

Safety Barriers

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Summary:

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

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SECTION 2 SPECIAL STRUCTURES

PART 8A

NRA TD 19/07

SAFETY BARRIERS

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1. INTRODUCTION

General

1.1 This Standard gives the requirements for roadside Safety Barriers on roads with a Design Speed of 85 km/h or above. However, much of the information within the Standard may be applicable to roads with Design Speeds below 85 km/h where the Designer considers that a particular hazard warrants the provision of a barrier

1.2 Safety barriers with a containment level of N2 or greater are required on roads with a Design Speed of 85 km/h or above (see Chapter 5). Where barriers are installed on roads with Design Speeds below 85 km/h, a containment level of N1 may be appropriate.

1.3 The Standard supersedes NRA TD 19/04. The principal changes from the previous Standard are:

- Revision of the hazard classifications of public lighting columns and sign posts;
- Revision of the requirements for Transitions;
- Revision of the requirements for Terminals.

1.4 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

1.5 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.

1.6 The Standard also provides guidance on the positioning and detailing of Safety Barriers.

1.7 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

1.8 This Standard should be used forthwith for all schemes for the construction and/or improvement of national roads. The Standard should be applied to the design of schemes already being prepared unless, in the opinion of the National Roads Authority, application would result in significant additional expense or delay progress. In such cases, Designers should confirm the application of this Standard to particular schemes with the National Roads Authority.

1.9 If this Standard is to be used for the design of local road schemes (non-national roads), the Designer should agree with the relevant Road Authority the extent to which the document is appropriate in any particular situation.

1.10 For the application of this Standard to side roads which are improved or diverted as part of a national road scheme, refer to the National Roads Authority.

1.11 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 or B)
- Working width, (W1, W2, 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 5.14 to 5.17).

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 5.27 to 5.39).

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.

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 or equipment, damage to which would result in high repair costs and/or 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 accident 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. 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 The possible mitigation measures for hazards within the Clear Zone are listed below in order of preference:

- a) Remove;
- b) Relocate;
- c) Reduce impact severity (e.g. by using a breakaway feature or by setting a culvert flush with the existing ground);
- d) Shield the object by using redirection landform, safety barrier, or crash cushion.

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 5/4 in Chapter 5 identifies where safety barriers are required. However, even where Table 5/4 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 5/4. The embankment heights defined in Table 5/4 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 Obstructions which comply with IS EN 12767, Passive Safety of Support Structures for Road Equipment – Requirements and Test Methods, and have a maximum Accident Severity Index (ASI) value of 1.0 at the appropriate Speed Class 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 $22,500\text{mm}^2$ that do not have breakaway features;
- b) Tubular steel posts or supports greater than 89mm diameter tube by 3.6mm thick, or equivalent strength;
- c) Lighting columns;
- d) Trees having a girth of 175mm or more measured at 1m above the ground;
- e) Substantial fixed obstacles extending above the ground by more than 150mm;

- f) Concrete posts with cross sectional area greater than 15,000mm²;
- g) Drainage items, such as culvert headwalls and transverse ditches that are not detailed to be traversed safely.

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 5/4;
- 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 can not 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).

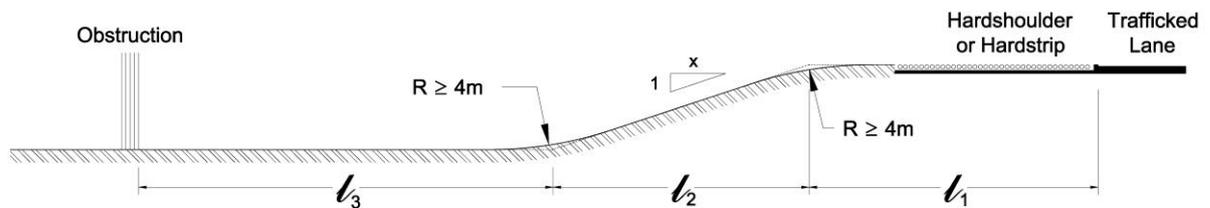
These inclinations present a danger of overturning or sudden halting of the vehicle. These areas are considered hazards if it is not possible to remove the risk in some way.

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.

