The Design of Road Restraint Systems (Vehicle and Pedestrian) for Roads and Bridges

DN-REQ-03034
May 2019
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Updates to TII Publications resulting in changes to

The Design of Road Restraint Systems (Vehicle and Pedestrian) for Roads and Bridges

DN-REQ-03034

Date: May 2019

Amendment Details:


The principal changes from the previous Standard are:

- The document title has been updated to The Design of Road Restraint Systems (Vehicle and Pedestrian) for Roads and Bridges to better reflect the updated document contents.
- DN-STR-03011, The Design of Vehicle and Pedestrian Parapets (June 2017) has been incorporated into this standard DN-REQ-03034.
- A VRS Design Process has been added to support a Designer in choosing the applicable standard for the design of VRS in various scenarios i.e. VRS for new build road schemes and VRS at constrained locations.
- The Risk Assessment Procedure for assessing the need for VRS on online improvement schemes (previously Chapter 8 of this standard DN-REQ-03034) has been moved to DN-REQ-03079, Design of Road Restraint Systems for Constrained Locations (Online Improvements, Retrofitting and Urban Settings).
- Chapters relating to Hazard Mitigation and Clear Zone have been relocated to DN-GEO-03036, Cross Sections and Headroom so that the provision of a Clear Zone through hazard mitigation is considered at the very outset of a scheme and considered as part of the landtake requirements.
- The hazard ranking for Timber Post and Rail Fencing has been increased to High within Appendix D.
- The minimum containment levels for VRS in various scenarios have been revised in Table 3.6.
- A separate Containment Level Assessment Procedure has been included to assess if the minimum containment level prescribed is appropriate for the specific application. The procedure requires the Designer to consider the site-specific circumstances and follow a prescribed process to assess if it is appropriate to increase the containment level.
- The requirements for Crash Cushions as per EN 1317 have been introduced as a new chapter.
- Guidance on the use of this standard for the design of Temporary Restraint Systems has been provided.
- Clarification has been included on the appropriate provision of terminals for various scenarios.
- Clarification has been provided in relation to the Exit Box Class requirements for terminals.
• Appendix H in relation to Parapet Local and Global Effects – Load Designation has been added to the document.
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1. Introduction

1.1 General

This Standard details the design requirements for Road Restraint Systems on National Roads for roads and bridges, including retaining walls and similar structures where there is a need to prevent vehicles, equestrians, livestock or pedestrians from falling off the edge of a structure.


The Standard adopts the performance requirements of:

- PD CEN/TR 16949:2016 Road Restraint System. Pedestrian restraint system. Pedestrian parapets; and

1.2 Scope

The requirements contained within this document apply to Vehicle Restraint Systems (VRS) in common situations in the verge and central reserve of roads, vehicle and pedestrian parapets, retaining walls and similar structures. The requirements for positioning and detailing of vehicle and pedestrian restraint systems required at wingwalls, headwalls and buried structures are also included within this document.

The requirements for assessing the need for VRS at constrained locations, and VRS design at constrained locations where full compliance with this Standard may not be achievable is provided in DN-REQ-03079 Design of Road Restraint Systems for Constrained Locations (Online Improvements, Retrofitting and Urban Settings).

1.3 Implementation

This Standard shall be used forthwith on all schemes for the construction and/or improvement of National Roads.
Prior to designing a VRS, it is expected that the principles of forgiving roadsides provided within DN-GEO-03036 will have been adopted and that suitable mitigation and/or removal of hazards from the Clear Zone has first been attempted. It is intended that this Standard be used when this has not been achievable and where a VRS is subsequently required on a scheme. Use of this Standard shall be confirmed by following the process outlined in Section 1.4 and Figure 1.1.

The three main reasons for installing a VRS are:

i. To minimise injuries to the occupants of vehicles which leave the carriageway;
ii. To provide protection to third parties who may otherwise be adversely affected by errant vehicles, and
iii. To protect property, damage to which would result in the instability of a structure.

If this Standard is to be used for the design of Regional and Local Roads (non-National Roads), the Designer should agree with the relevant Road Authority the extent to which the document is appropriate in any particular situation.

There may be situations where 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 TII for approval before incorporation into a design layout to ensure that safety is not unduly compromised. For new schemes, the Designer shall apply for a Departure in the normal manner. For schemes on existing roads and which fall within the types and categories described in DN-REQ-03079, the Designer is directed to the guidance provided therein for the development of such Departure documentation.

1.4 VRS Design Process Flow

An overview of the VRS design process is presented in the flowchart in Figure 1.1. The flowchart shall be followed at the commencement of the project to confirm that the correct design standards and associated processes are being followed. There are three Standards which are primarily applicable to the design and documentation of VRS, namely:

- DN-GEO-03036 Cross Sections and Headroom – for considering the Principles of Forgiving Roadsides and the opportunities therein to remove or mitigate the need for a VRS.
- DN-REQ-03034 (this Standard) – for use on all new projects and where project constraints permit the provision of a compliant restraint system (e.g. where sufficient space is available for the requirements of this Standard).
- DN-REQ-03079 Design of Road Restraint Systems for Constrained Locations (Online Improvements, Retrofitting and Urban Settings). – for assessing the need for VRS on online improvement projects and the design of VRS on projects which fall within the types and categories described in DN-REQ-03079 where project constraints do not permit the provision of a compliant system (e.g. where sufficient space is not available for the requirements of this Standard) or where a risk assessment identifies that a VRS provision may not be warranted (e.g. in an urban scenario).

Once it has been established that the use of this Standard is applicable then the Designer shall follow all requirements herein. It should be noted that this flowchart is non-exhaustive and does not preclude the Designer from following any requirements set out in the stated design standards.
Figure 1.1 Detailed Flowchart for VRS Design Process
1.5 Definitions

1.5.1 General
For the purposes of this Standard, the following terms defined in I.S. EN 1317-1 and I.S. EN 1317-3 apply:

- Road restraint system
- Vehicle restraint system
- Safety barrier
- Terminal
- Crash cushion
- Pedestrian restraint system
- Combined vehicle/pedestrian parapet
- Obstacle
- Front face of obstacle
- Family of crash cushions
- Crash cushion head

In other parts of TII’s Publications, 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.

1.5.2 Summary of I.S. EN 1317 Performance Classes
I.S. EN 1317 defines various performance parameters for Safety Barriers, Transitions, Terminals and Crash Cushions. These parameters are described in more detail in the following chapters.

a) 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.)

b) Terminals:
- Performance Class (T80, T110)
- Impact Severity Level (A, B, C)
- Permanent Lateral Displacement Class (X1/Y1, X1/Y2, etc.)
- Exit Box Class (Za1, Za2, Zd1, Zd4)
- Terminal Directions Class (uni-directional, bi-directional)

c) Crash Cushions:
- Performance Class (50, 80, 100, 110)
- Impact Severity Level (A, B, C)
- Permanent Lateral Displacement Class (X1/Y1, X1/Y2, etc.)
- Redirection Class (redirectional, non-redirectional)
The performance parameters for a particular design of safety barrier, transition, terminal and crash cushion are established empirically by full-scale testing of representative samples and simulations. Details of the tests are specified in I.S. EN 1317-2, I.S. EN 1317-3, I.S. ENV 1317-4 and prEN 1317-7.

1.5.3 Additional Definitions

a) Forgiving Roadsides: The principles of Forgiving Roadsides (as provided in DN-GEO-03036) are to minimise the risk and severity of loss of control; incidents. It seeks to reduce the number of fatalities and serious injuries associated with run-off road incidents through the design of safer roadsides that:
   − Minimise the risk of vehicles leaving the carriageway without resorting to safety barriers in the first instance;
   − Provide adequate recovery space when errant vehicles do run off the road;
   − Ensure that any collision that does occur in the roadside will be with objects that limit the impact forces on vehicle occupants to minor levels (no serious injury outcomes).

b) Hazard: A hazard is any physical obstruction which may, in the event of an errant vehicle leaving the carriageway, result in significant injury or death to the occupants of the vehicle.

c) Choice of Design/Operational Speed: Design / Operational Speed shall be determined based upon the following definitions:
   − For all new road schemes (including new builds, road realignments and minor improvements) where a new or revised road cross section is being provided, the Designer shall use the design speed as calculated using DN-GEO-03031 Rural Road Link Design;
   − For retrofitting works where the existing road cross section is not being changed i.e. VRS works only, the Designer may use the operational speed for the section of road under consideration subject to the conditions detailed within in DN-REQ-03079. Indicative operational speeds for use when designing VRS on legacy National Roads only are detailed in DN-REQ-03079.

d) Clear Zone: The Clear Zone is the total width of traversable land on the nearside or offside of a road 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, refer to DN-GEO-03036 for the required Clear Zone widths.

e) Set-back: The Set-back is the dimension between the traffic face of the restraint system and the edge of the road pavement, see Section 3.12.

f) Length of Need (LoN): The Length of Need is the length of a restraint system which provides the full level of protection required for a particular hazard. An additional length (Intermediate Length) may be required between the start of the Length of Need and the upstream terminal in order for the system to attain full performance over the full extents of the Length of Need, see Sections 3.15 and 3.16.
g) Transition: A product for safely connecting two safety barriers of different designs and/or performance class and for connecting a safety barrier to a crash cushion or parapet. Refer Section 6.

h) Vehicle parapet: safety barrier along a bridge, retaining wall, or similar structure where there is a vertical drop, and which may include additional protection and restraint for pedestrians or other road users.

i) Pedestrian parapet: Restraint system for pedestrians or other road users along a bridge, retaining wall, or similar structure which is not intended to act as a road restraint system.

j) Pedestrian guardrail: Restraint system for pedestrians or other road users intended to restrain such users from entering a road or other area likely to be hazardous including areas remote from the road (e.g. headwalls and wingwalls).

k) Bespoke parapet: A vehicle or pedestrian parapet which is not a product and thus not compliant with I.S. EN 1317, but which has been subject to a detailed design for a specific situation and set of circumstances. Where bespoke parapets are designed via numerical simulation they shall be designed in accordance to CEN/TR 16303-1-2-3-4-2012.

l) Effective longitudinal member: Those longitudinal members of a post and rail type parapet or safety barrier that become effective in restraining a vehicle in the event of an impact.

m) Front face: The face of a parapet or member nearest to vehicular traffic.

n) Outer face: The face of a parapet or member furthest from vehicular traffic.

o) Traffic face: A vertical plane aligned with the front face of the main longitudinal member or the bottom of a concrete parapet or plinth.

p) Adjoining paved surface: The paved area on the traffic side of a parapet immediately adjacent to the plinth or base of the parapet.

q) Designer: The organisation responsible for undertaking and/or certifying the design. Individuals within the organisation responsible for the design of a proposed VRS must have successfully completed the two-day TII Design of Vehicle Restraint Systems course run in conjunction with Engineers Ireland.

r) Direct Line of Traffic: The position and orientation of a terminal whereby an errant vehicle will likely strike the terminal end-face straight on and along the longitudinal alignment of the terminal.
2. Roadside Hazards

A hazard is any physical obstruction which may, in the event of an errant vehicle leaving the carriageway, result in significant injury or death to the occupants of the vehicle.

In completing the overall design of a road, the Designer shall consider the long-term implications of all design features e.g. planting of trees – the mature tree size should be considered rather than the planted tree size, or seasonal changes in water depths in streams or roadside drainage features.

2.1 Categories of Roadside Hazards

The general categories of roadside hazards include but are not limited to:

- Single fixed objects / Point hazards;
- Continuous / Linear hazards;
- Dynamic roadside hazards.

In addition to these, several other conditions may require special consideration:

- Locations with high collision histories;
- Locations with pedestrian and bicycle usage;
- Playgrounds, monuments, and other locations with high social or economic value;
- Central reserves

The following sections provide guidance for determining when the main categories of hazard present a significant risk to an errant vehicle. Appendix D provides descriptions of the Hazard Ranking associated with hazard types.

2.1.1 Single Fixed Obstacles/Point Hazards

The following obstructions within the Clear Zone shall be considered as hazards requiring mitigation unless they can be provided as easily deformable elements or have been tested and passed as passively safe for the appropriate speed class in accordance with I.S. EN 12767, Passive Safety of Support Structures for Road Equipment – Requirements, Classification and Test Methods:

- Wooden poles or posts with cross sectional area greater than 25,000mm² that do not have breakaway features;
- Tubular steel posts or supports greater than 89mm diameter and 3.2mm thick, or equivalent strength;
- Road sign posts not certified as passively safe in accordance with I.S. EN 12767;
- Lighting columns not certified as passively safe in accordance with I.S. EN 12767;
- Gantry poles/columns;
- Road or railway crossings;
- Emergency telephones & surrounding fencing that are not considered deformable;
• Trees having a girth of 314mm or a diameter of 100mm or more (measured at 0.3m above the ground);
• Substantial fixed obstacles extending above the ground by more than 150mm;
• Concrete posts with cross sectional area greater than 15,000mm²;
• Drainage features, such as culvert headwalls and transverse ditches that are not designed and installed to be traversed safely;
• Abutments, overpasses, bridge piers and walls of underpasses;
• Rocks and/or boulders.

Where an object is not considered a hazard but is grouped together with similar objects, the group may form a hazard (e.g. closely spaced lighting columns, road signs, etc). The Designer shall assess the risk presented in these scenarios when deciding on the need for a VRS.

2.1.1.1 Signs and/or Lighting Columns

Signs and lighting columns within the Clear Zone, which do not incorporate passively safe signage supports are classified as a hazard.

Steel tubular posts up to 76mm diameter and 3.2mm wall thickness may be used as passively safe posts where post centres are ≥ 750mm spacing. Steel tubular posts up to 89mm diameter and 3.2mm wall thickness may be used as passively safe posts where post centres ≥ 1500mm spacing. All other scenarios shall be considered a hazard. Where passively safe supports are used, they shall comply with I.S. EN 12767.

Mounting a large sign on passively safe supports may avoid the need for a safety barrier in front of the sign. However, such posts should not be used in the central reserve, since an impact could cause the sign to fall into the opposing carriageway. Sign supports and lighting columns shall be located beyond the working width of all VRS installations even if they are passively safe.

2.1.1.2 Trees

When evaluating new plantings or existing trees within the Clear Zone, the maximum allowable diameter shall not exceed 100mm or a girth of 314mm (when measured at 0.3m above the ground). For new plantings, the Designer shall consider the mature size of the tree).

The Designer should consider whether the grouping of trees with trunk diameters ≤ 100mm and/or girths ≤ 314mm together may constitute a hazard due to the cumulative impact of the trees on an errant vehicle. A spacing of less than 1500mm will warrant consideration.

2.1.1.3 Culvert Ends/Headwalls

Non-traversable end treatments are a hazard when the culvert end section or opening is on the roadway side slope and within the Clear Zone. Culverts exceeding the following criteria will require protection using a VRS:

• A single cross culvert opening exceeding 1000mm measured parallel to the direction of travel;
• Multiple cross culvert openings exceeding 750mm each, measured parallel to the direction of travel; or
• A culvert approximately parallel to the roadway that has an opening exceeding 600mm measured perpendicular to the direction of travel.
2.1.1.4 Hazardous Safety Barrier Ends
Poorly designed or positioned barrier ends, including end treatments which do not fulfil the requirements of I.S. EN 1317 and this Standard e.g. “fish tails” shall be considered a Hazard.

2.1.2 Continuous/Linear Hazards
Continuous/Linear hazards are distributed objects that are of considerable length often running parallel to the road, making it impractical to remove or relocate them. Examples of Continuous/Linear hazards are:

- Embankments and Slopes
- Rock Cuts / Retaining Walls or Structures / Drop offs
- Other Roads
- Railway lines
- Central Reserves / Medians / Kerbs
- Drainage Features / Water hazards / Ditches
- Rows of trees
- All fences and linear boundary delineations with horizontal rails, including knee rails, (but excluding those to CC-SCD-00320, CC-SCD-00321 or CC-SCD-00324);
- Non-conforming VRS (e.g. improper installation or a damaged barrier) which following a Designer’s risk assessment is deemed an unacceptable risk to errant vehicles.

The recommended procedure for dealing with a continuous / linear hazard is to first consider redesigning the hazard such that it is no longer a risk to road users as outlined in the Forgiving Roadsides paragraph of DN-GEO-03036. If unsuccessful, a safety barrier shall be designed in accordance with this Standard.

