m high)							
Standard Motorway or Type 1 Dual Carriageway	2.0	Yes	0.6 – 0.8	N2	A	W4	Assumes barrier is 100mm wide when deflected (see Note 1)
Type 2 and Type 3 Dual Carriageway or Reduced Single Carriageway	3.0	No	1.2 - 1.3	N2	A	W4	Assumes barrier is 100mm wide when deflected (see Note 1)
Existing Road	3.0	No	1.2 – 1.4	N2	A	W5	Assumes barrier is 100mm wide when deflected (see Note 1)
Slip Road	4.0	Yes	0.6 – 2.0	N2	A	W6	Assumes barrier is 100mm wide when deflected (see Note 1)
2. At Isolated Obstruction							
Pier	2.0 2.0* (Note 2)	Yes	0.6	N2	A	W4	
Abutment	2.0 4.5* (Note 2)	Yes	0.6 or: 1.1	N2	A	W5	Working Width limited by encroachment onto face of cutting slope
				N2	A	W4	
Existing Pier	2.0 2.0* (Note 2)	No	1.2	N2	B	W2	Impact Severity Level A would be difficult to achieve in such a restricted space

Notes: 1. Traffic face of barrier must not extend beyond the top of the embankment slope (see Paragraph 5.24).
2. * = distance from edge of road pavement to obstruction.

Table A/1: Typical Examples of Safety Barrier Layouts on Verges

Barrier Type and Position	Central Reserve Width (m) (see Note 1)	Set-back (m)	Safety Barrier Criteria		
			Containment Level	Impact Severity Level	Working Width
1. Double Sided Barrier					
Barrier 0.6m wide on centreline	2.6	0	H2	B	W4
Barrier 0.8m wide on centreline	2.8	0	H2	B	W5
Barrier 1.0m wide on centreline	3.2	0.1	H2	B	W6
Barrier 1.0m wide on centreline	4.5	0.75	H2	B	W7
Barrier 1.0m wide offset or on centreline	9.0	0.6 - 3.0	N2	A	W7
2. Single Sided Barrier					
At 2.0m wide bridge pier on centreline	9.0	0.6	N2	A or B	W5

- Note:
1. Central reserve width includes 2 x 1.0m hard strips.
 2. On motorways and type 1 dual carriageways the requirement to use safety barriers constructed from concrete will typically provide a reduced working width.

Table A/2: Typical Examples of Safety Barrier Layouts on Central Reserves

APPENDIX B: LENGTHS OF FLARED BARRIERS

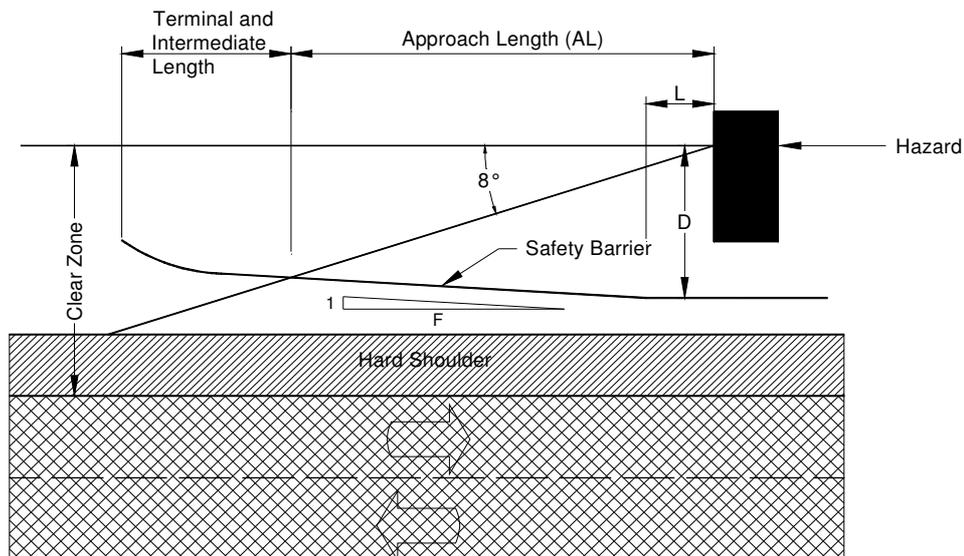
- B1 In addition to flaring the terminals, Approach and Departure Lengths of safety barriers may be flared away from the road. The rate of flare should not exceed 1:20.
- B2 For safety barriers with flares, the Approach and Departure lengths can be calculated as follows:

$$AL \text{ (or DL)} = \frac{D + (L/F)}{(1/F) + 0.141}$$

where:

- D = D_E , D_C or D_F in accordance with Paragraphs 5.31, 5.33 and 5.35 respectively
 F = Flare rate (e.g. use 20 if flare is 1:20)
 L = Distance from end of hazard to start of flare.

