Design Manual for Roads and Bridges

Highway Structures & Bridges
Inspection & Assessment

CS 461
Assessment and upgrading of in-service parapets

(formerly BA 37/92, IAN 97/07)

Version 0.1.0

Summary
This document provides requirements and advice for the assessment and upgrading of existing vehicle parapets on highway structures. It gives advice on the assessment of parapet and safety barrier supporting members on bridges and retaining walls. The document also sets out the requirements for the management of substandard parapets including parapet connections and transitions.

National Variation
This document has associated National Application Annexes providing alternative or supplementary content to that given in the core document, which is relevant to specific Overseeing Organisations. National Application Annexes are adjoined at the end of this document.

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Latest release notes

Document code	Version number	Date of publication of relevant change	Changes made to	Type of change
CS 461	0.**1**.0	January 2023	Core document	Incremental change to requirements

Version 0.1.0: Jan. 2023] Clarification of scope. Introduction of area-wide prioritisation tool. Alignment of risk outcomes. Alert on possibly defective rails. Various editorial and compliance corrections throughout. ALARP assessment advice added. Change of brand.

Previous versions

Document code	Version number	Date of publication of relevant change	Changes made to	Type of change
CS 461	0	March 2020		

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Foreword

Publishing information

This document is published by National Highways.

This document supersedes BA 37/92 and IAN 97/07 which are withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

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Introduction

Background

This document provides requirements and advice for the assessment and upgrading of existing vehicle parapets on highway structures. It gives advice on the assessment of parapet and safety barrier supporting members on bridges and retaining walls. This document also sets out the Overseeing Organisation's requirements for the management of substandard parapets including parapet connections and transitions. This document supersedes IAN 97/07, which has been withdrawn.

There are a variety of parapet types providing vehicular containment on the existing stock of structures on the road network. Highways Agency (now National Highways) produced and used a number of guidance documents to ensure consistency in the approach to the assessment and upgrading of existing parapets. These guidance documents also used incursion risk ranking and priority ranking tools to support investment and other asset management decisions.

Interim Advice Note 72/06 (IAN 72/06), "Interim Advice on the Upgrading of Existing Parapets", improved previous assessment and upgrading guidance by providing advice in the following areas:

1) the use of DfT and TRL incursion risk ranking tools (TAL 6/03 [Ref 5.I], Managing incursion [Ref 4.I]) to provide criteria for identifying sites requiring upgrading with very-high containment (H4a) road restraint systems; and,
2) amendments to BA 37/92, "Priority Ranking of Existing Parapets", to be consistent with the IRRRS, Interim Requirements for Road Restraint Systems (superseded by CD 377 [Ref 14.N]), and the incursion risk ranking tools (TAL 6/03 [Ref 5.I], Managing incursion [Ref 4.I]), to enable a consistent risk assessment approach.

IAN 72/06 was then superseded by Interim Advice Note 97/07 (IAN 97/07) "Assessment and Upgrading of Existing Vehicle Parapets"

IAN 97/07 revised the previous advice to be consistent with the risk-theory based approach of CD 377 [Ref 14.N], whilst enabling significant cost and programme related benefits, and reduced congestion.

IAN 97/07 also provided additional expanded advice, which enabled realistic risk levels to be ascertained together with associated upgrading advice through:

1) adopting a consistent risk-based approach;
2) using incursion and ALARP-based risk ranking tools; and,
3) applying the CD 377 [Ref 14.N] Road Restraint Risk Assessment Process RRRAP User Guide [Ref 5.N].

The introduction of IAN 97/07 resulted in the gradual deterioration of in-service parapets where, due to funding constraints, parapet works have been deferred, leading to a reduction in parapet containment resistance on the road network.

This document updates the philosophy of IAN 97 as part of the DMRB review but also introduces improvements to the standard that will assist in the assessment, management, and upgrading of parapets across the network.

This document also introduces tools to enable an area-wide parapet prioritisation and replacement programme which is:

1) regularly updated to assist both short and long-term planning; and,
2) aligned with the Overseeing Organisation's investment strategy.

The incursion and ALARP risk ranking tools have been modified to improve:

1) the identification of parapets with substandard containment; and,
2) the prioritisation and programming of parapet upgrading.