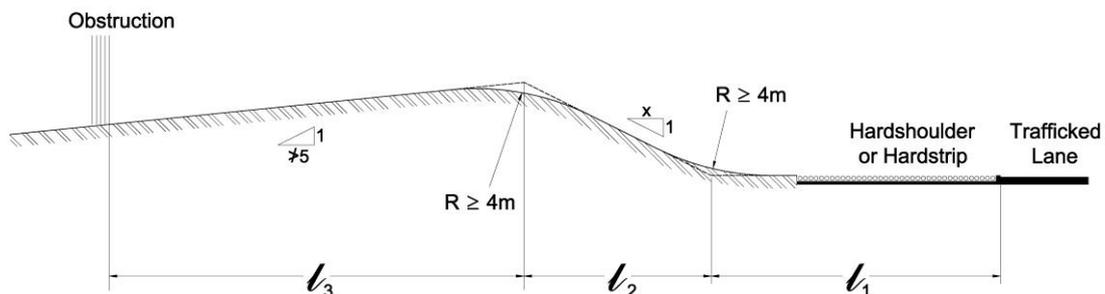
	Design Speed (km/h)		
	85	100	120
Horizontal radius (m)	Required Width of Clear Zone (m)		
Inside of bend or Straight	6.5	8.0	10.0
Outside of bend $\geq 1,000\text{m}$	6.5	8.0	10.0
“ 900m	7.1	8.8	12.4
“ 800m	7.7	9.6	14.9
“ 700m	8.3	10.4	17.5
“ 600m	8.8	11.2	20.0
“ 500m	9.4	12.0	
“ 400m	10.0	12.8	
“ 300m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

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 5/3 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 H2 H3	TB 42	70	15	10.0	Rigid HCV
	TB 51	70	20	13.0	Bus
	TB 61	80	20	16.0	Rigid HCV
Very High Containment H4a H4b	TB 71	65	20	30.0	Rigid HCV
	TB 81	65	20	38.0	Articulated HCV

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.

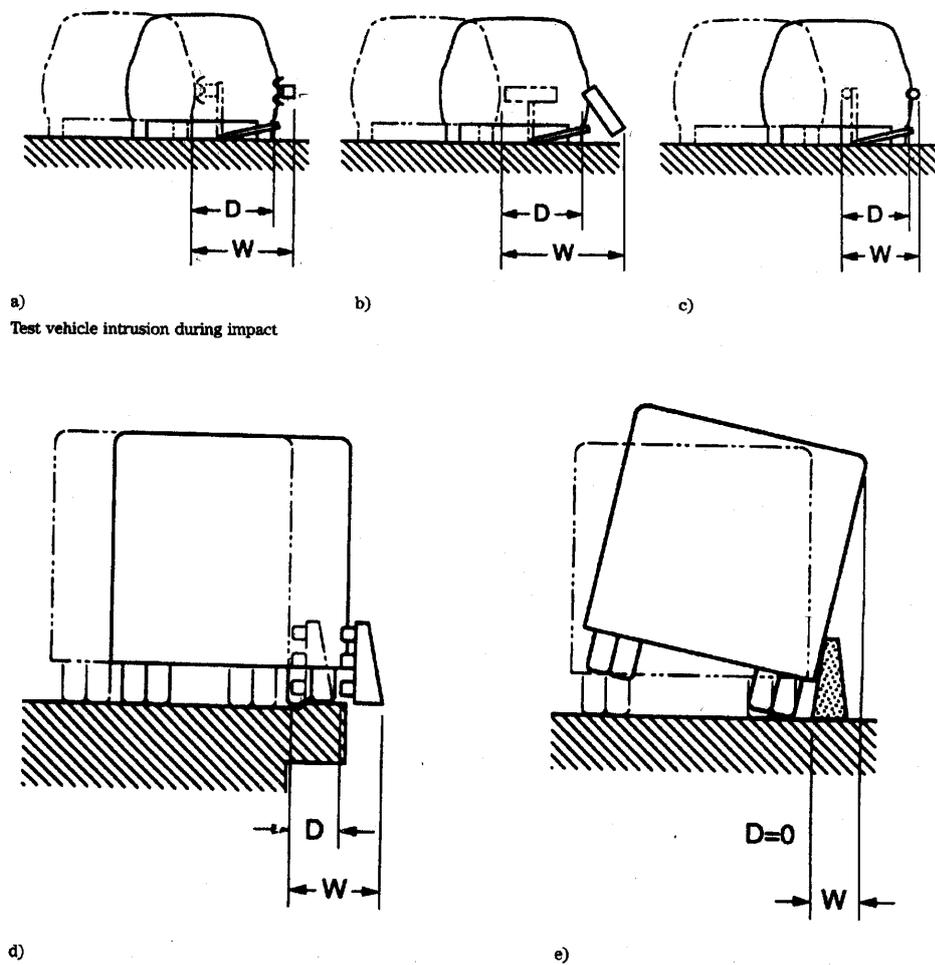
(Source: IS EN 1317-2)