An example is illustrated in Figure B/1.



$$AL \text{ (or DL)} = \frac{D + (L/F)}{(1/F) + 0.141}$$

where:

- D = D_E , D_C or D_F as defined in Paragraphs 5.31, 5.33 and 5.35 respectively
 F = Flare Rate (e.g. use 20 if flare is 1:20)
 L = Distance from hazard to start of flare

Figure B/1: Determination of Approach Length for Safety Barrier with Flare

APPENDIX C: RISK ASSESSMENT SHEET

 <p>Risk Assessment Sheet for Safety Barriers</p>							Date:			Completed by:			
							Location ID/Description:						
							Site Survey Conducted (Y/N):						
1	Hazard Type, Start and End Co-ordinates	Is Hazard within the Clear Zone (Y/N)	Can the hazard be mitigated?	(1) Hazard Ranking	Sinuosity Index (SI)	(2) Sinuosity Ranking	(3a) Collision Rate Threshold	(3b) Collision Rate Ranking	(4) Risk of a Vehicle Leaving the Road	(5) Overall Risk Rating	Distance to Hazard (m)	Barrier to be Installed (Y/N), Start and End Co-ordinates	Reasons for Installing/Not Installing the Safety Barrier

L = Low, M = Medium, H = High

(1) Hazard Ranking as per Appendix D

High (H) as per Appendix D
Medium (M) as per Appendix D
Low (L) as per Appendix D

(2) Sinuosity Ranking

High (H) > 1.02
Medium (M) = 1.004 ≤ SI ≤ 1.02
Low (L) < 1.004

(3a) Collision Rate Threshold

(1) Twice above Expected Rate
(2) Above Expected Rate
(3) Below Expected Rate
(4) Twice Below Expected Rate

(3b) Collision Rate Ranking

High (H) = Twice above Expected Rate
Medium (M) = Above Expected Rate
Low (L) = Below Expected Rate and Twice Below Expected Rate

Risk of a Vehicle Leaving the Road	Collision Rate Ranking		
	Sinuosity Ranking	H	M
H	H	H	M
M	H	M	L
L	M	L	L

Overall Risk Rating	Hazard Ranking		
	Risk of a Vehicle Leaving the Road	H	M
H	H	H	M
M	H	M	L
L	M	L	L

(4) Risk of a Vehicle Leaving the Road

(5) Overall Risk Rating

APPENDIX D: HAZARD RANKING

Hazard Ranking	Hazard Description
High	<ul style="list-style-type: none"> • Lighting Columns that are not passively safe. • Tubular Steel Signposts >89mm diameter by 3.2mm thick, or equivalent strength. • Wooden Poles or Posts with Cross Sectional Area > 25,000mm² that do not have breakaway features. • Trees having a girth 175mm or more measured at 1m above the ground. • Concrete posts with Cross Sectional Area > 15,000mm². • Playgrounds/Monuments and other locations of high socio-economic value. • Water of likely depth > 0.6m. • Bridge Parapets, Bridge Piers, Abutments, Railing Ends, Gantry Legs • Location where errant vehicle may encroach onto road/railway which crosses or runs parallel to road. • Substantial fixed objects e.g. walls extending above the ground by more than 150mm with projections or recesses > 100mm and running parallel to the road. • Underbridges or retaining walls >0.5m high supporting the road, where a vehicle parapet or vehicle/pedestrian parapet of the required performance class is not provided. • Buildings in danger of collapse. • Industrial sites with potential for explosion or chemical spill. • Rock cutting with rough face. • Steep Embankment Slopes, steeper than 1:2 and ≥1.0m height¹.
Medium	<ul style="list-style-type: none"> • Steep Embankment Slopes, steeper than 1:2 and between ≥0.5m and 1.0m height². • Embankment Slopes between 1:2 and 1:3 (inclusive) and ≥2m height. • Slopes to ditches. • Drainage Items such as culvert headwalls and transverse ditches that are not detailed to be traversed safely. • Hazardous topographical features beyond the road boundary, but within the width defined in Table 4/1. • Single cross culvert opening exceeding 1000mm measured parallel to the direction of travel. • Culvert approximately parallel to the roadway that has an opening exceeding 600mm measured perpendicular to the direction of travel. • Steep sided cuttings or earth bunds (steeper than 1:2) within the clear zone. • Multiple cross culvert openings exceeding 750mm each, measured parallel to direction of travel. • Linear V-ditches alongside the scheme. • all fences (including timber post and rail fences) if not being used as a road boundary³. • Environmental Barriers.
Low	<ul style="list-style-type: none"> • Shallow Slopes, between 1:3 and 1:5 gradient and ≥6m in height. • Substantial fixed objects e.g. walls extending above the ground by more than 150mm with projections or recesses ≤ 100mm and running parallel to the road.

¹ Amended as per Amendment No. 1, item 4

² Amended as per Amendment No. 1, item 4

³ Amended as per Erratum No. 1, item 3