2.1.2.1 Embankment Slopes
Embarkment slopes can present a hazard to an errant vehicle with the degree of severity dependent upon the slope and height of the embankment.

Embarkment Slopes are to be considered a hazard where the slope is steeper than 1:3 and the height of the embankment is greater than 0.5m, or where slopes are within the range of 1:3 to 1:5 but the embankment height is ≥ 6m; The depth of ditches sited adjacent to the toe of an embankment shall be included in the earthwork’s height measurement. Refer Figure 2.1.

Definitions for a number of Terrain Classes and the associated clear zone considerations are provided within DN-GEO-03036 Cross Sections and Headroom. Where safety barriers are not required due to slope steepness alone, obstacles on the slope may compound the hazard and thus warrant the provision of a safety barrier or some other safety feature. The Designer shall consider all factors that may, due to the sum of their parts, form a hazard requiring VRS protection.
2.1.2.2 Cut Slopes
A cut slope is usually less of a hazard than a VRS provided the toe is rounded to a minimum radius of 4m without narrowing the intended verge width. A slope steeper than 1:2 as shown in Figure 2.2 or a rock cut with a rough face that could cause vehicle snagging rather than providing relatively smooth redirection are considered hazards and shall be protected by a VRS unless mitigation can be applied.

2.1.2.3 Combinations of Slopes
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 slope 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 3.6. The embankment heights defined in Table 3.6 shall be the total height from the highest point to the lowest point within the Clear Zone.

2.1.2.4 Central Reserves
The Designer shall provide VRS in central reserves of dual carriageway roads to protect against errant vehicles crossing into the opposing flow of traffic. Further guidance on this is provided in Table 3.6 and Section 3.10 of this document. Such consideration should take due account of:

- The design speed for the road;
- The volume of traffic using the road (each carriageway);
- The type of traffic using the road (e.g. percentage Heavy Commercial Vehicles (HCVs));
- The width of the central reserve;
- The vertical alignment, horizontal alignment and super-elevation of each carriageway; and
- The existence of lighting columns, traffic signs and other potential obstructions within the reserve.
2.1.2.5 Water
Water with a likely depth of 0.6m or more and located within the Clear Zone 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 its relocation. In most cases however, it is likely that the feature is existing or cannot be moved and a VRS will need to be provided.

Water may be present in the form of ditches, rivers, lakes, canals or small ponds.

2.1.2.6 Ditches
Ditches will often present a continuous hazard running parallel to the roadway and will present both the potential to act as a destabilising hazard that increases the risk of a vehicle rolling and the risk of drowning to vehicle occupants.

2.1.2.7 Roads and Railways
Locations where the road crosses or runs alongside another road or railway must be provided additional consideration given the increased risk associated with an errant vehicle leaving the carriageway. The rules and guidance concerning Clear Zones and Length of Need may need to be increased for certain scenarios depending on the specific location. Additionally, the Designer should undertake a risk assessment to identify the type of VRS to be used in accordance with the containment level assessment procedure in this document.

2.1.2.8 Vehicle Restraint Systems
Vehicle Restraint Systems are themselves an obstacle to the movement of an errant vehicle and will have a physical impact on an errant vehicle and its occupants. They are, therefore, a special case as they can be both hazards and roadside treatments for safety. Where it is considered that the VRS may be more hazardous than that of the hazard it is protecting, the Designer shall attempt to remove or mitigate the hazard such that the VRS may be omitted.

2.1.2.9 Kerbs/Pavement Edge Drop Off
Kerbs or Edge Drop Offs alongside a road pavement can present a destabilising hazard which may lead to an increased risk of an errant vehicle overturning or becoming unstable when impacted. Refer Section 3.21 for further information.

2.1.3 Dynamic Roadside Hazards
Dynamic roadside hazards relate to moving objects and may include:

- Cyclists from nearby cycle facilities
- Pedestrians from shared cycle routes / footpaths

Dynamic hazards are not fixed but moving. They are more prevalent in urban scenarios and can be more complex than fixed or continuous hazards. The associated risks typically relate to pedestrians or cyclists using a facility, rather than the drivers of vehicles. They will typically require a different approach to typical roadside treatments and must be dealt with on a case by case basis.

In general, VRS should not be provided solely to protect pedestrians or cyclists – however, where they are required to protect other roadside hazards beyond a cycle track, a shared use cycle and pedestrian facility, or a footpath they should be located between the road and path.
2.2 Justification for the installation of VRS and the use of the SAVeRS Tool

Once a hazard has been identified as requiring protection by a VRS, the Designer is required to complete a VRS Justification Sheet as per Appendix C, utilising the suggested hazard rankings in Appendix D. The VRS Justification Sheet shall be used so that the Designer can systematically review each safety barrier and confirm its justification for use on the project. The SAVeRS (Selection of Appropriate Vehicle Restraint System) tool can be used as part of this justification process.

When assessing the requirements of a VRS or the measures required to implement a forgiving roadside it is often important to consider the whole life cycle cost analysis of the scheme. While the initial cost of mitigation measures may be higher than the installation of a VRS, e.g. purchasing additional land to allow removal of the hazard from the Clear Zone, the whole life costing of a VRS solution should be considered when carrying out the cost benefit analysis.

The SAVeRS tool was developed as part of the CEDR Call 2012 (Refer to DN-REQ-03079 for a worked example). It is a spreadsheet-based tool which can be used before a decision has been made to install a VRS in accordance with this Standard or DN-REQ-03079. The SAVeRS tool allows the Designer to:

- Assess the lifetime cost of VRS on a scheme
- Select the most appropriate VRS to be installed
- Justify up front mitigation costs which would allow for the removal of the need for a VRS

The SAVeRS Tool allows Designers to assess the merits of different VRS solutions in terms of

- Potential penetrations
- Potential fatalities
- Whole life costing

The SAVeRS tool, guideline document and user manual are available for download from the 'Downloads' Section of the TII publications website.
3. Permanent Safety Barriers

3.1 General

Permanent Safety Barriers should be considered an integral part of the road alignment design since their positioning may affect the stopping sight distance and clearance to structures etc. In particular, it will be necessary to ensure that the visibility requirements of DN-GEO-03031 Rural Road Link Design and DN-GEO-03060 Geometric Design of Junctions (priority junctions, direct accesses, roundabouts, grade separated and compact grade separated junctions) are not compromised by the presence of a safety barrier.

The introduction of a safety barrier adjacent to the carriageway shall only be considered where the elimination of all hazards within the Clear Zone is not reasonably practicable in terms of engineering, economic, environmental or sustainability considerations. The concept of creating a forgiving roadside and the mitigation steps outlined in DN-GEO-03036 should be followed by the Designer prior to designing a VRS. In cases where removal or mitigation of the hazard is not practicable, the provision of a VRS will be required.

The ideal position of a VRS in relation to the edge of the road will depend, inter alia, on the type of device being considered and on the type and location 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 to optimise the opportunity for an errant vehicle to regain control without striking the VRS.

3.2 I.S. EN 1317 Performance Classes

I.S. EN 1317-2 defines various performance parameters for safety barriers as outlined in Tables 3.1 to 3.4 and Figure 3.1, 3.2 and 3.3.

3.3 Containment Level

Containment level is an indication of the containment capacity of a system and is dependent on the type, weight and speed of vehicle which the VRS is designed to contain. The standard levels stipulated in I.S. EN 1317-2 and applied in this Standard are as shown in Table 3.1. Minimum containment levels are provided for a variety of Hazards in Table 3.6. A containment level assessment procedure is provided in Section 3.11.
### Table 3.1 Containment Level Tests

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

Note: Safety 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: I.S. EN 1317-2:2010)

### 3.4 Impact Severity Level

Impact Severity Level is measured as a function of the Acceleration Severity Index (ASI) and the Theoretical Head Impact Velocity (THIV). I.S. EN 1317-2 defines these terms and describes how they should be measured. The three levels given in the Standard are shown in Table 3.2.

Impact Severity Level A affords a greater level of comfort for vehicle occupants than Level B and Level C. Impact Severity Level C is not permitted for VRS. The following Impact Severity Levels are application for National Roads:
• Verges – Level A is preferred but can be relaxed to Level B
• Central Reserve of Motorways – Level A or B
• Central Reserve of other roads – Level A is preferred but can be relaxed to Level B.

### Table 3.2 Impact Severity Levels

<table>
<thead>
<tr>
<th>Impact Severity Level</th>
<th>Index Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ASI ≤ 1.0, THV ≤ 33 km/h</td>
</tr>
<tr>
<td>B</td>
<td>ASI ≤ 1.4, THV ≤ 33 km/h</td>
</tr>
<tr>
<td>C</td>
<td>ASI ≤ 1.9, THV ≤ 33 km/h</td>
</tr>
</tbody>
</table>

(Source: I.S. EN 1317-2:2010)

#### 3.5 Dynamic Deflection ($D_m$) and Working Width ($W_m$)

Dynamic Deflection ($D_m$) is a measure of the maximum lateral dynamic displacement of any point on the VRS before and after the impact of an errant vehicle irrespective of the final resting position of the VRS.

The Working Width ($W_m$) is the maximum lateral distance between any part of the safety barrier on the un-deformed traffic side and the maximum dynamic position of any part of the safety barrier during the impact. If the vehicle body deforms around the road safety barrier 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 Dynamic Deflection and Working Width are illustrated in Figure 3.1. Working Width is specified as one of the classes listed in Table 3.3.

![Figure 3.1 Dynamic Deflection ($D_m$) & Working Width ($W_m$) Measured Values](Source: I.S. EN 1317-2:2010)
### 3.6 Maximum Permanent Deflection

Maximun Permanent Deflection may be an important design parameter for the provision of lane segregating safety barriers (described in Section 3.10). It is recorded in the initial type test report of the system but is not provided in the declaration of performance for a VRS.

It is a measure of the maximum permanent deflection of any point on a VRS between the original face-line position on the trafficked face and the final resting position of the corresponding point on the opposing face of the VRS following impact with an errant vehicle, as shown in Figure 3.2 which illustrates a verge side barrier on a single carriageway. Maximum Permanent Deflection allows for a safety barrier to rebound from its maximum lateral dynamic displacement extent to its final resting position.

![Figure 3.2: Maximum Permanent Deflection](image)

### 3.7 Vehicle Intrusion (VIm)

The Vehicle Intrusion (VIm) of a VRS is the maximum dynamic lateral position of the body of a vehicle measured from the un-deformed traffic side of a safety barrier. It shall be evaluated from high speed photographic or video recordings during the safety barrier testing. The testing shall consider a vehicle with a notional load with the same width and length of the vehicle platform and a total height of 4m.

The VIm shall be evaluated by measuring the position and angle of the vehicle platform. It assumes that the notional load remains un-deformed and rectangular to the vehicle platform. An illustration of Vehicle Intrusion is provided in Figure 3.3.
Vehicle Intrusion is specified as one of the classes listed in Table 3.4.

### Table 3.4  Vehicle Intrusion Classes

<table>
<thead>
<tr>
<th>Class of Working Width</th>
<th>Level of Vehicle Intrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI₁</td>
<td>≤ 0.6m</td>
</tr>
<tr>
<td>VI₂</td>
<td>≤ 0.8m</td>
</tr>
<tr>
<td>VI₃</td>
<td>≤ 1.0m</td>
</tr>
<tr>
<td>VI₄</td>
<td>≤ 1.3m</td>
</tr>
<tr>
<td>VI₅</td>
<td>≤ 1.7m</td>
</tr>
<tr>
<td>VI₆</td>
<td>≤ 2.1m</td>
</tr>
<tr>
<td>VI₇</td>
<td>≤ 2.5m</td>
</tr>
<tr>
<td>VI₈</td>
<td>≤ 3.5m</td>
</tr>
<tr>
<td>VI₉ &gt; 3.5m</td>
<td></td>
</tr>
</tbody>
</table>

(Source: I.S. EN 1317-2:2010)

A suitable value of VI shall be specified by a Designer to avoid the potential for a high vehicle striking a vertical hazard adjacent to the road. Vehicle Intrusion is of particular importance when installed at structures, tunnel entrances and gantries.

Clearances, both horizontal and vertical, must account for potential vehicle intrusion in the event of a vehicle coming into contact with the VRS.

![Figure 3.3 Vehicle Intrusion Level](image)

**Note**: $D_m$ refers to the Dynamic Deflection of the Safety Barrier; $W_m$ refers to the Working Width of the Safety Barrier; $V_{Im}$ refers to the Vehicle Intrusion of the Safety Barrier described elsewhere in this document.

### 3.8 VRS Provision Criteria

A safety barrier shall be provided in central reserves of dual carriageways and where there is a hazard within the Clear Zone which requires protection.
Justification for the proposed VRS installation is to be recorded as per the form located in Appendix C and utilising the hazard rankings provided in Appendix D.

Table 3.6 outlines the minimum containment levels that shall be provided in various scenarios for verges. To determine if the minimum containment values specified are appropriate for the site-specific circumstances, the Designer shall complete the containment level assessment procedure as described in Section 3.11.

On motorways and Type 1 dual carriageways safety barriers within the central reserve shall be constructed from concrete. This safety barrier shall have a H2 Containment Level and in general, requires a Working Width of W2. However, where the safety barrier transforms to provide a vertical face in line with a bridge, tunnel portal or gantry support in a central reserve, as shown in the Standard Construction Detail CC-SCD-00405, a working width of zero may be assumed.

Safety barriers on central reserves shall have an Impact Severity Level of A or B. However, on central reserves wider than 7.5m, provision of Impact Severity Level A is preferred. The Designer should attempt, in all instances, to provide the lowest Impact Severity Level.

Central reserve VRS shall be fitted with reflectors in accordance with the relevant section of the Traffic Signs Manual (TSM).

Relaxations of up to two Design Speed steps below the Desirable Minimum Stopping Sight Distance are permitted for visibility to the low object at the lane segregating VRS, provided Desirable Minimum Stopping Sight Distance is obtained to a 1.05m high object, see DN-GEO-03031.

3.9 Precast and In-Situ Concrete Barriers

Precast and in-situ Concrete barriers shall be CE marked products in accordance with CC-SPW-00400.

3.10 Lane Segregating VRS on Type 2 and 3 Dual Carriageways

Lane segregating VRS for Type 2 and 3 Dual Carriageways shall be H2 containment as per VRS in central reserves and shall also comply with the following additional requirements in order to perform within the 1.5m central median:

- The VRS shall be a double-sided safety barrier which is generally open in nature along its longitudinal section with a maximum height of 0.8m above the road surface. End terminals shall also be double sided and comply with the requirements of this standard.
- The Working Width shall be no greater than W4.
- The segregating VRS shall not exceed 0.3m width at any point above the road surface to achieve a minimum set back of 0.6m.
- The segregating VRS shall not rely on a tensioning system to achieve the required performance criteria such that any loss in tension under impact impedes the barrier’s function along its length.
3.11 Containment Level Assessment Procedure

The Designer shall assess if the minimum containment levels specified in Table 3.6 are appropriate for a given situation by completing the Containment Level Procedure outlined in Figure 3.4 and further detailed in Appendix F. This procedure is applicable to safety barriers provided in the verge only. The minimum containment levels for bridge parapets are detailed in Table 8.1. Where Table 3.6 specifies a minimum containment level greater than that assessed using the Containment Level Assessment Procedure, the containment level specified in Table 3.6 shall apply.

Appendix G includes a worked example to assist the Designer in completing the containment level assessment procedure. The procedure comprises of four key steps:

1. Determine the hazard ranking;
2. Define the speed (design speed or operational speed, as applicable);
3. Determine if Increased Risk Factor exists, and
4. Assess the level of HCV traffic.

This procedure shall be undertaken at each hazard location where the need for a safety barrier has been identified. Where several hazards are located in close proximity, or where a linear hazard runs parallel to the road at varying lateral distances, the highest required Containment Level shall be provided across the entire VRS length to avoid the need to transition between multiple containment levels.

The Containment (Record) Assessment Sheet contained within Appendix F shall be used to record the assessment made at each hazard location.

The Designer's engineering judgement is required when completing the assessment. For online improvements and VRS retrofit schemes, the Designer is equipped with additional data such as collision history at the particular location and shall use this in conjunction with engineering judgement to assess the Increased Risk Factor and inform the decision on the most appropriate containment level, for the specific site circumstances.