Table 5/1: EN 1317 Containment Level Tests

Impact Severity Level	Index Values		
	ASI	THIV	PHD
A	≤ 1.0	$\leq 33 \text{ km/h}$	$\leq 20g$
B	≤ 1.4	$\leq 33 \text{ km/h}$	$\leq 20g$

(Source IS EN 1317-2)

Table 5/2: EN 1317 Impact Severity Levels



(Source: IS EN 1317-2)

Figure 5/1: Dynamic Deflection (D) and Working Width (W)

Impact Severity Level

5.6 Impact Severity Level is measured as a function of the Acceleration Severity Index (ASI), the Theoretical Head Impact Velocity (THIV) and the Post-impact Head Deceleration (PHD). IS EN 1317-2 defines these terms and describes how they should be measured. The two levels given in the Standard are shown in Table 5/2.

5.7 Impact Severity Level A affords a greater level of safety for vehicle occupants than Level B (see Paragraph 5.11).

Working Width

5.8 Working Width (W) is the distance between the side facing the traffic before impact of the safety barrier and the maximum dynamic lateral position under test of any major part of the system. If the vehicle body deforms around the road restraint system so that the latter cannot be used for the purpose of measuring 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

Provision Criteria

5.10 On new roads with a Design Speed of 85km/h or more, 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 5/4, the barrier shall have at least the Containment Level indicated.

5.11 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.

5.12 The Designer shall agree the provision of safety barriers with the National Roads Authority where:

- a) the Design Speed is less than 85 km/h; or
- b) there are exceptional local hazards or conditions which are not identified in Table 5/4 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.

5.13 Where several hazards are in close proximity, the highest required Containment Level shall be provided throughout the safety barrier length.

Set-back

5.14 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.

5.15 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.

Location	Containment Level												
<p>1. Within the Clear Zone:</p> <p>Embankments:</p> <table border="0"> <tr> <td><u>Slope Angle</u></td> <td><u>Slope Height</u></td> <td></td> </tr> <tr> <td>Steeper than 1:2 (see Note 3)</td> <td>≥0.5</td> <td>N2</td> </tr> <tr> <td>Between 1:2 and 1:3 (inclusive)</td> <td>>2m</td> <td>N2</td> </tr> <tr> <td>From 1:3 and up to 1:5</td> <td>≥6m</td> <td>N2</td> </tr> </table> <p>Cuttings: At steep sided cuttings or earth bunds (steeper than 1:2) within the Clear Zone</p> <p>Verges and Central Reserves:</p> <p>a) At individual hazards such as bridge piers or abutments, sign posts, gantry legs and trees, etc. (see Chapter 3) (see Note 4) N2</p> <p>b) At lighting columns that are not passively safe N2</p> <p>c) At substantial obstructions such as retaining walls which extend more than 150mm above the carriageway level (See Note 7). N2</p> <p>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</p> <p>Central Reserves:</p> <p>a) At central reserves up to 7.5m wide H2</p> <p>b) At central reserves greater than 7.5m wide N2</p> <p>c) Where the difference in adjacent carriageway channel levels exceeds 1.0m and the slope across the reserve exceeds 1:4 H2</p> <p>Parapets (see BD 52):</p> <p>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 (but not less than the parapet)</p> <p>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. H2</p>	<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	
<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											
<p>2. Within or Beyond the Clear Zone</p> <p>Verges:</p> <p>a) At locations where an errant vehicle may encroach onto an adjacent road (but see Note 6) or impact another significant hazard H2</p> <p>b) At locations where an errant vehicle may encroach onto an adjacent railway H2</p> <p>c) At hazardous topographical features beyond the road boundary, but within the width defined in Table 4/1 N2</p>													

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.