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This document clarifies the requirement for the need to replace substandard parapets when opportunity arises, as part of maintenance works to obtain whole-life cost efficiencies, reduce network disruption, and improve safety on the road network.

The aim is to better understand the asset both in the short and long term and enable effective asset management decisions reversing the decline in parapet containment capacity and reach a steady state of asset management renewal.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 8.N] apply to this document.

Mutual Recognition

Where there is a requirement in this document for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with the Mutual Recognition clause in GG 101 [Ref 8.N].

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Abbreviations and symbols

Abbreviations

Abbreviation	Definition
AADT	Annual average daily traffic
ALARP	As low as reasonably practicable
CDM	Construction, design and management (regulations)
D&B	Design and build
DBFO	Design, build, finance and operate
DfT	Department for Transport
ECI	Early contractor involvement
EMU	Electric multiple unit
HCD	Highway construction details
HGVs	Heavy goods vehicles
IAN	Interim Advice Note
IRRRS	Interim requirements for road restraint systems
NPSBS	Non-proprietary safety barrier systems
RRRAP	Road Restraint Risk Assessment Process
RTA	Road traffic accident
SPADS	Signals passed at danger
SRVAs	Sleep-related vehicle accidents
SSD	Sight stopping distance
TAA	Technical Approval Authority
TPI	Targeted programme of improvement
TRL	Transport Research Laboratory (now TRL Ltd.)
vpd	Vehicles per day
WCH	Walking, cycling and horse-riding

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Symbols

Symbol	Definition
γ_{fl}	partial factor for loads
γ_{f3}	partial factor for load effects
C_{ALL}	allowable resistance
C_{MIN}	minimum resistance
C_{REQ}	required resistance
N1, N2	normal containment level
R_{ALARP}	ALARP-based risk-ranking score
R_{CONT}	remnant resistance
R_{INC}	incursion risk ranking score
W	working width

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Terms and definitions

Term	Definition
BACO	trade name of a type of aluminium bridge parapet system.
Hazard	a hazard is a feature (e.g. embankment) or object (e.g. lighting column) that can cause harm or loss. Harm or loss can be physical, financial or economic, strategic, or be time-based, or any combination of these, see CD 377 [Ref 14.N].
N1, N2	parapet type with normal containment level.
H1, H2	parapet type with higher containment level.
H4a	parapet type very high containment level.
NETRAFF	a Network Rail System Interface - Network Planned Traffic Data by ELR.
Risk	a risk is the chance, high or low, that somebody or something will be harmed by the hazard; see CD 377 [Ref 14.N].

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1. Scope

Aspects covered

1.1 This document shall be used for all proposals to assess or upgrade existing parapets or parapet connections on highway structures on the motorway and all-purpose trunk road network.

1.2 The document shall be applicable for all maintenance works (excluding routine maintenance) and improvement works on the motorway and all-purpose trunk road network.

1.3 This document shall be applicable where there are proposals for carriageway widening or realignment of highways on the motorway and all-purpose trunk road network.

1.4 This document shall be used in conjunction with CD 377 [Ref 14.N].

NOTE The terminology, definitions and abbreviations in CD 377 [Ref 14.N] are relevant to this document.

1.5 This document shall not be used for the assessment of risks associated with:

1) bridges/structures over or adjacent to high-risk facilities (such as schools and chemical plants); nor,
2) on-deck vehicle collision with main structural members of bridges (e.g half-through girders).

1.5.1 The Technical Approval Authority (TAA) should be consulted for advice on assessing the risks associated with:

1) bridges/structures over or adjacent to high-risk facilities; or,
2) on-deck vehicle collision with main structural members of bridges.

Implementation

1.6 This document shall be implemented forthwith on all schemes involving the assessment and upgrading of existing vehicle containment parapets on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 8.N].

Use of GG 101

1.7 The requirements contained in GG 101 [Ref 8.N] shall be followed in respect of activities covered by this document.

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2. ALARP-based risk assessment framework

2.1 The assessment and upgrading of existing parapets shall be in accordance with the 'as low as reasonably practicable' (ALARP) principle of assessing the tolerability of risk levels that is consistent with the risk-theory based approach adopted in CD 377 [Ref 14.N].