The containment level procedure requires the Designer to assess if an Increased Risk Factor (IRF) is present at the location in question which can be determined based on the parameters listed in Table 3.5. Determination of the IRF is fully described in Appendix F.

Depending on the outcomes of the IRF assessment, combined with appropriate engineering judgment, the minimum containment level for the safety barrier as described in Table 3.6 may need to be increased.
**Figure 3.4 Containment Level Assessment Procedure Flow Chart**

Notes:

1. As per Table 3.1 of this document, L1 containment requires a VRS to be certified to both N2 and H1 containment levels. This has the benefit of ensuring the VRS remains appropriate for lighter vehicles at high speeds (N2) as well as being capable of containing the heavier (H1) vehicle.

2. Vehicle intrusion is not a reported parameter for N2 barriers. Therefore, where Vehicle Intrusion (as per Section 3.7) is a governing parameter, the minimum containment level to be provided is H1.

3. Where the VRS is required to protect property which, if damaged, would result in the instability of a structure, the containment level shall be increased appropriately in agreement with the road authority.

**Table 3.5 Parameters that may impact on the Increased Risk Factor**

<table>
<thead>
<tr>
<th>Increased Risk Factor</th>
<th>Additional Factors (requiring engineering judgement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of Hazard within Clear Zone, i.e. Proximity to Carriageway</td>
<td>Slope/Angle of Run-Off Area</td>
</tr>
<tr>
<td>Road Geometry / Sinuosity / Bendiness / Located Outside of Bend</td>
<td>High Design/Operational Speed of Section of Road</td>
</tr>
<tr>
<td></td>
<td>Collision History</td>
</tr>
</tbody>
</table>
Table 3.6 Hazard Definition and Minimum Containment Level for VRS

<table>
<thead>
<tr>
<th>Hazards Location</th>
<th>Minimum Containment Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Within the Clear Zone:</strong></td>
<td></td>
</tr>
<tr>
<td>Embankments:</td>
<td></td>
</tr>
<tr>
<td>Slope Angle</td>
<td></td>
</tr>
<tr>
<td>Steeper than 1:3</td>
<td>≥0.5</td>
</tr>
<tr>
<td>From 1:3 and up to 1:5</td>
<td>≥6m</td>
</tr>
<tr>
<td>Cuttings:</td>
<td></td>
</tr>
<tr>
<td>At steep sided cuttings or earth bunds (steeper than 1:2) within the Clear Zone</td>
<td>N2</td>
</tr>
<tr>
<td>Verges and Central Reserves:</td>
<td></td>
</tr>
<tr>
<td>Protecting bridge piers or abutments</td>
<td>H2</td>
</tr>
<tr>
<td>At overhead gantry legs and foundations for Type 1 Dual Carriageways / Motorways</td>
<td>H2</td>
</tr>
<tr>
<td>At individual hazards such as sign posts, gantry legs (on all roads other than Type 1 Dual Carriageways / Motorways) and trees, etc. (see also Note 3)</td>
<td>N2</td>
</tr>
<tr>
<td>At lighting columns that are not passively safe</td>
<td>N2</td>
</tr>
<tr>
<td>At substantial obstructions such as retaining walls which extend more than 150mm above the carriageway level (See Note 6).</td>
<td>N2</td>
</tr>
<tr>
<td>At underbridges, underpasses or at retaining walls &gt;0.5m high supporting the road and a vehicle parapet or vehicle/pedestrian parapet of the required performance class is not provided.</td>
<td>H2</td>
</tr>
<tr>
<td>Central Reserves:</td>
<td></td>
</tr>
<tr>
<td>At central reserves up to 7.5m wide for Type 1 Dual Carriageways / Motorways</td>
<td>H2</td>
</tr>
<tr>
<td>At central reserves for Type 2 and Type 3 Dual Carriageways</td>
<td>H2</td>
</tr>
<tr>
<td>At central reserves greater than 7.5m wide</td>
<td>N2</td>
</tr>
<tr>
<td>Where the difference in adjacent carriageway channel levels exceeds 1.0m and the slope across the reserve exceeds 1:4</td>
<td>H2</td>
</tr>
<tr>
<td>Parapets (see Chapter 8):</td>
<td></td>
</tr>
<tr>
<td>For a minimum of 30m in advance of the approach end and 30m after the departure end of a vehicle parapet or vehicle/pedestrian parapet.</td>
<td>See Note 4</td>
</tr>
<tr>
<td>For a minimum of 30m in advance of the approach end and 30m after the departure end of a vehicle parapet or vehicle/pedestrian parapet over a railway.</td>
<td>See Note 4</td>
</tr>
<tr>
<td><strong>2. Within or Beyond the Clear Zone:</strong></td>
<td></td>
</tr>
<tr>
<td>Verges:</td>
<td></td>
</tr>
<tr>
<td>At locations where an errant vehicle may encroach onto an adjacent road (but see Note 5) or impact another significant hazard</td>
<td>H2</td>
</tr>
<tr>
<td>At locations where an errant vehicle may encroach onto an adjacent railway</td>
<td>H2</td>
</tr>
<tr>
<td>At hazardous topographical features within the Clear Zone.</td>
<td>N2</td>
</tr>
</tbody>
</table>

Notes:
1. This Table provides minimum Containment Levels for situations. Higher Containment Levels may be justified in certain situations as determined through the Containment Level Assessment Procedure included in this document.
2. Where there is more than one reason for a VRS (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.

3. 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 shall be specified.

4. The Containment Level of the safety barrier on the approach to and departure from a bridge parapet shall be at least equal to that of the parapet. The lengths upstream and downstream of a parapet are minimum values. The actual lengths shall be as per the Length of Need required to protect the given Hazard.

5. A VRS is not required (unless there is another reason) where the adjacent road joins the road under consideration, e.g. at slip roads and junctions.

6. Retaining walls may incorporate a concrete safety barrier in accordance with CC-SPW-00400 rather than require a separate safety barrier. In doing so, the Designer shall ensure that the surface of the wall presents a smooth traffic face for at least 1.5m above the carriageway level and that the Vehicle Intrusion is assessed.

3.12 Set-back

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

The desirable Set-back on a verge shall be 1.2m. This may be reduced to minimum value of 0.6m if a hard strip with a width of 1m or more or hard shoulder is present or where the road design/operational speed is 85km/h or less.

At central reserves, the minimum Set-back shall be 0m (zero) where a hard strip of width 0.6m or greater is present. If there is no hard strip present, the minimum Set-back shall be 0.6m.

The performance of the VRS must not be compromised by the presence of a filter drain, service ducts or the like close to the system foundations. The clear distance required between the safety barrier and any feature which may affect the VRS performance shall be ascertained.

The inclusion of surface water channels in the set-back area is acceptable in accordance with the requirements of DN-DNG-03068.

3.13 Lateral Positioning and Working Width

For normal containment safety barriers, the Working Width should be maximised where space is available. However, this must be balanced with providing a suitable Set-back which provides 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 VRS unduly.

Design decisions regarding the lateral position of the safety barrier and its Working Width are further complicated by factors such as the 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 safety barrier or a larger Set-back.

For isolated hazards, the VRS 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.
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 3.12 above) as this will minimise the angle of impact and consequently reduce the severity of impact on the occupants of the errant vehicle.

Where combinations of hazards are to be protected by a single length of VRS, the Set-back of the safety barrier shall be established by assessing the obstruction nearest to the road as if this was an isolated hazard. This Set-back shall 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 safety barrier are subject to suitable transitions being available.

On verges, the Working Width of the VRS shall not allow the traffic face of the system, when deflected to the full Working Width, to extend beyond the intersection of the embankment or cut slope and the verge.

On central reserves, the VRS position and Working Width shall be such that under design impact conditions, no part of the system will deflect into the opposing traffic lane, barring scenarios described for Type 2 an 3 carriageways in the Section 3.10 of this document.

### 3.14 Total Length of VRS

The total length of VRS shall be derived from a detailed consideration of each location.

The total length of VRS will normally comprise the Length of Need plus the length of terminals at each end, and an ‘intermediate length’ (refer Definitions) in advance of the calculated Length of Need over which the safety barrier attains full containment.

The length over which various VRS achieve full containment varies. The Designer must specify a total length of VRS that is sufficient so that commonly used systems attain full containment over the required extents of the Length of Need for a given hazard. The Designer shall refer to the VRS performance criteria within various manufacturer’s installation manual for commonly used systems.

### 3.15 Minimum Length

An appropriate system must be provided whose minimum tested length is equal to or greater than the minimum length of safety barrier required by the design calculations, thus ensuring fully compliant operation of the VRS.

### 3.16 Length of Need (LoN)

The Length of Need, as a minimum, consists of the approach length, the length of the hazard and the departure length, as referred to in Figure 3.5 and Figure 3.6. It is dependent on the geometry and delineation of the road, the location and geometry of the hazard, the direction(s) of traffic, and the type and location of VRS. The lengths of terminals are not to be included in the Length of Need. A Transition between the safety barrier and the terminal can be included in the Length of Need.
Note: The approach lengths presented above are provided to illustrate the calculation of the Length of Need minimum requirements. For approach & departure lengths, refer to section 3.17 and 3.19 respectively.

Figure 3.5 Sample Length of Need (Overtaking Section)

Note: The approach lengths presented above are provided to illustrate the calculation of the Length of Need minimum requirements. For approach & departure lengths, refer to section 3.17 and 3.19 respectively.

Figure 3.6 Sample Length of Need (Non-Overtaking Section)
3.17 Approach Length (AL)

The calculation of the Approach Length is based on the premise that the errant vehicle should not be able to leave the carriageway, travel behind the safety barrier and thereby impact the obstacle or hazard. The calculations are based on an impact angle of 8° (1:7).

3.17.1 Embankments and Level Ground

Where the ground behind the safety 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:

\[ AL = 7 \times D_E \]

Where \( D_E \) = distance from traffic face of the VRS either to the rear extent of the hazard or to the back of the Clear Zone, whichever is the less. A typical example is illustrated in Figure 3.7.

Where the hazard is the embankment slope itself, the hazard shall be determined as per that described in Chapter 2 Roadside Hazards i.e. based on the embankment slope and height. The Length of Need shall be determined as per the normal approach described in Section 3.16.

3.17.2 Cuttings and Environmental Bunds

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

\[ AL = 7 \times D_C \]

Where \( D_C \) = distance from traffic face of the VRS to the edge of the Clear Zone.

Additional protection of the obstacle may be provided by the use of dense vegetation or gravel beds behind the safety barrier to provide a deceleration force on the vehicle. Safety barrier ends should be returned to the cutting face wherever practicable as per CC-SCD-00409 to CC-SCD-00411, as this will minimise the risk of end impact by an errant vehicle.

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:

\[ AL = 7 \times D_F \]

where \( D_F \) = distance from traffic face of the VRS to the face of the hazard.
Figure 3.7  Example of Approach Length with a hazard within the clear zone

Figure 3.8  Example of Approach Length with a hazard extending beyond the clear zone
3.17.3 Horizontal Curvature

The equations given in Sections 3.17.1 and 3.17.2 are applicable to all normal road curvatures. For particularly onerous circumstances, the Designer shall ensure that the Length of Need is sufficiently long for the circumstance and provide suitable protection to the identified hazard(s).

3.18 Overlaps and Gaps

Where an overlap between two safety barriers is to be provided, the Designer shall ensure that the lateral space between systems is minimised as far as possible (taking into account the space required for the working width) so as to not allow an errant vehicle to pass between the systems. This may be particularly applicable where breaks in vehicle safety barriers are provided for pedestrian or cycle routes or similar.

Overlapping between safety barriers must not be undertaken within the Length of Need (LON) of the higher containment barrier. For example, where the hazards are a bridge abutment located along a length of road with a high containment barrier on approach, and cut slopes in advance of the bridge are protected by a lower containment barrier and a transition cannot be provided, the overlapping shall not occur within the length of need of the higher containment barrier.

Gaps of 100m or less between lengths of safety barriers shall be avoided. If the distance between the ends of terminals is less than 100m, the systems shall be connected to form a continuous system. Access for maintenance should be considered when determining whether it is acceptable and logical to connect two sections of safety barrier.

3.19 Departure Length

The length of safety barrier beyond the hazard is termed the Departure Length. For dual carriageways and motorways, the Departure Length shall extend at least 15m beyond the downstream extremity of the hazard, unless the obstacle is only a hazard due to a face parallel to the road, such as a rock cutting or a retaining wall with buried ends, in which case Section 3.17.2 applies.

For two-way carriageways, the departure length shall generally be determined using the same equations as for the Approach Length (but must consider an overtaking vehicle colliding with the hazard from the opposing lane of traffic) and shall be at least 15m long on non-overtaking sections and 30m long on overtaking sections (except where the obstacle is only a hazard due to a face parallel to the road, in which case Section 3.17.2 applies). The Clear Zone for the Departure Length commences at the divide between opposing traffic flows on non-overtaking sections and from the edge of carriageway for overtaking sections. Additional consideration shall be given to the sinuosity of the road when calculating the Departure Length as the road curvature may impact the effectiveness of the system.

An overtaking section of road is to be considered as any section of road where lane separation is not defined by a continuous white line.
Figure 3.9  Departure Length for two-way Trafficked Roads on Non-Overtaking Section

Figure 3.10  Departure Length for two-way Trafficked Roads on Overtaking Section

3.20  Height of VRS

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

Where the Set-back is less than 1.5m, the height of the safety barrier 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 safety barrier.
3.21 Kerbs

Kerbs can have a significant impact upon the performance of a VRS and on the stability of a vehicle impacting upon the VRS. Therefore, the placement of kerbs in front of a VRS should be avoided. If kerbs in front of the VRS cannot be avoided, they shall be splayed over the full height by at least 45° to the vertical and not higher than 80mm.

3.22 Flare

VRS should be installed in accordance with the manufacturer’s requirements. Where these allow and wherever practicable, the ends of safety barrier shall be flared. There are three functions of the flare:

i. To locate the safety barrier end and its terminal as far from the carriageway as is feasible;

ii. To minimise a driver’s reaction to the introduction of an object adjacent to the carriageway;

iii. To reduce the Length of Need.

Flaring of safety barriers may be used:

a) If to do so does not conflict with the manufacturer’s requirements, and

b) If it is necessary to change the Set-back of a safety barrier (e.g. at the approaches to bridge piers in the central reserve).

It has been shown that an object (or safety 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 safety barrier so that the driver does not perceive the system as a hazard.

However, a flare increases the angle at which a vehicle may impact the safety barrier. A compromise between flare and impact angle is needed. Flare rates less than 1:20 shall therefore not be used.

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.

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 safety barriers.

3.23 Ground Conditions

All VRS rely on certain ground conditions in order to function satisfactorily. Testing, as described in the CC-SPW-00400, shall be undertaken to ensure that the system performs as intended.

3.24 Sloped Verges

VRS shall be installed on level ground. Where, due to site constraints, it is considered necessary to install a VRS on a sloped verge, an application for a Departure from Standards will be required.
3.25 Emergency Crossover

Where a central reserve safety barrier is to be installed, a removable safety barrier section, tested and approved to EN1317-4, must be provided.

The section must be specifically designed to match the profile of the central reserve system and its minimum level of containment must be N2 or the equivalent containment value of the adjacent safety barrier, whichever is greater. Removable safety barrier sections and adjacent systems may not differ by more than one containment class. Where containment or dynamic deflections of the upstream and downstream adjacent systems differ, the section of removable safety barrier is to match the greater containment value. Refer to Section 6.4 for additional information.

The full length of removable central reserve safety barrier in central reserve crossing points shall be provided in accordance with the requirements of DN-GEO-03031 as a minimum.

3.26 VRS at Junctions

At junctions, safety barrier layouts shall be adjusted to suit the requirements of both converging roads. Consideration shall 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 VRS in front of such a hazard, even though the safety barrier will follow the line of the adjacent edge of pavement and may not be parallel to the main road.

The design of VRS at junctions must be assessed on a case by case basis. The type, size and orientation of the hazard as well as the type and size of junction will affect the choice of VRS implemented. The Designer must assess each junction on its own merits to provide the most appropriate design for the given scenario. Some reduction in the crashworthiness of the safety barrier may be unavoidable in such circumstances, but the installation shall be made as forgiving as practical.