Table 5/4: Minimum Containment Level

5.16 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.

5.17 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

5.18 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.

5.19 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.

5.20 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.

5.21 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 5.16 above) as this will minimise the angle of impact and

consequently reduce the severity of impact on the occupants of the errant vehicle.

5.22 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.

5.23 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.

5.24 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.

5.25 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

5.26 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)

5.27 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.

5.28 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.

5.29 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

5.30 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

5.31 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.

5.32 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

5.33 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.

5.34 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.

5.35 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

5.36 The equations given in Paragraphs 5.31, 5.33 and 5.35 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

5.37 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 (except where Paragraph 5.35 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).

5.38 For dual carriageways and motorways, the Departure Length shall be at least 15m long (except where Paragraph 5.35 applies).

Minimum Length

5.39 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.

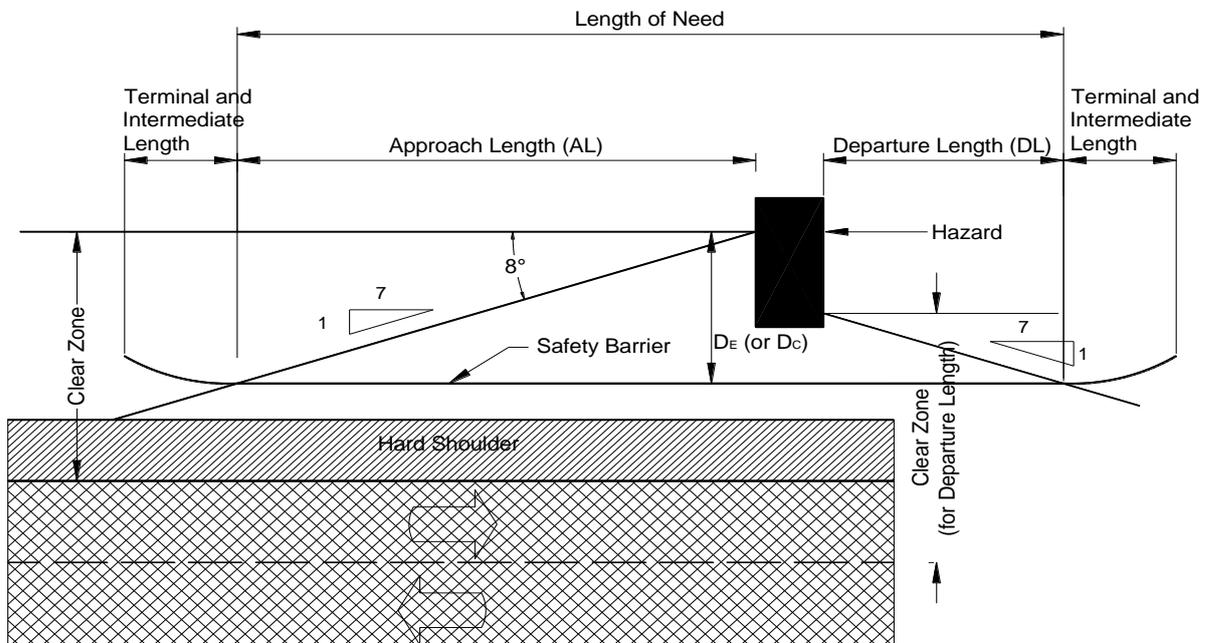


Figure 5/2: Example of Approach and Departure Lengths

Height of Safety Barrier

5.40 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.

5.41 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

5.42 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

5.43 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.

5.44 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.

5.45 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.

5.46 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.

5.47 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

5.48 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

5.49 The diagrams detailing the In-situ Concrete Barrier are contained in 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.

5.50 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 and a Working Width of W2.

Emergency Crossovers

5.51 Emergency crossovers shall be provided in accordance with NRA TD9

Safety Barriers at Junctions

5.52 At junctions, safety barrier layouts should be adjusted to suit the requirements of both roads. In general, the safety barrier on the main road should be flared back, in accordance with the manufacturer's requirements, so as to avoid encroaching on the visibility splays. 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.

5.53 At roundabouts, safety barriers will rarely be needed, since the design speed of the circulatory carriageway is normally less than 85 km/h.