NOTE 1 The ALARP principle in addressing risk originated in the nuclear industry as a method for ranking and prioritising responses to risks.

NOTE 2 The Health and Safety at Work etc Act 1974, UKPGA 1974/37 (HASAWA) [Ref 2.I], recognises the ALARP principle in addressing risk. There is a level of risk considered "intolerable" to individuals and society, and similarly a level of risk considered "broadly acceptable". If the risk falls in the "tolerable region" between these two levels, then the Act requires that the risk be reduced to a level which is "as low as reasonably practicable" provided that the cost or effort required to reduce the risk is not grossly disproportionate to the benefits (the ALARP principle).

2.2 Where existing parapets are risk-assessed to be within the "broadly-acceptable region", or those which satisfy the ALARP principle, they shall be deemed acceptable and do not require upgrading.

2.3 Where parapets are upgraded, the risk shall either be:

1) reduced to "broadly acceptable"; or,
2) satisfy the ALARP principle.

NOTE Upgraded parapets where the risks are reduced to "broadly acceptable"; or satisfy the ALARP principle do not need departures from standards.

2.4 The risks associated with existing parapet sites shall be managed in accordance with the ALARP principle by use of the:

1) ALARP-based risk ranking tools given in Appendix A; and,
2) incursion risk ranking tools given in Appendix B.

2.4.1 The road restraint risk assessment process (RRRAP) should be utilised only where the risks associated with existing parapets cannot be demonstrated to be "as low as reasonably practicable".

2.5 The relative risk levels shall be established, together with mitigation measures in accordance with Table 2.5.

Table 2.5 Risk level, ALARP and risk mitigation

Risk level	Relative risk (ALARP)	Risk mitigation[4]
High	ALARP requires H4a or N1/N2[2] upgrade	Upgrade to H4a or N1/N2[2]
Medium[1]	ALARP requires H1/H2 or N1/N2[2] upgrade	Upgrade to H1/H2 or N1/N2[2]
Low[1]	ALARP requires N1/N2[2] upgrade	Upgrade to N1/N2[2]
Very low	Existing parapet is ALARP	Monitor risk[3]
Negligible	Existing risk is "broadly acceptable"	Do nothing

Notes:

1) Existing parapets with remnant resistance less than the required level of minimum containment are ranked as high risk, requiring upgrading to appropriate containment levels determined by ALARP (refer to clause 3.4).
2) N1 or N2 dependent on CD 377 [Ref 14.N] minimum design containment requirements.
3) No mitigation is required but monitor the risk against ALARP (see clause 2.6).
4) As determined by the ALARP-based risk assessment process in Section 3.

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2.6 Where the risk level is very low in accordance with Table 2.5, the risk monitoring programme shall be planned and recorded.

2.6.1 Planned monitoring may be undertaken concurrently with other inspections in accordance with CS 450 [Ref 7.N].

2.7 Where the RRRAP identifies the need for a higher level of containment than N2 on an existing structure, and the provision of the higher level of containment is cost prohibitive, the cost-related default values in the risk ranking tools shall be overwritten with the agreement of the TAA.

2.8 Where the RRRAP identifies the need for very high containment level (H4a) on an existing site, this shall only be provided after consultation with the responsible authorities and subject to prior approval of the TAA.

2.9 The results of ALARP-based risk assessments carried out in the development of parapet upgrading works shall be included in the works information in accordance with MCHW Series NG 0400 [Ref 11.N].

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3. Risk assessment of existing parapet sites and prioritisation of parapet upgrading

Risk assessment of existing parapet sites

3.1 The ALARP-based risk assessment shall be used for existing parapet sites with:

1) bridges over roads;
2) bridges over railways; and,
3) other sites given in this section.

3.2 The ALARP-based risk assessment process for bridges over roads and bridges over railways shall be carried out in accordance with the flowcharts illustrated in Figure 3.2a and Figure 3.2b respectively.