At junctions, as for typical roadside situations, where possible the hazard shall be removed from the Clear Zone or modified to provide a forgiving roadside. If the hazard cannot be removed or mitigated, then Designers shall assess the junction and hazard and provide VRS as appropriate in order of preference outlined below:

1. Flared safety barriers with flares not exceeding 1:20, can be provided to shield the hazard. Where appropriate, two flared safety barriers may provide the required protection for the hazard. In some situations, it may be beneficial to install an additional shielding safety barrier upstream of the junction as additional protection of the hazard. The effects on visibility should be a major consideration in the installation of all safety barriers at all junction scenarios. (See Figures 3.11 to 3.13 below)
2. In some cases, a crash cushion may provide the most appropriate form of protection of the hazard. Crash Cushions can operate in limited space and are often suitable for use at junctions.

3. A curved safety barrier with intermediate terminals or anchor points as shown in Figure 3.14 may be installed following the approval of a Departure from Standards. It may in some high-risk situations be necessary to install a section of high containment safety barrier on the radius as shown in Figure 3.15 although this scenario is not preferred given the impact on an errant vehicle should it strike the high containment safety barrier at such an angle. The Designer must assess this risk against the risk of striking the unprotected hazard. Radius safety barriers have not generally been tested to I.S. EN 1317 and as such are not CE marked. The use of curved safety barriers requires a Departure from Standard.
In all instances bar those identified above, care shall be taken to avoid positioning safety barriers at greater than 20 degrees maximum to the likely approach direction of an errant vehicle. In particular, safety barriers shall 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). Where the above scenarios are applicable, the Designer must assess the risk of applying the scenario against the risk of striking the unprotected hazard.

VRS are not an appropriate solution to potential hazards at diverge junction nosings (such as at commencement of free flow egress routes from routes). Alternative arrangements shall be made to create a forgiving environment.

3.27 VRS in Urban Settings within Reduced Speed Limit Zones

VRS should be avoided in urban settings wherever possible unless exceptional circumstances dictate that one is required, such as in one of the scenarios described below. The design process to be followed when considering provision of a VRS located in an urban setting or speed limit zone is presented in DN-REQ-03079. As an introduction, a risk-based assessment should be carried out by the Designer when considering the installation of VRS in urban settings or their removal from part of a legacy system as outlined in Figure 3.16.

Hazards which may require the installation of a VRS within an urban setting include but are not limited to the following:

a) Playgrounds
b) Playing pitches
c) Schools
d) Monuments
e) Electrical/telecommunication sub-stations
f) Bridges with pedestrians
g) Areas with high/regular pedestrian traffic.
3.28 Cycle Tracks

A VRS shall only be provided adjacent to pedestrian/cycle tracks where it is required to protect an additional hazard within the Clear Zone, i.e. it should not be provided to protect pedestrian/cycle tracks alone.

Where provided, the VRS shall be located between the carriageway and the pedestrian/cycle track as indicated in Figure 3.17.

The minimum distance between the cycle track and the VRS shall be at least equal to the working width of the VRS and comply with the lateral clearance requirements contained within DN-GEO-03036 for cyclist safety.

Where a pedestrian/cycle facility is to be located behind a VRS, an enclosed double-sided box or rounded beam type safety barrier shall be specified to limit the risk of injury to cyclists posed by posts and rail sharp edges. The Designer shall consider this requirement in relation to the lateral distance from the safety barrier. If sufficient distance is available for an errant bicycle to regain control, then a single sided safety barrier may be considered.
3.29 Motorcyclists

The installation of a VRS can cause particular risk to motorcyclists as the impact (particularly of the posts) on dismounted riders can be considerable. However, additional protective measures such as under riders or motorcycle protection systems can affect the performance of a VRS in the event of impact with other vehicle types and as such these additional measures shall not be specified as standard.

At locations identified as particularly high risk to motorcyclists, through historical collision records and vehicle counts, such as tight bends or sub-standard sections of legacy networks, additional protective measures shall be considered by the Designer to provide additional protection for motorcyclists. Examples would include scenic roads with a high volume of motorcyclists where sub-standard curves may be unavoidable.

The Designer must confirm the adequacy of VRS performance levels with the VRS manufacturer / supplier when proposing additional protective measures on VRS and will require a Departure from Standards.

3.30 Examples of VRS Requirements

Examples of the parameters of VRS in typical situations – in terms of Containment Level, Impact Severity Level, Working Width, Vehicle Intrusion and Set-back – are indicated in Appendix A.
4. **Temporary Safety Barriers**

Temporary safety barriers shall comply with the requirements of the Traffic Signs Manual (TSM) Chapter 8, Temporary Traffic Measures and Signs for Roadworks, its associated guidance documents and any project specific works / employer’s requirements. Where a temporary safety barrier is proposed, the principles of permanent VRS design detailed within this document shall be applied to the temporary safety barrier design. The performance parameters specified shall be appropriate for the site-specific circumstances. The following information is provided as guidance only. Further information in relation to the provision of temporary safety barriers is contained within Chapter 8 of the Traffic Signs Manual and Temporary Traffic Management Design Guidance document.

- The appropriate containment level shall be determined based on the type and likely speed of vehicles using the road;
- The Working Width and Vehicle Intrusion shall be determined based on the proximity of any hazards and the minimum set back and lateral safety zones as detailed within the TSM Chapter 8;
- The Length of Need of safety barriers to be specified shall be appropriate for the extent of the hazard/ work zone being protected but shall also account for the additional longitudinal safety zone requirements detailed within Chapter 8 of the TSM. The location and frequency of site access points needs to be considered along with any specific manufacturer requirements for the chosen system such as any requirements for a minimum installation length;
- The Designer shall also assess the requirements for terminating lengths of temporary safety barriers, particularly where the safety barrier end is in the direct line of traffic flow.
- Appropriate anchoring shall be determined and provided as per manufacturer’s installation manual.
- On National Roads, a minimum containment level of N2 shall be provided for all temporary barriers.
5. Terminals

5.1 General

A Terminal is the treatment of the beginning and/or end of a VRS. In addition, it can provide an anchorage for the safety barrier.

All full height terminals proposed for use on the National Road Network must be assessed for compliance as per the requirements of DN-REQ-03080 - Terminal Assessment Procedure.

5.2 Options for Terminating Barriers

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

Options for terminating safety barriers located in the verge in order of preference include:

a) Ramping the barrier down to ground level and anchoring the safety barrier as it was anchored during the Initial Type Test (System Anchorage) where the terminal is located outside of the Clear Zone;

b) Returning the safety barrier such that the end is buried in a cutting face in accordance with CC-SCD-00409 to CC-SCD-00412; or

c) Terminating with a full height prEN 1317-7 compliant terminal of suitable performance class for the design/operational speed of the road; the terminal shall have been assessed for compliance under DN-REQ-03080 and be included on the TII Compliant Terminal Systems list.

Terminating safety barriers as described in a) and b) above shall have a flare rate of not less than 1:20 away from the road.

Upstream terminals shall comply with the requirements of I.S. ENV 1317-4 and prEN 1317-7 (see Appendix E) for the performance criteria detailed below.

Downstream terminals may be of types a), b) or c), dependent on the adjacent road environment. If a full height terminal is used, this shall comply with the requirements of I.S. ENV 1317-4 and prEN1317-7 (see Appendix E) for the performance criteria detailed below.

Regardless of design/operational speed, the minimum Performance Class for full height terminals on National Roads is T80.

Based on the above criteria, the following arrangements described within Table 5.1 and further demonstrated within Figures 5.1 to 5.3 are permissible:
Table 5.1  Suitable Terminal Provision

<table>
<thead>
<tr>
<th>Location (refer Note 2)</th>
<th>Terminal Type</th>
<th>Minimum Terminal Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Lane Carriageway (No overtaking, &lt; 85km/h)</td>
<td>Upstream</td>
<td>T80</td>
</tr>
<tr>
<td></td>
<td>Downstream</td>
<td>T80 or as per System Anchorage (refer Note 1)</td>
</tr>
<tr>
<td>Single Lane Carriageway (With overtaking, &lt; 85km/h)</td>
<td>Upstream</td>
<td>T80</td>
</tr>
<tr>
<td></td>
<td>Downstream</td>
<td></td>
</tr>
<tr>
<td>Single Lane Carriageway (No overtaking, ≥ 85km/h)</td>
<td>Upstream</td>
<td>T110 or as per System Anchorage (refer Note 1)</td>
</tr>
<tr>
<td></td>
<td>Downstream</td>
<td>T110 or as per System Anchorage (refer Note 1)</td>
</tr>
<tr>
<td>Single Lane Carriageway (With overtaking, ≥ 85km/h)</td>
<td>Upstream</td>
<td>T110 or as per System Anchorage (refer Note 1)</td>
</tr>
<tr>
<td></td>
<td>Downstream</td>
<td>T110 or as per System Anchorage (refer Note 1)</td>
</tr>
<tr>
<td>Dual Carriageway/Motorway (&lt; 85km/h)</td>
<td>Upstream</td>
<td>T80</td>
</tr>
<tr>
<td></td>
<td>Downstream</td>
<td>As per System Anchorage</td>
</tr>
<tr>
<td>Dual Carriageway/Motorway (≥ 85km/h)</td>
<td>Upstream</td>
<td>T110 or as per System Anchorage (refer Note 1)</td>
</tr>
<tr>
<td></td>
<td>Downstream</td>
<td>As per System Anchorage</td>
</tr>
</tbody>
</table>

Note:

1. The above table assumes that all upstream terminals are provided within the Clear Zone. A System Anchorage can only be provided for this scenario if it is outside the clear zone.
2. The speeds noted in the table relate to the Design / Operational Speed of the road as relevant.
3. Safety Barriers which terminate by ramping down to ground level shall be anchored as per the Initial Type Tests of the system (System Anchorage).
4. The above values are minimum values for given scenarios, the use of higher performance terminals (T100, T110, etc) in these scenarios is permitted.

Figure 5.1  Permitted Terminal Arrangements – Single Carriageway (With Overtaking)
5.3 Performance Class

Full height terminals of Performance Class T80 and T110 shall be tested and comply with all 6 relevant Tests Codes for that performance class as defined in Table 1 of prEN 1317-7. This includes the additional tests for Approach Reference 3 and 6 reproduced in Table 5.2 which were not previously required under I.S. ENV 1317-4.

The performance requirements for terminals located in the median are to be specified as per terminals in the verge with the exception that they are required to be double-sided terminals.
Table 5.2 Vehicle Impact Test Configurations and Performance Classes for Upstream Terminals

<table>
<thead>
<tr>
<th>Performance Class</th>
<th>Approach</th>
<th>Approach Reference</th>
<th>Vehicle Mass kg</th>
<th>Velocity km/h</th>
<th>Test Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>T110</td>
<td>head (centre) at 15°</td>
<td>3</td>
<td>1 500</td>
<td>110</td>
<td>TT3.3.110</td>
</tr>
<tr>
<td>T110</td>
<td>side, 165° at the critical impact point</td>
<td>6</td>
<td>1 500</td>
<td>110</td>
<td>TT6.3.110</td>
</tr>
</tbody>
</table>

(Extracted from prEN 1317-7: Table 1)

5.4 Terminal Direction Class

In addition to the Performance Class, the terminal shall also be classified according to the Direction Class for which it has been tested as detailed in Table 5.3.

The following terminal direction classes are sub-levels applying to performance classes T80 to T110:

a) UDTA Uni-directional terminal – Approach
b) UDTD Uni-directional terminal – Departure
c) BDT Bi-directional terminal

Table 5.3 Direction Classes and Acceptance Tests Required for Terminals

<table>
<thead>
<tr>
<th>Category</th>
<th>Direction</th>
<th>Acceptance Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>T80</td>
<td>BDT</td>
<td>TT1.2.80, T2.1.80, T3.2.80, T4.2.80, TT5.1.80, TT6.2.80</td>
</tr>
<tr>
<td></td>
<td>UDTA</td>
<td>TT1.2.80, T2.1.80, T3.2.80, T4.2.80</td>
</tr>
<tr>
<td></td>
<td>UDTD</td>
<td>TT5.1.80, TT6.2.80</td>
</tr>
<tr>
<td>T110</td>
<td>BDT</td>
<td>TT1.3.110, TT2.1.100, TT3.3.110, TT4.3.110, TT5.1.100, TT6.3.110</td>
</tr>
<tr>
<td></td>
<td>UDTA</td>
<td>TT1.3.110, TT2.1.100, TT3.3.110, TT4.3.110</td>
</tr>
<tr>
<td></td>
<td>UDTD</td>
<td>TT5.1.100, TT6.3.110</td>
</tr>
</tbody>
</table>

(Source: Draft BS EN 1317-5: Table 14)

5.5 Impact Severity Level

Impact Severity Level (ISL) = B is acceptable for full height terminals tested in accordance with prEN 1317-7 and it is permitted to connect such terminals to safety barriers of ISL = A.
5.6 Permanent Lateral Displacement Class

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 I.S. ENV 1317-4.

$D_a$ is the maximum permissible deflection in front of the original front face line of the connecting VRS. $D_d$ is the maximum permissible deflection behind the original front face line of the connecting VRS.

If the VRS is to be flared to maintain setback to the end terminal, this should be included in the measurement of $D_d$ and the measurement should still be taken from the original front face of the connecting VRS.

The Permanent Lateral Displacement Class shall be specified as one of the classes listed in Table 5.4 (e.g. X2/Y2, X1/Y2, etc.). 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) and does not encroach beyond the available clear space behind the terminal.

The distances $D_a$ & $D_d$ are shown by the lines $A_a$ & $A_d$ in Figure 5.4 below. The extents of Permanent Lateral Displacement must remain within these extents.

Table 5.4 Permanent Lateral Displacement of Terminals

<table>
<thead>
<tr>
<th>Class code</th>
<th>Displacement (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$D_a$ 0.5</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$D_d$ 1.0</td>
</tr>
<tr>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>4</td>
<td>&gt;3.5</td>
</tr>
</tbody>
</table>

(Source: I.S. ENV 1317-4)

Note: References 1 to 6 relate to the Test Approaches detailed within prEN1317-7

Figure 5.4 Permanent Lateral Displacement for Terminals in Direct Line of Traffic & Flared
5.7 Exit Box Class

The Exit Box Class is a measure of the vehicle redirection following an impact with a terminal, as defined in I.S. ENV 1317-4. Exit box testing requirements are defined in prEN 1317-7.

When defining the values for the Exit Box Class of a terminal, the Designer shall specify a value for $Z_a$ and $Z_d$ as per the following Table 5.5 and as illustrated in Figures 5.5 and 5.6 for upstream and downstream terminals. The Designer must consider the list of approved Terminals available on the ‘Downloads’ section of the TII publications website to ensure the availability of terminals to meet the specified values of $Z_a$ and $Z_d$.

### Tables 5.5 Exit Box Dimensions for Terminals

<table>
<thead>
<tr>
<th>Class</th>
<th>Dimension</th>
<th>Class</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z_{a1}$</td>
<td>4</td>
<td>$Z_{d1}$</td>
<td>4</td>
</tr>
<tr>
<td>$Z_{a2}$</td>
<td>6</td>
<td>$Z_{d2}$</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$Z_{d3}$</td>
<td>No limit</td>
</tr>
</tbody>
</table>

$Z_a$ (as defined within Figures 5.5 and 5.6) is the maximum vehicle redirection in front of the original front face line of the connecting safety barrier. The value of $Z_a$ specified by the designer shall ensure that an errant vehicle does not encroach beyond the first traffic lane adjacent to the safety barrier, and in the case of dual carriageways, with a central reserve, beyond the hard strip of the opposite carriageway.

$Z_d$ (as defined within Figure 5.6) is the maximum vehicle redirection behind the original front face line of the connecting safety barrier. In circumstances where the full length of need of a safety barrier is achieved and the terminal is only protecting the end of the safety barrier, the value of $Z_d$ is not a critical design parameter. At constrained locations, where the full length of need cannot be achieved, e.g. where a terminal is provided at a field access, the $Z_d$ value chosen shall be appropriate to the available space behind the terminal.

Notes:
1. References 1 to 6 relate to the Test Approaches detailed within prEN1317-7.
2. Figure is indicative and is intended to cover both verge and median VRS scenarios.