5.54 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).

5.55 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.

Types of Terminal

6.3 All safety barriers shall be terminated such that the risk of injury to the occupants of errant vehicles is minimised.

6.4 Types of terminal include:

- a) returning the barrier such that the end is buried in a cutting face or bund;
- b) terminating at a full height terminal or anchorage;
- c) ramping the barrier down to ground level. For steel barriers this often includes a concrete foundation or shaped anchorage block.

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

6.5 Terminals shall be specified in accordance with the performance criteria defined in the standard IS ENV 1317 Part 4 and comply with the requirements outlined in this standard.

6.6 Ramped ends to Safety Barriers shall not be used on upstream terminals. Due account shall be taken of the possibility of a vehicle crossing from the opposite lane of a two-way single carriageway road and the possibility that contraflow working will be required at times on a dual carriageway.

Requirements for Terminals

6.7 All terminals shall comply with the requirements of IS ENV 1317-4 for the following

performance criteria as described in that document. Evidence of compliance for all tested systems shall be submitted to the National Roads Authority in accordance with the Specification for Road Works.

Performance Class

6.8 Upstream terminals shall be of Performance Class P4.

6.9 Downstream terminals shall be of performance Class P1. However where there is the possibility of a vehicle crossing from the opposite lane of a two-way single carriageway road, both end terminals shall be treated as if upstream.

Impact Severity Level

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

Permanent Lateral Displacement Class

6.11 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.

6.12 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.

6.13 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 .

6.14 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	Da	0.5
	2		1.5
	3		3.0
y	1	Dd	1.0
	2		2.0
	3		3.5
	4		>3.5

(Source: IS EN 1317-4)

Table 6/1: Permanent Lateral Displacement of Terminals

6.15 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

6.16 The Exit Box Class is a measure of the vehicle redirection following an impact with a terminal, as defined in IS ENV 1317-4.

6.17 Za is the maximum vehicle redirection in front of the original front face line of the connecting safety barrier. Zd is the maximum vehicle redirection behind the original front face line of the connecting safety barrier.

6.18 The Exit Box Class shall be specified as one of the classes listed in Table 6/2.

Classes of Z	Approach Side Za (m)	Departure Side Zd (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: Permanent Lateral Displacement

6.19 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.

6.20 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

6.21 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 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 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.

9 ENQUIRIES

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

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



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

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	N2	A	W5	Working Width limited by encroachment onto face of cutting slope
			or: 1.1	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.

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:

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

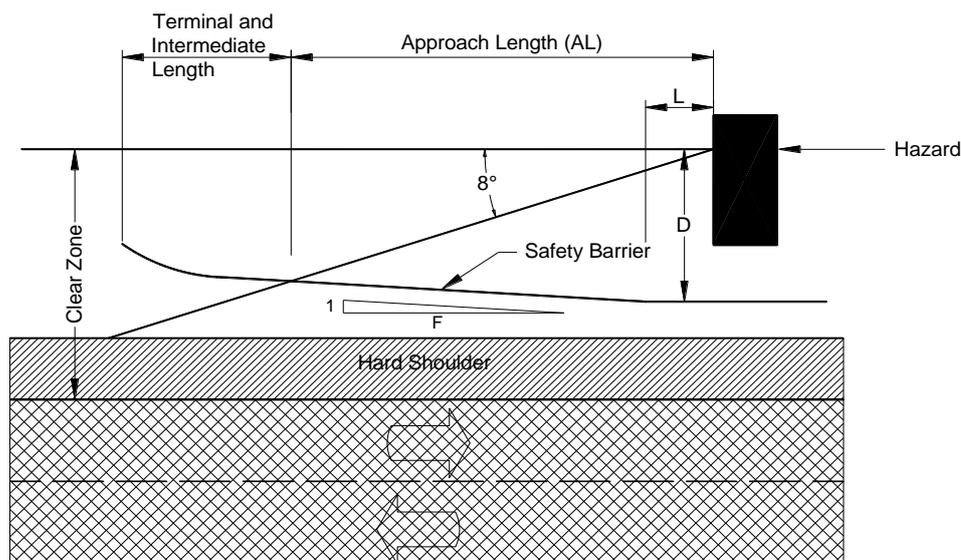
where:

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