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Figure 3.2a Assessment flowchart - bridges over roads

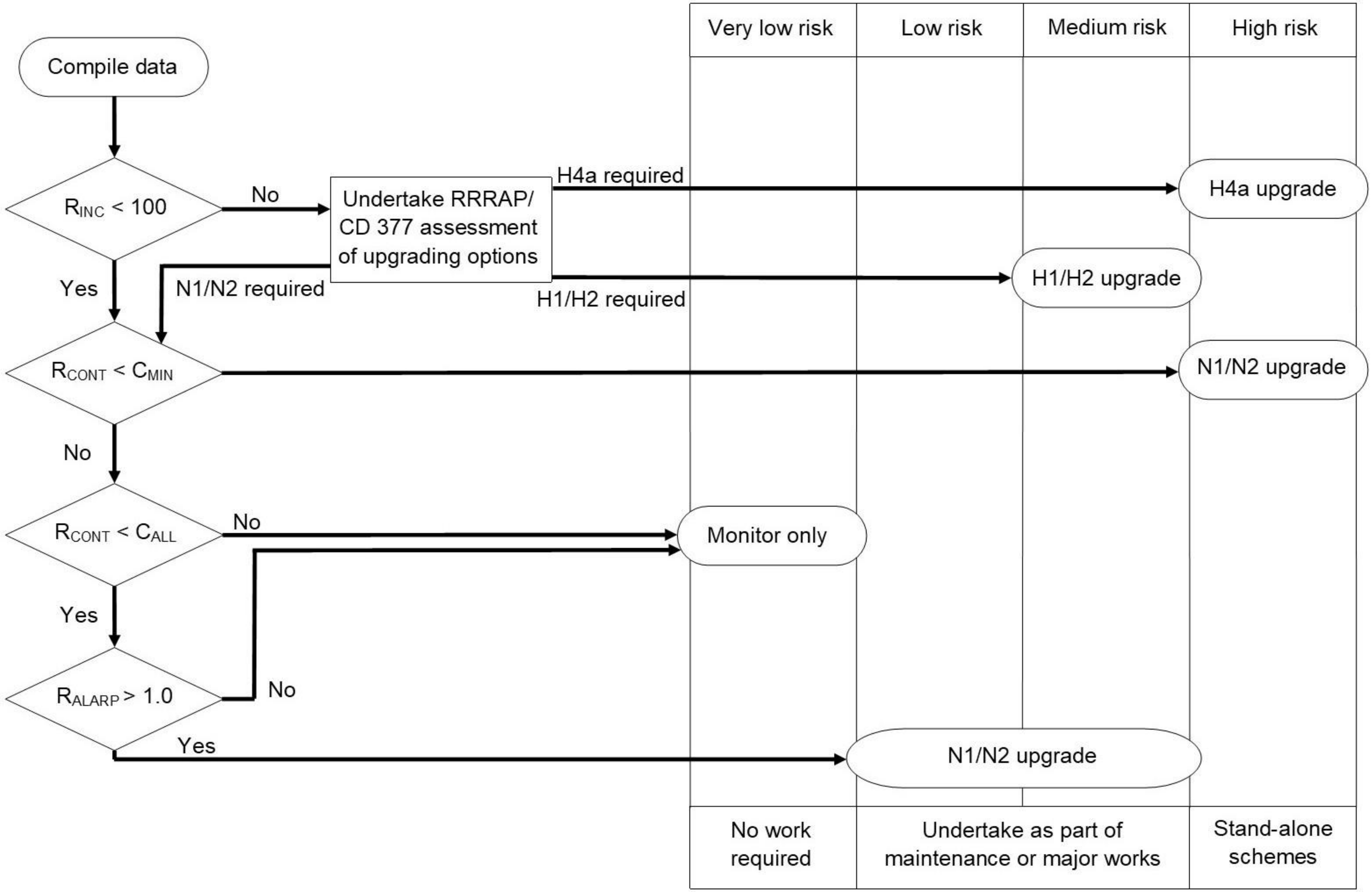

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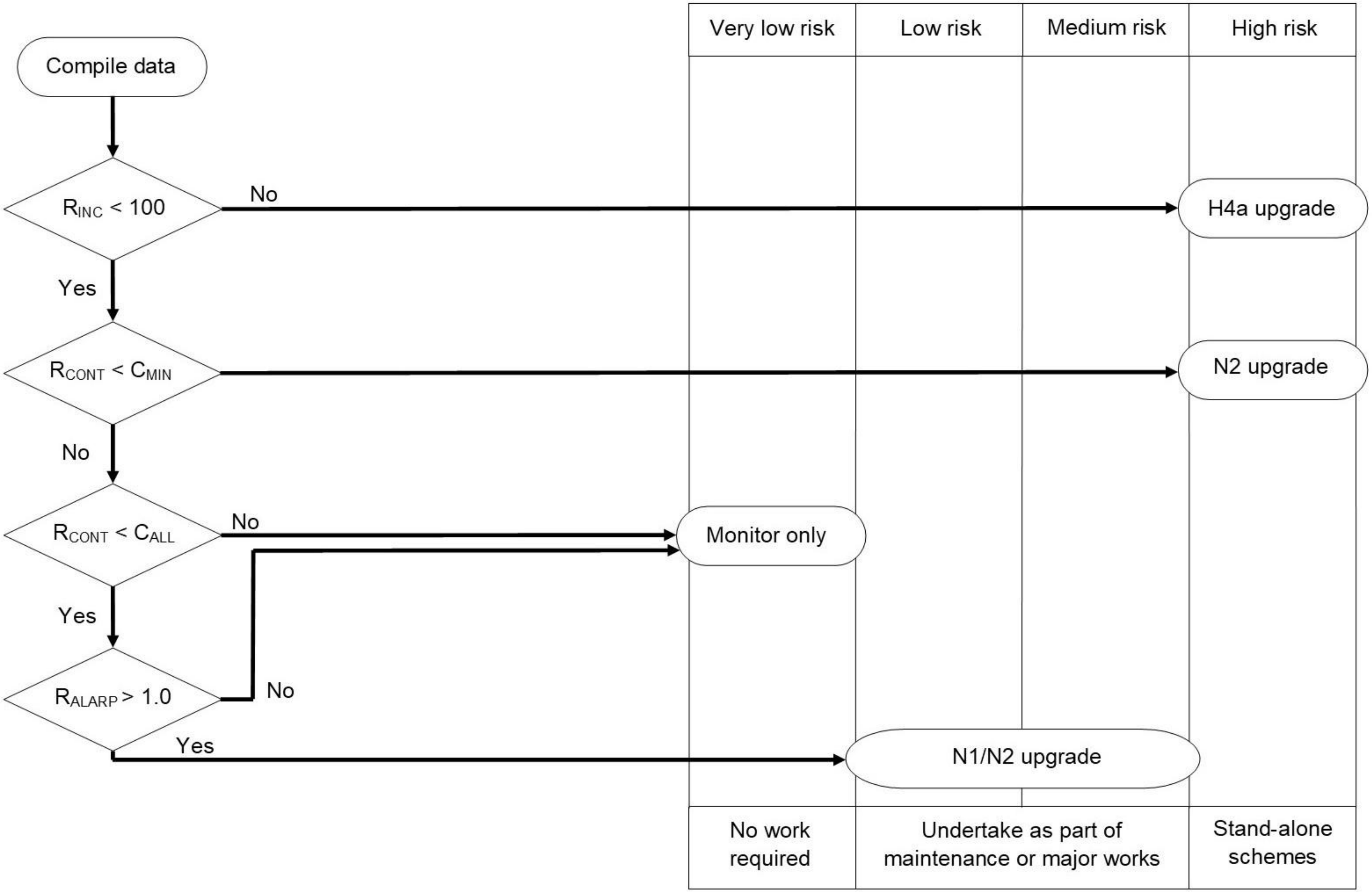
Figure 3.2b Assessment flowchart - bridges over railways



3.3 The ALARP-based risk assessment flowcharts illustrated in Figure 3.2a and Figure 3.2b shall also be used for the following conditions/sites:

1) retaining walls supporting roads over railways or roads;
2) retaining walls adjacent to rivers, canals and walking, cycling and horse-riding (WCH)/agricultural access routes; and,
3) bridges over rivers, canals and WCH/agricultural access routes.