Figure 5.5 Exit Box Extents (on Downstream)
Exit Box Class 3 or 4 (as defined within IS ENV 1317-4) for Za (i.e. Za3 and Za4) are not utilised in this Standard as their dimensions are the same as Za1 and Za2. Exit Box Class 4 (as defined within IS ENV 1317-4) for Zd (i.e. Zd4) is not utilised in this Standard as its dimension is the same as Za3.

Terminals with Exit Box Class Zd3 should be used with caution due to the unlimited dimension of the Exit Box on the departure side. Terminals with Exit Class Zd8 should not be considered where limited space or hazards exist on the departure side of a terminal, such as at confined locations, due to the undefined extents of the exit box in these scenarios.

There may be a number of locations where more than one Z class will meet the needs of the particular scenario e.g. where a hazard is located greater than 6m behind a Terminal a Zd1 and Zd2 would be applicable. The Designer shall specify the Z class most closely suited to the available dimension at the specific location and should not default to specifying Za1 and Zd1 for all scenarios.

### 5.8 Compatibility

It must be ensured that the terminal can function adequately in combination with the type of VRS it is attached to. The TII Compliant Terminal Systems list available in the “Downloads” section of the TII Publications website lists terminals permitted for use on the National Road Network and the VRS they are permitted to connect with.

Where it is proposed to connect the terminal to a VRS other than that which it was tested with, approval shall be sought from TII as per DN-REQ-03080.
6. Transitions

6.1 General

Transitions are necessary between safety barriers with different Working Widths or Containment Levels. They are also required between safety barriers and bridge parapets and safety barriers and terminals.

A Transition is an interface between two VRS of different cross section or different lateral stiffness to provide a gradual change from the first to the second system, to prevent the hazard of an abrupt variation, often referred to as “snagging” or “pocketing”. A transition is designed to connect two specified VRS.

![Diagram of Transitions](image)

**Note:**

* A Transition is required if:
  - Type 1 and Type 2 have incompatible cross sections
  - Type 1 and Type 2 have different lateral stiffnesses
  - Type 1 is a safety barrier and Type 2 is a parapet, terminal or a crash cushion

**Figure 6.1 Requirement for Transition**

The junction between two safety 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 and is often referred to as “system progression”. This also applies when connecting an A-profile barrier to a B-profile barrier of the same containment once the Working Width does not vary by more than one class.

Where several hazards are located in close proximity to each other and a variety of working widths are required, the lowest required Working Width value shall be provided throughout the safety barrier length to avoid multiple changes in working widths over short distances. In such circumstances, the containment level should also remain the same to meet the highest required containment level at the location.

The design of transitions shall be such that changes in Working Width and Containment Level are introduced gradually and evenly along its length. 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 8 m or at least 10 to 12 times the change in Working Width (whichever is greater) shall normally be provided. Where a transition is made to an immovable safety barrier, the working width should be assumed to be zero for the purpose of this calculation.

Direct connections between a safety barrier and a vehicle parapet shall be treated as transitions and shall be subject to all transition requirements in this document. So too shall expansion joint assemblies.
All transitions proposed for use on the National Road Network must be assessed as per the requirements of DN-REQ-03081 - Transition Assessment Procedure until such time as there is a harmonised European Standard. Refer to the TII Compliant Transitions list available in the “Downloads” section of the TII Publications website for a list of transitions permitted for use on the National Road Network and the VRS they are permitted to connect.

The definitions of the Containment Level, Impact Severity Level and Working Width for transitions are the same as specified in I.S. 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 systems. Its Working Width shall not be larger than the larger Working Width of the two connected systems. All transitions shall comply with the requirements of the impact assessment test criteria specified in I.S. EN 1317-2 for safety barriers and the critical impact requirements in Section 3.4. Evidence of compliance shall be submitted to TII as per the requirements of DN-REQ-03081.

### 6.2 Transition between Safety Barriers and Bridge Parapets

#### 6.2.1 On Approach / Departure to Bridge Parapets

To prevent direct impact between a vehicle and the end of the vehicle parapet, a safety barrier shall be provided on each end of the parapet. The safety barrier shall be at least 30m long at full height in advance of the approach end and at least 30m long at full height after the departure end and should continue the line of the traffic face of the parapet. Where the safety barrier extends beyond the 30m departure length, to a maximum of 60m, the containment level shall be maintained for the full length of the system.

On roads with a mandatory speed limit of 50km/h or less, the requirements for safety barriers, in accordance with the preceding paragraph may be relaxed subject to the approval of TII.  

The Containment Level of the safety barrier on the approach to and departure from the parapet shall be at least equal to that of the parapet.

For bridges over railways the safety barrier requirements on approach and departure shall be subject to discussion/ agreement with Iarnród Éireann and shall be justified by means of a site-specific risk analysis.

#### 6.2.2 At the Connection Point Between a Safety Barrier and a Bridge Parapet

Where a safety barrier adjoins a vehicle parapet, a transition shall be provided between the parapet and the safety barrier which shall be capable of maintaining the continuity of the Containment Level and provide a gradual transition between the containment level and working width of the safety barrier and the parapet.

Similar to safety barrier to safety barrier transitions, the Containment Level for the transition between a safety barrier and parapet shall not be lower than the lower containment level, nor higher than the higher, of the connected safety barrier or parapet. The Working Width of the transition shall not be greater than either that of the safety barrier or parapet which it is connecting.

Where a transition is composed of posts and rails, the maximum change in height at any point shall be 450mm. The projecting end of any terminated upper rail shall be treated so as to avoid the possibility of an errant vehicle impacting directly with it.

Where it is necessary to transition between a safety barrier and a bridge parapet and the bridge is narrower or wider than the approach road, it is essential that the change in width is introduced gradually to prevent increasing the risk of pocketing between the safety barrier and bridge parapet or of vehicles being redirected into oncoming traffic.
The change in width shall be introduced at a flare rate of not less than 1:20 in advance of the transition length required on Approach and Departure as per Figure 6.2 and 6.3 below.

*NOTE
(1) Minimum Flare between VRS installation and Bridge Parapet to be 1:20 to reduce risk of pocketing in VRS.
(2) Ensure adequate space and ground strength is provided behind VRS and transition to ensure full performance requirements can be achieved.

Figure 6.2 Transition between safety barrier and bridge parapet (bridge narrower than approaches)

*NOTE
(1) Minimum Flare between VRS installation and Bridge Parapet to be 1:20 to reduce risk of pocketing in VRS.
(2) Ensure adequate space and ground strength is provided behind VRS and transition to ensure full performance requirements can be achieved.

Figure 6.3 Transition between safety barrier and bridge parapet (bridge wider than approaches)
When transitioning from a safety barrier to a bridge parapet, it is of vital importance that the bridge parapet structure extends upstream and downstream sufficiently into the adjacent embankment and the embankment is constructed to provide adequate embankment width behind the VRS/Transition. This embankment width is critical to allow the VRS/transition foundations to function as designed and tested. This is of particular importance when steepened reinforced earth embankments are provided which may result in reduced embankment/verge widths.

An embankment/verge width behind the safety barrier less than the working width of the safety barrier immediately adjacent to bridge abutments may result in the VRS not performing as tested in the event of an impact due to inadequate ground support behind the post. In such instances a suitable safety barrier foundation shall be designed to ensure the performance of the system. A suitably designed detail similar to the foundation detail in CC-SCD-00412 and CC-SCD-00414 may be appropriate.

6.3 Testing

All transitions shall comply with the requirements of the test acceptance criteria specified in I.S. ENV 1317-4 and be assessed for compliance in accordance with DN-REQ-03081. For a transition to be approved for use based on its compliance it must pass two tests. These tests are as specified in I.S. EN 1317-2 for safety barriers, one with a light vehicle for impact severity and another with a heavy vehicle for maximum containment. Further details and clarification in relation to testing, including the critical impact points for the specified tests is included within DN-REQ-03081.

6.4 Removable Safety Barrier Sections

A Removable Safety Barrier Section not longer than 40m shall be considered a special transition connecting two pieces of the system, installed to allow quick removal and reinstallation. It shall be tested as a single transition.

A Removable Safety Barrier Section longer than 40m shall be considered a different system, connected to the normal safety barrier by two transitions. The safety barrier must have passed the two tests specified in I.S. EN 1317-2 relative to its class. The transition shall be tested as specified in Section 1.1.

If the Removable Safety Barrier Section is longer than 40m but shorter than 70m, the systems 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 I.S. EN 1317-2) on this impact point can be omitted.
7. Crash Cushions

7.1 General

A crash cushion is a standalone device installed in front of an obstacle to protect the occupants of a vehicle from colliding with the roadside hazard. They may be provided where a suitable length or provision of VRS cannot be provided or is not appropriate. Roadside hazards for which the installation of a crash cushion may be considered appropriate for may include the ends of retaining walls, abutments, bridge piers, concrete safety barriers, tunnel portals and blunt walls in tunnels, concrete buffers at toll stations etc. Connections between a crash cushion and a safety barrier shall be treated as a transition and shall be submitted for assessment in accordance with DN-REQ-03081 on case by case basis.

Crash cushions must be compliant with the general Test Acceptance Criteria requirements of I.S. EN 1317-3, entitled, “Road Restraint Systems: Crash Cushions – Performance Classes, impact test acceptance criteria and test methods” and the following criteria. They are tested and approved as standalone structures.

Crash cushions are specified by their Performance Class, Redirection Zone Class, Impact Severity Level and Permanent Lateral Displacement Zone Class.

7.2 Options for Crash Cushions

Crash cushions are divided into two types according to their ability to contain and decelerate or redirect the vehicle in a side impact.

The options for crash cushions include:

a) Redirective (R)

b) Non-Redirective (NR)

In a frontal collision, both types will satisfactorily contain and decelerate a vehicle. A redirective crash cushion will redirect the vehicle and thus perform similarly to a safety barrier in a side collision. A non-redirective crash cushion is not designed to redirect a vehicle in a side impact must satisfy only some of the tests in EN 1317-3.

7.3 Performance Class

The selection of a crash cushion is dependent of the design/operational speed of the road. The Performance Class requirements are as follows:

<table>
<thead>
<tr>
<th>Performance Level</th>
<th>Design / Operational Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>≤ 50</td>
</tr>
<tr>
<td>80</td>
<td>≤ 80</td>
</tr>
<tr>
<td>100</td>
<td>≤ 100</td>
</tr>
<tr>
<td>110</td>
<td>&gt; 100</td>
</tr>
</tbody>
</table>
7.4 Redirection Zone Class

For a crash cushion to be acceptable, during tests, the wheels of the test vehicle must not encroach the lines of what is called the Exit Box unless the velocity of the vehicle at the instant of encroachment is less than 10% of the prescribed impact speed. The size of the Exit Box depends upon the Redirection Class of the Crash Cushion. The Exit Box is bounded by the front face of the object that the crash cushion is protecting, a line 6 m in advance of the crash cushion and by lines parallel to and offset from each side of the crash cushion (i.e. ‘Za’ m offset on the approach side and ‘Zd’ m offset on the departure side). Table 7.2 includes both Za and Zd dimensions for each Redirection Zone Class (Z).

**Table 7.2 Classes of Z for Redirection Zone Classes**

<table>
<thead>
<tr>
<th>Classes of Z</th>
<th>Approach side Za</th>
<th>Departure side Zd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z1</td>
<td>4m</td>
<td>4m</td>
</tr>
<tr>
<td>Z2</td>
<td>6m</td>
<td>6m</td>
</tr>
<tr>
<td>Z3</td>
<td>4m</td>
<td>≥ 4m, test 3, Figure 3*</td>
</tr>
<tr>
<td>Z4</td>
<td>6m</td>
<td>≥ 6m, test 3, Figure 3*</td>
</tr>
</tbody>
</table>

* Refer to EN 1317-3 for test 3, Figure 3

7.5 Impact Severity Level

The Impact Severity Level (ISL) of crash cushions shall not exceed ISL B, as stipulated in Table 3 of EN 1317-3.

7.6 Permanent Lateral Displacement Zone Class

Each crash cushion should have its Permanent Lateral Displacement Zone Class specified according to the Classes given Table 7.3. The crash cushion under test should remain within distances Da and Dd from the initial face of the crash cushion.

**Table 7.3 Permanent Lateral Displacement Zone Classes with corresponding Displacement**

<table>
<thead>
<tr>
<th>Classes</th>
<th>Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approach side Da (m)</td>
</tr>
<tr>
<td>D1</td>
<td>0.5</td>
</tr>
<tr>
<td>D2</td>
<td>1.0</td>
</tr>
<tr>
<td>D3</td>
<td>2.0</td>
</tr>
<tr>
<td>D4</td>
<td>3.0</td>
</tr>
<tr>
<td>D5</td>
<td>0.5</td>
</tr>
<tr>
<td>D6</td>
<td>1.0</td>
</tr>
<tr>
<td>D7</td>
<td>2.0</td>
</tr>
<tr>
<td>D8</td>
<td>3.0</td>
</tr>
</tbody>
</table>

* Refer to EN 1317-3 for Test 3, Figure 3
8. Vehicle Parapets

8.1 General

Vehicle parapets are required on the edges of all bridges where there is a vertical drop and the bridge is designed to carry vehicular traffic. Vehicle parapets are also required on the edges of retaining walls or similar structures where there is a vertical drop in excess of 1m and there is access for vehicles adjacent to the top of the wall.

Unless particular circumstances apply which require the use of a bespoke parapet, vehicle parapets shall be fully crash tested in accordance with I.S. EN 1317-2 and meet the acceptance criteria of I.S. EN 1317-2 for the performance requirements specified below. The use of a bespoke parapet requires the written agreement of the TII Structures Section.

<table>
<thead>
<tr>
<th>Location</th>
<th>Minimum Parapet Containment Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>All structures not otherwise explicitly dealt with in this table</td>
<td>H2</td>
</tr>
<tr>
<td>Structures in urban areas where the legal speed limit is 60km/h or less, except where:</td>
<td>N2</td>
</tr>
<tr>
<td>• The structure crosses or adjoins a road or railway</td>
<td></td>
</tr>
<tr>
<td>• The structure is on a horizontal curve and / or gradient and the radius and / or gradient does not comply with relevant desirable minimum standards. Relevant desirable minimum standards are described in DN-GEO-03031.</td>
<td></td>
</tr>
<tr>
<td>All accommodation bridges serving a single landholding except accommodation bridges over the railway.</td>
<td></td>
</tr>
<tr>
<td>All structures crossing or adjoining the railway</td>
<td>H4a</td>
</tr>
</tbody>
</table>

8.2 Containment Level

At the locations described in Table 8.1, the vehicle parapet shall have at least the Containment Level indicated. Vehicle parapets of containment level N1, T1, T2 or T3 shall not be used.

The containment levels in Table 8.1 are minimum requirements only. The responsibility rests with the Designer to provide the appropriate containment level taking account of the following factors:

- The hazard formed by the parapet itself;
- The risk to vehicles from penetrating the parapet and reaching the hazard below;
- The risk to others (either on or below the structure) arising from a vehicle penetrating the parapet.

Where structures correspond to more than one location in Table 8.1, the highest relevant Containment Level shall be used.

The Designer is required to obtain the agreement of Iarnród Éireann to any proposed road safety barrier either over or alongside an existing (or proposed) railway.
With the exception of bridges over the railway, vehicle parapets of Very High Containment Level (H4a) shall only be considered in high risk locations where the consequences of parapet penetration are judged to outweigh the hazards to vehicle occupants or other road users resulting from the effects of the very high containment parapets. Such cases shall be considered (by the Designer) on their merits and submitted for consideration (by TII) as part of the structure’s Technical Acceptance process (refer DN-STR-03001).

### 8.3 Impact Severity Level

Vehicle parapets of Normal Containment Level (N2) should have Impact Severity Level A. Parapets of Higher or Very High Containment Level may have Impact Severity Level B.

### 8.4 Working Width

The Working Width of a parapet system shall be no greater than W4. Notwithstanding this, it remains the responsibility of the Designer to ensure that the parapet system chosen has been tested to circumstances similar to those in which the parapet is proposed to be used. In particular, the Designer shall ensure that no wheel of an errant vehicle can fall between the parapet edge beam and the deformed safety barrier.

### 8.5 Height

The height of the parapet shall be measured above the adjoining paved surface and shall not be less than the highest of the minimum parapet heights given in Table 8.2 for the criteria relevant to the structure in question.

<table>
<thead>
<tr>
<th>Structure Criteria</th>
<th>Minimum Parapet Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures carrying motorways or roads to motorway standard from which pedestrians,</td>
<td>1000</td>
</tr>
<tr>
<td>animals and cyclists are excluded by Order</td>
<td></td>
</tr>
<tr>
<td>Other road structures not otherwise explicitly dealt with in this table</td>
<td>1250</td>
</tr>
<tr>
<td>Where a cycleway is adjacent to the parapet</td>
<td>1400</td>
</tr>
<tr>
<td>Accommodation bridges</td>
<td>1500</td>
</tr>
<tr>
<td>Very High Containment Level applications except railway structures</td>
<td>1500</td>
</tr>
<tr>
<td>All structures over railways</td>
<td>1800</td>
</tr>
<tr>
<td>Bridleway bridges</td>
<td>1800</td>
</tr>
</tbody>
</table>

Notwithstanding the above, the heights of parapets over railways shall be subject to the approval of Iarnród Éireann.

Special conditions at particular sites may signify the need for higher parapets. Such cases should be considered (by the Designer) on their merits and submitted for consideration (by TII) as part of the structure’s Technical Acceptance process (refer DN-STR-03001).
8.6 Form and Aesthetics

Parapet form is an important feature of the appearance of a structure. The aesthetic effects of the vehicle parapet, including its details, shall be considered at the initial stage of the design of the structure and also during development of the design. The aesthetic suitability of the parapet shall be subject to the approval of TII Structures Section. TII may, at its discretion, refuse to approve a proposed system based upon its aesthetics and suitability for the receiving environment.

The aesthetic effects of the vehicle parapet would include both the appearance (and detailing) of the vehicle parapet itself as well as the inter relationship of the parapet with the main structure (e.g. the setting out of the parapet posts with respect to bridge supports and/or joints in deck fascia etc.).

Signature structures and long span bridges greater than 60m shall include open post and rail type parapets that add to the aesthetic merit of the structure. The designer shall include aesthetic requirements for parapets within the contract specific Appendix 4/1.

Parapet posts shall be set out symmetrically with respect to bridge supports (piers and abutments) and any joints in the deck fascia.

8.7 Pedestrian Restraint on Vehicle Parapets

For all structures with vehicle parapets, except structures carrying motorways or roads to motorway standard from which pedestrians, animals and cyclists are excluded by law, the parapets shall restrain pedestrians as well as vehicles.

It is not practical to make vehicle parapets completely unclimbable but, where pedestrians have access, infilling shall be provided such that the parapet will not have footholds.

Since pedestrians are excluded, infilling will not normally be required on motorway underbridges or structures adjacent to motorway carriageways, except where they cross or are adjacent to railways.

Pedestrian restraint shall be provided as an integral part of the vehicle parapet. Separate vehicle and pedestrian parapets shall not be used.

Infills shall extend from not more than 25mm above the plinth at the traffic face to the full height of the parapet.

On road bridges where provision is made for other road users, such as cyclists, equestrians or livestock, pedestrian restraint in accordance with the preceding paragraphs of this Section shall be provided.
There may be a need for mesh infilling to part height on parapets with or without pedestrian restraint, in order to prevent loose debris, stones or snow from falling onto the area beneath the bridge.

Similarly, there may be a need for solid infill in order to prevent splash, reduce noise, screen railway electrification equipment or, on accommodation bridges, to avoid frightening livestock crossing the bridge. Such cases should be considered (by the Designer) on their merits and submitted for consideration (by TII) as part of the structure’s Technical Acceptance process (refer DN-STR-03001).

At locations subject to vandalism, there may be a need for a significant increase in height in the pedestrian restraint. Mesh screening should be inclined away from the traffic and positioned such that it cannot be struck by an errant vehicle. Also, at some bridges the parapet may need to incorporate environmental barriers. Such cases should be considered (by the Designer) on their merits and submitted for consideration (by TII) as part of the structure’s Technical Acceptance process (refer DN-STR-03001).

On all bridges over or adjacent to railways, irrespective of whether pedestrians have access to the bridge, infill or other restraint for pedestrians or other road users will be required in accordance with the preceding paragraphs of this Section and with the following additional requirements:

a) On all bridges over railways, solid infill shall be provided over the full height of the traffic face of the parapet. Infill shall extend so as to be no more than 3mm above the plinth at the traffic face. Metal infill panels shall be of a type approved by Iarnród Éireann and shall be at least 3mm in thickness;

b) In order to discourage walking on top of the parapet, either the overall width of the top of the parapet shall be no greater than 100mm or the top shall have a steeply inclined face at an angle not less than 45 degrees to the horizontal;

c) Metal parapets over railways shall also be provided with solid sheeting or mesh on the outer face of the parapet, extending to the full height of the parapet and with the lower part shaped to cover the outer ledge of the parapet beam. The outer face sheeting shall deny access to the outer ledge and extend along the length of the parapet for the width of the railway tracks plus one parapet panel or 2.0m, whichever is the greater. In cases where overhead electrification equipment is present, the sheeting shall extend to at least 3.0m from the outside edge of the nearest rails or from any overhead electrification equipment, whichever is greater. It shall also be provided at the ends of the parapet for a distance of 2.0m, see Figure 8.1;

![Figure 8.1 Metal Parapets over Railways](image-url)
d) The outer face sheeting at the ends of the parapet shall be extended in length in locations where the outer ledge is deemed to be readily accessible from any area adjacent to the bridge;

e) Any other method of denying access to the outer ledge of the parapet shall be subject to the agreement of Iarnród Éireann.

8.8 Paved Verge

In order to discourage the stationing of vehicles with their wheels close to the vehicle parapet, a raised verge shall be provided between the parapet and the edge of hard shoulder, hard strip or carriageway. The raised verge shall have a minimum width of 600mm and be edged with a minimum kerb height of 75mm. The paved surface of the verge shall fall towards the top of the kerb. At the ends of the bridge, the kerb and verge shall slope at a gradient no greater than 5% to the level of the road verge or footway on the bridge approaches.

8.9 Divided Structures

When designing a divided structure to carry a dual carriageway, the gap between the two structures should be narrow (<100mm) and present no danger to pedestrians or vehicles. If a wider gap of between 100mm and 2.0m is unavoidable, a horizontal grid or slab designed to carry appropriate bridge deck traffic loading in accordance with I.S. EN 1991-2 shall be provided. If the structure is over a railway, a grid is not permitted and a solid slab is required.

Where these provisions are impractical or the gap is greater than 2m, vehicle parapets shall be provided.
9. Bespoke Parapets

9.1 General

As stated in Section 8.1, vehicle parapets shall wherever possible be tested to and conform to the requirements of I.S. EN 1317-2. However, it is acknowledged that, in certain limited circumstances, suitable crash tested vehicle parapets may not be available and that a designed, non-crash tested, bespoke vehicle parapet may be appropriate. This section provides specific requirements for bespoke parapets which are to be considered as additional to the general requirements for all parapets specified elsewhere in this Standard.

The need for bespoke vehicle parapets may arise, inter alia, for bridges over a railway, where particular safety criteria apply, for heritage structures where particular aesthetic criteria may apply, or in urban areas where traffic speeds are low and aesthetic criteria may apply. Wherever possible safety barriers tested in accordance with I.S. EN 1317 should be used in these circumstances and only as a last resort should a bespoke vehicle parapet be provided.

Subject to the above paragraphs, bespoke vehicle parapets shall be provided on bridges and retaining walls at the locations described in Section 8.1.

Design of bespoke vehicle parapets shall be in accordance with the relevant Part of BS 6779 as amended by this Standard. It will not be necessary for parapets designed to BS 6779 to be tested to demonstrate the Impact Severity Level.

Containment level N1 in I.S. EN 1317 shall be taken as equivalent to Low Level of Containment in BS 6779. Containment level N2 in I.S. EN 1317 shall be taken as equivalent to Normal Level of Containment in BS 6779. Containment level H4a in I.S. EN 1317 shall be taken as equivalent to High Level of Containment in BS 6779.

There is no containment level in BS 6779 equivalent to the H2 containment level specified in I.S. EN 1317. Where bespoke parapets of containment level H2 are required, these shall be designed from first principles for the vehicle impact criteria specified in I.S. EN 1317.

The design requirements given in this Standard for vehicle parapets are based on cantilever action from the bridge deck. Main structural members of bridges shall not be designed to act as vehicle parapets.

Transitions between safety barriers and bespoke parapets, provided in accordance with Section 6 of this Standard, shall be designed to meet the requirements of Section 6.2.2. The requirements of Section 6.3 do not apply in these circumstances.

9.2 Materials

Bespoke vehicle parapets may be steel, aluminium, reinforced concrete (precast or in-situ) or a combination of these. Where it is necessary to harmonise with local conditions, the outer face of concrete vehicle parapets may be clad in masonry provided the cladding is securely fixed to the concrete.

Masonry vehicle parapets shall not be used on new bridges over, under or adjacent to National Roads. However, where it is necessary to replace parapets on existing masonry bridges, reinforced or unreinforced masonry parapets may be used. Masonry parapets shall be designed in accordance with BS 6779: Highway Parapets for Bridges and Other Structures, Part 4: Specification for Parapets of Reinforced and Unreinforced Masonry Construction, as amended by this Standard.
Designers shall also take account of the relevant guidance contained within the UK Department of Transport's 2012 document “Guidance on the Design, Assessment and Strengthening of Masonry Parapets on Highway Structures”.

Where a reinforced concrete core with masonry cladding parapet detail is used to replace parapets on existing masonry bridges, and there is a connecting safety barrier, the Safety Barrier to Concrete Parapet connection detail as detailed in CC-SCD-00412 to CC-SCD-00414 may be used subject to the conditions listed within the SCDs.

9.3 Vehicle Parapets of Metal Construction

Metal vehicle parapets of open frame design, such as post and rail or post and beams shall be designed in accordance with BS 6779: Highway Parapets for Bridges and Other Structures, Part 1: Specification for Vehicle Containment Parapets of Metal Construction Annex B, as amended by this Standard, for the relevant Containment Level.

Metal vehicle parapets of open frame design, such as post and rail or post and beam shall be designed for durability in accordance with BS 6779: Highway Parapets for Bridges and Other Structures, Part 1: Specification for Vehicle Containment Parapets of Metal Construction Section 6.4, as amended by this Standard.

Joints shall be provided in metal vehicle parapets in accordance with BS 6779: Highway Parapets for Bridges and Other Structures, Part 1: Specification for Vehicle Containment Parapets of Metal Construction Section 6.5, as amended by this Standard.

The parapet shall consist of at least two effective longitudinal members. The overall depth of each longitudinal member, measured as the depth of its projection onto a vertical plane, shall be not less than 50mm or more than 150mm for Low or Normal Levels of Containment and not less than 100mm or more than 200mm for High Level of Containment. The clear gap between longitudinal members and between the lowest longitudinal member and the top surface of the concrete plinth shall be not more than 300mm. For parapets on accommodation bridges, the clear gap may be increased to not more than 400mm.

On roads with a mandatory speed limit not greater than 50km/h, the vehicle parapet may, as an alternative, be a design incorporating two longitudinal members and closely spaced vertical members. The clear space between adjacent vertical members shall not exceed 100mm.

Parapets shall incorporate a reinforced concrete plinth (of height 50-100mm) and the front faces of the effective metal longitudinal members shall be in the vertical plane containing the top edge of the front face of the reinforced concrete plinth.

Metal rails or beams shall present smooth surfaces on the traffic face and on the top and bottom faces and be free from sharp edges or corners on the front face.

Projections or depressions on the front, top and bottom faces shall only be allowed at joints in rails and at connections to posts and shall be within the following limits:

a) Front face and top and bottom faces within 15mm of the front face: a maximum of 15mm including the heads of any fastenings, which shall be of a well-rounded shape.

b) Top and bottom faces beyond 15mm from the front face: a maximum of 25mm including the heads of any fastenings.
c) Tops of posts, including any caps or straps, shall not project above the level of the top of the top rail by more than 16mm and the heads of any fastenings to the top of the posts shall not project above the top face of the top rail by more than 35mm, making allowance for sloping rails.

On post and rail type parapets with an overall height of 1.5m or more, the top rail may be a ‘non-effective longitudinal member’. Such a member shall be designed to withstand a horizontal ultimate load of at least 1.4kN/m and the parapet posts shall be designed to ensure that they are capable of providing support for the consequential effects.

This loading need not be considered co-existent with the loading required for vehicle containment. In the case of an application of such a rail to a High Level of Containment parapet, the post extensions to carry the non-effective rail shall be designed for this purpose only.

On post and rail type parapets with an overall height of 1.5m or more over railways, the top rail shall be of the same section as the main longitudinal members of the parapet. Where a small extension in height is required, consideration may be given to the provision of a steeple coping profile continuously attached to the top rail.

Bespoke metal parapets over the railway shall, in addition to the above requirements, comply with the requirements of Section 8.7 of this Standard.

### 9.4 Vehicle Parapets of Concrete Construction


Vehicle parapets of insitu reinforced concrete construction shall be designed in accordance with BS 6779: Part 2 as amended by this Standard and I.S. EN 1991-2.

All reinforced concrete parapet panel walls shall have a minimum thickness of 180mm for Normal Level of Containment Level and 325mm at the critical design section for High Level of Containment.

All reinforced concrete parapet panel walls shall have a minimum panel length of 1.5m and a maximum panel length of 1/5th span or 3.5m whichever is lesser.

\( \gamma_m \) for the reinforcement in the in-situ and precast parapet panel wall shall be 1.0, not 0.8 as given in Table 4 of BS 6779: Part 2.

Concrete parapets for Normal Level of Containment shall be designed for an equivalent static nominal load (for calculating panel nominal bending moment) of 100kN over 1.0m, not 50kN over 1.0m as given in Table 2 of BS 6779: Part 2.

Concrete panel walls of parapets for Normal Level of Containment shall be designed with shear transfer provision between panels. An equivalent static nominal load of 50kN shall be transferred between panels within the top 0.5m of the panels.
9.5 Vehicle Parapets of Combined Metal and Concrete Construction

Vehicle parapets of combined metal and concrete construction shall be designed in accordance with BS 6779: Highway Parapets for Bridges and Other Structures, Part 3: Specification for Vehicle Containment Parapets of Combined Metal and Concrete Construction as amended by this Standard.

\[ \gamma_m \]

for the reinforcement in the in-situ and precast parapet panel wall shall be 1.0, not 0.8 as given in Table 6 of BS 6779: Part 3.

In addition to the requirements of BS 6779: Part 3, concrete panel walls and bases for vehicle parapets of combined metal and concrete construction for Normal Containment Level (or more severe) shall have a capacity not less than that required to satisfy BS 6779: Part 2, as modified by this Standard, for a vehicle parapet of equivalent overall height.

Concrete panel walls of parapets shall be designed with shear transfer provision between panels. An equivalent static nominal load of 50kN shall be transferred between panels within the top 0.5m of the panels.

Bespoke parapets of combined metal and concrete construction over the railway shall, in addition to the above requirements, comply with the requirements of Section 8.7 of this Standard.

9.6 Masonry Cladding

Where masonry cladding to concrete parapets is provided on new bridges the following criteria shall be satisfied:

a) Fixings shall be spaced at not more than 450mm horizontally and 300mm vertically;

b) Fixings shall be in stainless steel and shall not be placed in contact with carbon steel reinforcement;

c) Uncoursed work will only be permitted where there is a low probability of detached masonry presenting a hazard to the public. Such cases should be considered (by the Designer) on their merits and submitted for consideration (by TII) as part of the structure’s Technical Acceptance process (ref DN-STR-03001).

Masonry cladding to the front face of a parapet will only be permitted in exceptional cases (based principally on aesthetic considerations). Pointing shall be flush. Masonry on the front face may have an irregular surface subject to the maximum amplitude of the steps and undulations in the surface not exceeding 30mm when measured with respect to a plane through the peaks. The plane shall be flat for straight parapets and curved to follow the nominal parapet curvature for parapets which are curved on plan.

The above requirements of this Section 9.6 do not apply to the replacement of existing masonry parapets on existing bridges.

Stone or precast concrete copings may only be used with vehicle parapets of concrete construction where the mandatory speed limit is 50km/h or less. Such copings shall be fixed to the concrete core by fixings capable of resisting, at the ultimate limit state, a horizontal force of 33kN per metre of coping.
10. Pedestrian Parapets and Guardrails

10.1 Scope

This Chapter gives requirements and guidance on parapets for pedestrians, cyclists and equestrians on bridges without vehicular traffic and also on pedestrian guardrails to provide pedestrian restraint at structures. It does not provide guidance on the use of pedestrian guardrails at locations away from structures.

The requirements in this Chapter for infill to pedestrian parapets are equally applicable to infill on vehicle parapets where pedestrian restraint is also required, subject to the requirements of Chapter 8 of this Standard.

This Chapter should be read in conjunction PD CEN/TR 16949:2016 Road restraint systems - pedestrian restraint system - pedestrian parapets.

10.2 Height of Pedestrian Parapets

The height of pedestrian parapets (H_o) shall be measured above the adjoining pedestrian walking surface and shall not be less than the highest of the minimum parapet heights given in Table 10.1 for the criteria relevant to the structure in question.

<table>
<thead>
<tr>
<th>Structure Criteria</th>
<th>Minimum Parapet Height, H_o (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footbridges except over railways</td>
<td>1250</td>
</tr>
<tr>
<td>Cycleway bridges except over railways</td>
<td>1250</td>
</tr>
<tr>
<td>Where a cycleway is adjacent to the parapet</td>
<td>1450</td>
</tr>
<tr>
<td>Bridleway bridges</td>
<td>1850</td>
</tr>
<tr>
<td>All non-vehicular bridges over railways</td>
<td>1850</td>
</tr>
</tbody>
</table>

Notwithstanding the above, the heights of parapets over railways shall be subject to the approval of Iarnród Éireann.

The height requirements given in Table 10.1 shall include for a plinth of minimum height 50mm.

10.3 Pedestrian Parapets Design Criteria

Footbridges, cycleway bridges and bridleway bridges shall be provided with pedestrian parapets complying with the requirements of PD CEN/TR 16949:2016.

The design working life for pedestrian parapets shall be as given in CC-SPW-00400.

Pedestrian parapets shall be designed or tested to conform to the requirements of PD CEN/TR 16949:2016.
For designed parapets, horizontal uniformly distributed traffic loads shall be calculated in accordance with Method 2 in PD CEN/TR 16949:2016. For all other traffic loads, the minimum values given in PD CEN/TR 16949:2016 shall be used.

Pedestrian parapets of concrete construction shall be designed in accordance with I.S. EN 1992. The horizontal traffic loads in PD CEN/TR 16949:2016 shall be assumed to act within 25mm of the top of the parapet.

Snow and wind loads on pedestrian parapets shall be in accordance with I.S. EN 1991-1-3 and I.S. EN 1991-1-4.

Pedestrian parapets shall be provided with infilling such that the parapet will not have footholds.

Infilling shall comply with the requirements of Section 8.7 of this Standard. Unless solid infilling is required to meet other requirements of this Standard, the infilling shall contain spaces or voids with a maximum $D_s$ equal to 30mm in accordance with PD CEN/TR 16949:2016. Notwithstanding this, vertical bar infilling shall have a maximum $D_s$ equal to 100mm.

Stone or precast copings used with pedestrian parapets should be secured to the concrete backing by fixings capable of resisting a horizontal force of 10kN at the ultimate limit state per metre of coping.

### 10.4 Pedestrian Restraint at Head Walls, Wingwalls and Retaining Walls

Within the road boundary, retaining walls often support the slope of a cutting or embankment. Also present may be head walls and wingwalls at underbridges, underpasses, subways and culverts. On motorways and some other rural National Roads, pedestrians are not normally expected to be present near these walls. However, drivers and passengers of broken down or damaged vehicles, maintenance staff, emergency services personnel and others may on occasion walk near them.

Suitable protective safety barriers or pedestrian guardrails should be provided at these locations in accordance with the following:

- Where a structure such as a retaining wall, head wall or wingwall presents a vertical or near vertical face 1.5m or more in height and it would be possible for a person to gain access to the upper edge of the structure, a pedestrian barrier such as a protective safety barrier or guardrail should be installed close to or on top of the structure.
- Consideration should also be given to installing a pedestrian protective safety barrier or guardrail at walls less than 1.5m high if a particular hazard, such as a watercourse or road, is in close proximity.

Examples of locations where pedestrian measures would generally be necessary are shown in Figures 10.1 to 10.3.

The type of pedestrian protective measure to be used will need to be determined for each specific location depending on the ease of pedestrian access to the hazard in question. It could be a pedestrian guardrail, a pedestrian parapet or an appropriate type of boundary fencing (in accordance with the TII Publications Series 300 SCDs). It will need to be in keeping with any structural, drainage, environmental and aesthetic considerations of the site in question. The choice of pedestrian protective measure shall be supported by a site-specific risk assessment.
Figure 10.1  Typical Locations for Pedestrian Guardrailing/Protection
Figure 10.2  Typical Locations for Pedestrian Guardrailing/Protection
Figure 10.3 Typical Locations for Pedestrian Guardrail/Protection

**FIGURE (e)**

**RECTANGULAR**

**FIGURE (f)**

**CURVED**

**SIDE ELEVATION**

CULVERTS ETC. (N.T.S.)
11. Requirements for Parapet Anchors and Supports

11.1 Anchorages General

The design of parapet attachment systems and anchorages shall be such that:

- removal and replacement of damaged sections may be achieved readily;
- under no loading conditions (including the event of a failure) is damage sustained by any part of the bridge.

Anchorages, attachment systems, bedding and plinths for metal parapets shall meet the requirements of the tested vehicle parapet system and, unless otherwise specified in this Standard or I.S. EN 1991-2, shall comply with the requirements of BS 6779: Part 1 Clause 6.6 as amended by this Standard.

Anchorages and attachment systems for concrete parapets shall meet the requirements for the tested vehicle parapet system and unless otherwise specified in this Standard or I.S. EN 1991-2, shall comply with the requirements of BS 6779: Part 2 Clauses 6.2 and 10.

Reinforcement used to tie precast concrete parapets to the bridge deck or other supporting structure (e.g. kentledge slab) shall comply with one of the following:

- shall be stainless steel reinforcement Type 1.4301 to I.S. EN 10088 or
- shall be protected by bridge deck waterproofing system and the cover ($C_{min}$) to the face of all concrete forming part of the anchorage shall be in excess of 80mm.

Drill and fix anchors to parapets behave differently to parapets anchored using cast in cradles. Parapet installations shall be anchored as per the installation type used during the Initial Type Testing. If it is proposed to use an anchorage different than that used in the Initial Type Test, evidence that the change in anchorage will not affect the performance of the parapet will be required to ensure that the specified anchor is appropriate for its intended use.

11.2 Main Structure

The local and global effects of vehicular collision with the parapets is to be considered in the design of elements of the main structure and on the superstructure, bearings and substructure of the bridge and shall be as specified in I.S. EN 1991 Part 2 Traffic Loads on Bridges and Appendix H of this Standard.

Where the Contractor has the facility to choose the vehicle parapet system to be used on a particular structure, the parapet system to be used will not be known at the time that the detailed bridge design is prepared. Accordingly, it will not be possible to design fully the corresponding anchor requirements, nor to specify the requirements in terms of either the design resistance or the characteristic resistance. The Designer will, therefore, need to check the adequacy of the selected anchors after the Contractor’s proposals are known.

The Designer is responsible for assessing the condition and proving the strength sufficiency of an existing structure on which a new or replacement vehicle parapet is to be erected and for evaluating the factors to be used in determining the design resistance value of the Contractor’s chosen anchorage. Since the parapet system to be used may not be known at the time of preparing the design, the Designer will be required to make assumptions relating to the loads applied to the supporting structure.
If these loads are incapable of being carried by the structure then it will be necessary for the Contractor to propose an alternative parapet design so as to not exceed the limitations of the structure. Any limitations to the design of the parapet that emanate from this assessment will be made clear to the Contractor as soon as they are known.

Information shall be included in the Appendices to the Specification to enable the Contractor to make an initial selection of the parapet and its anchorages.

### 11.3 Assessment of Existing Structures

Because of the interaction of the proposed safety barrier with the existing structure it will be necessary for the Designer to undertake a bridge inspection/assessment to determine whether the proposed containment level/parapet system is appropriate to the limitations of the structure.

Approval to a proposed system will not be given by TII until the results of the above bridge inspection / assessment are known and the Contractor has verified suitability of their proposed system. In the event of failure to meet the specified criteria the Contractor will be required to consider, and submit for approval, an alternative which maintains the specified containment level.

In the event that no alternative system that meets the specified containment level is available or viable, a risk-based approach, including a cost benefit analysis, for identifying the appropriate containment level shall be used.

The Designer will specify site tests which the Contractor has to carry out on anchors to demonstrate that they have been installed correctly.
12. References

12.1 TII Publications (Standards):

- DN-STR-03001 Technical Acceptance of Road Structures on Motorways and Other National Roads
- DN-GEO-03031 Road Link Design
- DN-GEO-03036 Cross Sections and Headroom
- DN-REQ-03079 Design of Road Restraint Systems for Constrained Locations (Online Improvements, Retrofitting and Urban Settings).
- CC-SPW-00400 Specification for Road Works Series 400 - Road Restraints Systems (Vehicle and Pedestrian)

12.2 Irish and European Standards

- prEN 1317-7, Road Restraint Systems - Part 7: Performance Classes, Impact Test Acceptance Criteria and Test Methods for Terminals of Safety Barriers
- BS 6779 Highway parapets for bridges and other structures - Part 3: Specification for vehicle containment parapets of combined metal and concrete construction.
- BS 6779 Highway parapets for bridges and other structures - Part 4: Specification for parapets of reinforced and unreinforced masonry construction.
Appendix A:
Examples of Safety Barrier Parameters
Examples of Safety Barrier Parameters

The following Tables A.1 and A.2 give examples of the parameters (Containment Level, Impact Severity Level, Working Width and Set-back) which the Designer could 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.

### Table A.1. Typical Examples of Safety Barrier Layouts on Verges

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Grassed Verge Width (m)</th>
<th>Hard Shoulder or 1m Hard Strip</th>
<th>Set Back (m)</th>
<th>Safety Barrier Criteria</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Containment Level</td>
<td>Impact Severity Level</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N2</td>
<td>A</td>
</tr>
<tr>
<td>1. Top of Embankment (1:2, 2m to 6m high)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Motorway or Type 1 Dual Carriageway</td>
<td>2.0</td>
<td>Yes</td>
<td>0.6 – 0.8</td>
<td>N2</td>
<td>A</td>
</tr>
<tr>
<td>Type 2 and Type 3 Dual Carriageway or Reduced Single Carriageway</td>
<td>3.0</td>
<td>No</td>
<td>1.2 – 1.3</td>
<td>N2</td>
<td>A</td>
</tr>
<tr>
<td>Existing Road</td>
<td>3.0</td>
<td>No</td>
<td>1.2 – 1.4</td>
<td>N2</td>
<td>A</td>
</tr>
<tr>
<td>Slip Road</td>
<td>4.0</td>
<td>Yes</td>
<td>0.6 – 2.0</td>
<td>N2</td>
<td>A</td>
</tr>
<tr>
<td>2. At Isolated Obstruction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier</td>
<td>2.0 2.0* (Note 2)</td>
<td>Yes</td>
<td>0.6</td>
<td>H2</td>
<td>A</td>
</tr>
<tr>
<td>Abutment</td>
<td>2.0 4.5* (Note 2)</td>
<td>Yes</td>
<td>0.6 or:</td>
<td>H2</td>
<td>A</td>
</tr>
<tr>
<td>Existing Pier</td>
<td>2.0 2.0* (Note 2)</td>
<td>No</td>
<td>1.2</td>
<td>H2</td>
<td>B</td>
</tr>
</tbody>
</table>

Notes:
1. Traffic face of safety barrier must not extend beyond the top of the embankment slope.
2. * = distance from edge of road pavement to obstruction.
### Table A.2. Typical Examples of Safety Barrier Layouts on Central Reserves

<table>
<thead>
<tr>
<th>Restraint System Type and Position</th>
<th>Central Reserve Width¹ (m)</th>
<th>Set Back (m)</th>
<th>Safety Barrier Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Containment Level</td>
</tr>
<tr>
<td>1. Double-Sided Restraint System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System 0.6m wide on centreline</td>
<td>2.6</td>
<td>0</td>
<td>H2</td>
</tr>
<tr>
<td>System 0.8m wide on centreline</td>
<td>2.8</td>
<td>0</td>
<td>H2</td>
</tr>
<tr>
<td>System 1.0m wide on centreline</td>
<td>3.2</td>
<td>0.1</td>
<td>H2</td>
</tr>
<tr>
<td>System 1.0m wide on centreline</td>
<td>4.5</td>
<td>0.75</td>
<td>H2</td>
</tr>
<tr>
<td>System 1.0m wide offset or on centreline</td>
<td>9.0</td>
<td>0.6 - 3.0</td>
<td>N2</td>
</tr>
<tr>
<td>2. Single-Sided Safety Barrier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At 2.0m wide bridge pier on centreline</td>
<td>9.0</td>
<td>0.6</td>
<td>N2</td>
</tr>
</tbody>
</table>

**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.
Appendix B:
Lengths of Flared Barriers
Lengths of Flared Barriers

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.

For safety barriers with flares, the Approach and Departure lengths can be calculated as follows:

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

where:
- \( D = D_E, D_C \text{ or } D_F \) in accordance with Sections 3.17.1 and 3.17.2.
- \( F = \) 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.

Figure B.1: Determination of Approach Length for Safety Barrier with Flare
Appendix C:
VRS Justification Sheet
<table>
<thead>
<tr>
<th>Date:</th>
<th>Completed By:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location ID/Description:</td>
<td></td>
</tr>
<tr>
<td>Site Survey Conducted (Y/N):</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazard Type /Description (Start and End Coordinates)</th>
<th>Is Hazard within the Clear Zone? (Y/N)</th>
<th>Hazard Ranking (Appendix D)</th>
<th>Mitigation/Modification Options Considered*</th>
<th>Can the Hazard be Mitigated? (Y/N)</th>
<th>Has Lifetime Cost Analysis of Barrier Been Carried Out? (SAVeRS)</th>
<th>Length of Hazard (m)</th>
<th>Barrier to be Installed (Y/N) Start and End Coordinates</th>
<th>Reasons for Installing the Safety Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>2</td>
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<td></td>
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<tr>
<td>3</td>
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<td></td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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</tr>
</tbody>
</table>

*See DN-GEO-03036 for options for mitigation of hazards*
Appendix D:
Hazard Ranking
## Hazard Ranking

<table>
<thead>
<tr>
<th>Hazard Ranking</th>
<th>Hazard Description</th>
</tr>
</thead>
</table>
| **Very High**  | • High volume of Road/Railway Crossing  
• Power/Chemical/Industrial Plant  
• High volumes of off-road vulnerable road users  
• Structures not designed for accidental collision loading  
• Building with risk of collapse |
| **High**       | • Lighting Columns that are not passively safe  
• Tubular Steel Posts > 89mm diameter and 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 of 314mm or more measured at 0.3m above the ground  
• Concrete posts with Cross Sectional Area > 15,000mm²  
• All fences and linear boundary delineations with rails (including knee rails but excluding those to CC-SCD-00320, CC-SCD-00321 or CC-SCD-00324).  
• 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  
• Isolated location where an errant vehicle may encroach onto road/railway which crosses or runs parallel to the 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  
• Industrial sites with potential for explosion or chemical spill  
• Rock cutting with rough face  
• Steep Embankment Slopes, steeper than 1:2 and ≥ 1m height |
| **Medium**     | • Steep Embankment Slopes, steeper than 1:2 and between ≥ 0.5m and < 1m height  
• 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 outside the Clear Zone  
• 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  
• Environmental Barriers |
| **Low**        | • Shallow Slopes, between 1:3 and 1:5 gradient and ≥ 6m in height  
• Embankment Slopes between 1:2 and 1:3 (inclusive) and between 0.5m and 2m 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 |
Appendix E:
prEN 1317 PART 7
The current Draft of prEN 1317 Part 7 is available for download from the ‘Downloads’ section of the TII Publications website [https://www.tiipublications.ie/downloads/](https://www.tiipublications.ie/downloads/).
Appendix F:
Containment Level Assessment Procedure
Containment Level Assessment Process

Step 1: Hazard Proximity Ranking

The Hazard Proximity Ranking is based on the percentage of Clear Zone that is available to an errant vehicle. It is calculated based on the ratio of the lateral distance from the edge of the nearest trafficked lane to the hazard versus the full Clear Zone width as detailed in DN-GEO-03036 for the design/operational speed of the section of road in question as appropriate.

The designer shall assign a Hazard Proximity Ranking based on the percentage of Clear Zone width available based on the following and record it in the Containment Assessment (Record) Sheet:

- High (H) – percentage of clear zone width available ≤ 30%;
- Low (L) – percentage of clear zone width available > 30%

Regardless of the above calculation, where a hazard is within 2m of the edge of the nearest trafficked carriageway, it shall be ranked as High (H).

For continuous hazards, or in a case of multiple isolated hazards in close proximity, the proximity of the hazard to the road edge is to be considered for the worst-case scenario and applied to the entire length of need of the VRS.

Step 2: Increased Risk Ranking

The Designer shall assess the Sinuosity Ranking of the section of road at the hazard location. The process for assessing this is described in detail within the Risk Assessment Procedure section of DN-REQ-03079. Sinuosity is divided into three sinuosity rankings as follows:

- High (H) - Sinuosity Index > 1.02;
- Medium (M) – 1.004 ≤ Sinuosity Index ≤ 1.02;
- Low (L) - Sinuosity Index < 1.004

The resulting Sinuosity Ranking combined with the Hazard Proximity Ranking shall be used to determine the Increased Risk Ranking using Table F.1.

<table>
<thead>
<tr>
<th>Hazard Proximity Ranking</th>
<th>Sinuosity Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>M</td>
</tr>
</tbody>
</table>

Notes:

a) Where hazard is located on the inside of a bend or straight, it shall be assigned a 'Low' Sinuosity Ranking.

b) Where a hazard is located on the outside of bend equal to or greater than 1000m radius, a 'Low' Sinuosity Risk Ranking shall be assigned.
Step 3: Result interpretation - Increased Risk Factor

For each hazard location, the Hazard Ranking shall be assessed against the Increased Risk Rating obtained in the previous step to determine if an Increased Risk Factor applies using Table F.2. The determination shall be made as follows:

1. If the Increased Risk Rating is High, then the hazard is considered to have an increased risk factor.
2. If the Increased Risk Rating is Medium and the Hazard Ranking as per Appendix D is either High or Very High, then the hazard is considered to have an increased risk factor.
3. If the Increased Risk is Low, the hazard is not considered to have an increased risk factor.

Table F.2. Increased Risk Factor – Yes or No

<table>
<thead>
<tr>
<th>Hazard Ranking (Appendix D)</th>
<th>Increased Risk Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
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<tr>
<td>Very High</td>
<td>Yes</td>
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<tr>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>Low</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Upon completion of the Containment Level Assessment Procedure, the designer shall record the results in the Containment Record Assessment sheet on the following page.
<table>
<thead>
<tr>
<th>Barrier Ref.</th>
<th>Design speed (km/h) *</th>
<th>AADT (HGV) *</th>
<th>Hazard description</th>
<th>Hazard Risk Ranking *</th>
<th>Lateral distance to hazard from edge of trafficked lane (m)</th>
<th>Required Clear Zone (m) **</th>
<th>Clear zone requirement satisfied up to (%)</th>
<th>Hazard Proximity Ranking *</th>
<th>Straight / Curved *</th>
<th>Inside or Outside of bend *</th>
<th>Curve radius (m)</th>
<th>Sinuosity Index (SI) ***</th>
<th>Sinuosity Ranking *</th>
<th>Proposed Containment Level</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

* Denotes key steps/parameters in the containment level design process that may influence the final Increased Risk Factor.

** Required Clear Zone as per DN-GEO-03036.

*** As described in the Risk Assessment Procedure section of DN-REQ-03079.
Appendix G:
Containment Level Assessment Procedure - Worked Example
Worked Example of Containment Level Assessment Procedure

The following provides a worked example of the application of the Containment Level Assessment Procedure described in this Standard. It is intended as a guide to support the Designer in following the requirements described heretofore.

The hazard in question is a directional informational sign with tubular Steel Posts > 89mm diameter and 3.2mm thick, located on the outside of a 720m radius bend and provided as part of an Offline / Green Field Project. The arrangement is as per Figure G.1 below. As per Table 3.6 the minimum containment level to protect individual hazards such as sign posts within the verge is N2. To assess if the minimum N2 requirement is appropriate at this location, the Designer shall complete the containment level assessment procedure as described in the Steps below.

Step 1 - Hazard Ranking identification

Consulting Appendix D - the Hazard Ranking for a sign with tubular Steel Posts > 89mm diameter and 3.2mm thick is High.

Step 2 - Governing Speed (Design speed or operational speed, as applicable)

As this is an offline / green field scheme, the governing speed to be used for this assessment is the design speed which in this instance is 100km/h.

Step 3 - Increased Risk Factor determination

In order to assess if there is an increased risk factor, the following must be considered:
• Hazard proximity ranking (distance to hazard and clear zone availability); and
• Risk Ranking (sinuosity ranking and hazard proximity ranking).

Hazard proximity ranking

The appropriate clear zone as described in DN-GEO-03036 is 10.4m for a 720m horizontal centreline radius curve and a design speed of 100 km/h, as replicated in Figure G.2. This value is denoted A in Figure G.3

<table>
<thead>
<tr>
<th>Horizontal radius (m)</th>
<th>Design Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Inside of bend or Straight</td>
<td>2.2</td>
</tr>
<tr>
<td>Outside of bend = 1,000m</td>
<td>2.2</td>
</tr>
<tr>
<td>Outside of bend = 900m</td>
<td>2.4</td>
</tr>
<tr>
<td>Outside of bend = 800m</td>
<td>2.6</td>
</tr>
<tr>
<td>Outside of bend = 700m</td>
<td>2.6</td>
</tr>
<tr>
<td>Outside of bend = 600m</td>
<td>2.5</td>
</tr>
<tr>
<td>Outside of bend = 500m</td>
<td>2.6</td>
</tr>
<tr>
<td>Outside of bend = 400m</td>
<td>2.8</td>
</tr>
<tr>
<td>Outside of bend = 300m</td>
<td>2.9</td>
</tr>
<tr>
<td>Outside of bend = 200m</td>
<td>3.4</td>
</tr>
<tr>
<td>Outside of bend = 100m</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Figure G.2 – Clear zone determination example

There are two additional dimensions, B and C in Figure G.3, which need to be considered.
Where

\[ A = \text{Clear zone width} \]
\[ B = \text{Lateral distance to hazard (from the edge of the trafficked lane to the face of the hazard)} \]
\[ C = \text{Hardstrip width (or Hardshoulder width, as applicable)} \]

**Figure G.3 – Clear zone and hazard arrangement example Illustration**

Assuming that the hazard is 2.4m set back from the edge of carriageway pavement and there is a 0.5m hardstrip, the percentage of clear zone available is calculated as follows:

\[
\frac{B}{A} \times 100 = \text{Percentage of proscribed clear zone free from hazard}
\]

\[
\frac{2.4 + 0.5}{10.4} = 28\%
\]

28% < 30% therefore, a High Hazard Proximity Ranking is assigned.

**Risk Ranking**

Following a sinuosity index calculation procedure performed as described in the Risk Assessment Procedure within DN-REQ-03079, a Low Sinuosity Ranking is applicable.

Combining the High Hazard Proximity Ranking with the Low Sinuosity Ranking the Increased Risk Ranking is calculated as Medium, see Figure G.4.
**Figure G.4 – Increased Risk Ranking determination example**

A *Medium* Increased Risk Ranking combined with a *High* hazard type ranking indicates there is an *Increased Risk Factor* to be applied as shown below in Figure G.5.

**Figure G.5 – Increased Risk Factor determination example**

**Step 4 - Assessment of HCV flow projection**

Consulting the TII Traffic Count data for the route in question, a HCV traffic figure of 1020 AADT applies to the location. Consulting Figure 3.4 Containment Level Assessment Procedure flow chart, the containment level should be increased from the minimum N2 containment in Table 3.6 to L1 containment based upon the site specific risk analysis undertaken. The containment level determination process of this worked example is summarised in Figure G.6 and recorded in the Containment (Record) Assessment Sheet shown below.
Figure G.6 – Use of Containment Level Assessment Procedure Flowchart for Worked Example
# Worked Example of Containment (Record) Assessment Sheet

![Table with data](image)

**Figure G.7 – Containment (Record) Assessment Sheet for Worked Example**
Appendix H:
Parapet Local and Global Effects
– Load Designation
H1.1 General

Global Effects are defined as effects which relate to the response of the structure to the applied loads. Examples of relevant global effects are as follows:

- Load effects in structural elements due to the overall deformation of the structure. An example of elements of interest typically include (but are not limited to) deck cantilevers, longitudinal beams, piers, piled foundations, etc.
- Stability of the structure. Elements impacted by stability issues include (but are not limited to) the overall stability of the structure (sliding, overturning, bearing etc), bearing deformation, superstructure dislodgement, etc.

Local Effects are defined as effects which relate to the portion of the structure directly supporting the bridge parapet. Local effects are typically associated with parapet anchorages and the supporting deck structure to which they are attached.

H1.2 Loads for the Assessment of Global Effects

Loads to be applied as the Accidental Action when assessing Global Effects due to a vehicle collision load with the bridge parapet are summarised in Table H.1 below.

The loads applied directly to the parapet and the Simultaneous Vertical Axle Load are to be treated as a single load event and represent the Accidental Action, $A_d$, as defined in Table NA.11 of I.S. EN 1990.

These loads are to be applied in accordance with Table NA.11 of I.S. EN 1990.
Table H.1. Global Effect Assessment of Accidental Loads due to a Vehicle Collision with a Bridge Parapet

<table>
<thead>
<tr>
<th>Class</th>
<th>Transverse Force (kN)</th>
<th>Longitudinal Force (kN)</th>
<th>Vertical Force (kN)</th>
<th>Simultaneous Vertical Axle Load (kN)</th>
<th>Examples of Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>225</td>
<td>Normal Containment (N1 &amp; N2 Level) flexible e.g. metal post and rail parapets</td>
</tr>
<tr>
<td>B</td>
<td>200</td>
<td>-</td>
<td>-</td>
<td>225</td>
<td>Normal Containment (N1 &amp; N2 Level) rigid e.g. reinforced concrete parapets</td>
</tr>
<tr>
<td>C</td>
<td>400</td>
<td>100</td>
<td>175</td>
<td>225</td>
<td>Very High Containment (H4a &amp; H4b) flexible e.g. metal post and rail parapets</td>
</tr>
<tr>
<td>D</td>
<td>600</td>
<td>100</td>
<td>175</td>
<td>225</td>
<td>Very High Containment (H4a &amp; H4b) rigid e.g. reinforced concrete parapets</td>
</tr>
<tr>
<td>E</td>
<td>225</td>
<td>50</td>
<td>75</td>
<td>225</td>
<td>High Containment (H2) flexible e.g. metal post and rail parapets</td>
</tr>
<tr>
<td>F</td>
<td>375</td>
<td>50</td>
<td>75</td>
<td>225</td>
<td>High Containment (H2) rigid e.g. reinforced concrete parapets</td>
</tr>
</tbody>
</table>

(a) the collision load shall be applied 100mm below the top of the selected vehicle restraint system or at a height of 1.25m above the level of the adjacent carriageway/raised verge whichever is the lower over a length of 3m.

(b) the direction of application is to be the most onerous for the loadcase considered.

(c) Accompanying Variable Actions shall be applied in accordance with NA 2.31 of the National Annex to I.S. EN 1991-2
Figure H.1  Plan – Accidental Actions due to Global Effects

Figure H.2  Elevation – Accidental Actions due to Global Effects

Figure H.3  Elevation – Variation where Safety Barrier is in front of Parapet
H1.3  Loads for the Assessment of Local Effects

When assessing Local Effects, both the barrier itself and the supporting structural element are considered below.

For clarity, bridge parapets are divided between those of Metal Construction and those of Concrete Construction.

H1.3.1  Metal Parapets

Metal parapets, which are typically designed by the supplier, are designed to provide a certified level of containment as defined in I.S. EN 1317-2.

The support posts, which form part of the metal parapet system, are to be supplier designed to provide the certified level of containment.

The section directly beneath the anchorages should have a minimum capacity of 1.25 times the lesser of the characteristic capacity of the anchorage or the parapet post.

Any reinforcement required to resist the forces should be adequately anchored into the next element in the structural system (bridge deck or parapet support slab foundation) beyond the post anchorages.

Structural elements beyond the connection i.e. the bridge deck or parapet support slab foundations should be designed to resist the greater of either the effects of the global loads described previously in this document or 1.25 times the lesser of the characteristic capacity of the anchorage or the parapet post.

Engineering judgement must be used to ensure that the correct hierarchy of failure is maintained along the load path of the collision forces through the structure.

Figure H.4  Metal Parapet on Bridge
H1.3.2 Concrete Parapets

It is common practice in Ireland for concrete bridge parapets to be designed as bespoke barriers. Table H.2 below defines loads to be used for the design of bespoke concrete parapets of in-situ or precast construction.

The concrete section directly beneath the parapet section should have a minimum capacity of 1.25 times the characteristic capacity of parapet section itself.

Any reinforcement required to resist the forces in the point above should be adequately anchored into the next element in the structural system (bridge deck or parapet support slab foundation) beyond the bottom of the parapet;

Concrete sections beyond this point i.e. the bridge deck or parapet support slab foundations should be designed to resist the greater or either the effects of the global loads described previously in this document or 1.25 times the characteristic capacity of parapet section itself;

Engineering judgement must be used to ensure that the correct hierarchy of failure is maintained along the load path of the collision forces.

The information presented above is illustrated in Figures H.6 and H.7.
Table H.2. Loads for Assessing the Local Effects of Bespoke Concrete Parapets

<table>
<thead>
<tr>
<th>Examples of Applications</th>
<th>Panel Normal Bending&lt;sup&gt;(a)&lt;/sup&gt;</th>
<th>Panel Nominal Shear&lt;sup&gt;(b)&lt;/sup&gt; (kN)</th>
<th>Panel Joint Nominal Shear Transfer&lt;sup&gt;(c)&lt;/sup&gt; (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal containment (N1 &amp; N2 level) without shear transfer between panels&lt;sup&gt;(d)&lt;/sup&gt;</td>
<td>105 kN over 1m of panel</td>
<td>225</td>
<td>0</td>
</tr>
<tr>
<td>High containment (H2) with shear transfer between panels</td>
<td>(145 + 20L) kN/panel</td>
<td>225</td>
<td>65</td>
</tr>
<tr>
<td>High containment without shear transfer between panels</td>
<td>(155 + 20L) kN/panel</td>
<td>225</td>
<td>0</td>
</tr>
<tr>
<td>Very high containment (H4a &amp; H4b) with shear transfer between panels&lt;sup&gt;(e)&lt;/sup&gt;</td>
<td>(190 + 40L) kN/panel</td>
<td>225</td>
<td>110</td>
</tr>
<tr>
<td>Very high containment (H4a &amp; H4b) without shear transfer between panels</td>
<td>(220 + 40L) kN/panel</td>
<td>225</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>(a)</sup> the bending moment to be resisted is produced by applying transversely a horizontal, continuous, uniformly distributed nominal load at a level 100mm below the top of the selected vehicle restraint system or 1.25m above the level of the adjacent carriageway/raised verge whichever is the lower.

<sup>(b)</sup> the nominal shear force to be resisted by any transverse section of a panel.

<sup>(c)</sup> minimum ultimate transverse shear resistance to be provided within the top 1.2m of the panel wall.

<sup>(d)</sup> shear transfer provision between panels of normal containment parapets is not recommended because of the problem of joint formation in the thinner sections.

<sup>(e)</sup> all end panels shall be designed as standalone units without any load shedding due to shear transfer arrangements.
Figure H.6  Concrete Parapet on Bridge

Figure H.7  Concrete Parapet on Parapet Support Structure