NOTE The flowcharts in Figures 3.2a and 3.2b can be applied to bridges over rivers, canals and WCH/agricultural access routes without the incursion risk ranking tools.

3.3.1 The incursion risk ranking tools for bridges given in Appendix B should be used for retaining walls supporting roads where it is possible for a parapet penetrating vehicle (or associated debris) to affect the lower route (railway or road).

3.4 Where highway users other than motorists are at risk, any substandard parapet site shall be:

1) assessed as high risk; and,
2) upgraded to the required containment resistance.

NOTE Other highway users can include pedestrians, walkers, cyclists, and equestrians.

3.5 The parameters to be used for risk process flowcharts illustrated in Figure 3.2a and Figure 3.2b shall be determined in accordance with Table 3.5.

Table 3.5 Definition for parameters used in risk process flowcharts

Parameter	Definition	Notes
R_{ALARP}	ALARP-based risk ranking score	Refer to A2 and A4 of Appendix A.
R_{INC}	incursion risk ranking score for the highest scoring corner	Refer to Appendix B (also see sub-clauses 3.5.1 and 3.5.2).
R_{CONT}	remnant resistance of the parapet	expressed as a proportion of the required containment resistance C_{REQ} . Refer to Section 4 for guidance.
C_{ALL}	allowable resistance of the parapet	Refer to Equation 3.6.
C_{MIN}	minimum resistance of the parapet	Refer to Equation 3.7 and Table 3.8.
C_{REQ}	required containment resistance of the parapet	Refer to Equation 3.6 and Table 3.6.

3.5.1 For bridges over roads, when using Figure 3.2a, the incursion risk ranking score for the highest scoring corner, R_{INC} should be taken as $R_{INC} < 100$ where the two-way AADT on either the upper or lower road is less than 25000.

3.5.2 For bridges over railway, assessors should also consult the guidance included within the DfT report, "Managing the accidental obstruction of the railway by road vehicles" TAL 6/03 [Ref 5.I].

3.6 The allowable resistance of the parapet, C_{ALL} shall be determined in accordance with Equation 3.6.

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Equation 3.6 Allowable resistance of the parapet

$$C_{ALL} = 0.67 C_{REQ}$$

where:

C_{ALL} is the allowable resistance of the parapet; and,

C_{REQ} is the required containment resistance of the parapet determined in accordance with Table 3.6 and expressed as a proportion of N2 .

Table 3.6 Required containment resistance

Bridge/structure over or adjacent to:	Speed limit (mph)				
	70	60	50	40	30[2]
Railway	1.00N2 at all speed limits				
Road or Other[1]	1.00N2	0.73N2	0.50N2	0.33N2	0.20N2

Notes:

1) Other refers to river, canal, WCH/agricultural access routes, open land, etc.
2) Speed limit restrictions apply for accommodation bridges and roundabouts in accordance with clauses 3.6.1 and 3.6.2.

3.6.1 For accommodation bridges a speed limit of 30 mph should be assumed.

3.6.2 On roundabouts the speed limit of the road should apply unless the geometry of the roundabout or other restrictions indicate that a lesser speed can be used.

3.7 For railway bridges/structures, the minimum resistance of the parapet, C_{MIN} shall be determined in accordance with Equation 3.7.

Equation 3.7 Minimum parapet resistance for railway bridges/structures

$$C_{MIN} = 0.5\text{N2}$$

where:

C_{MIN} is the minimum resistance of the parapet; and,

N2 is normal containment level.

3.8 For non-railway bridges/structures, the minimum resistance of the parapet, C_{MIN} shall be determined in accordance with Table 3.8.

Table 3.8 Minimum resistance of parapet for non-railway bridges/structures

Non-railway bridges/structure	C_{MIN}
On roads with speed limit 70 mph	0.33N2
All other bridges/structure	0.15N2 or 0.30N1

Prioritisation of parapet upgrading

3.9 A prioritised list of all existing parapets identified as requiring upgrading/replacement shall be developed and updated regularly.

3.10 Existing parapets which are ALARP risk assessed for upgrading in accordance with this Section as high risk, medium risk or low risk shall be included in a prioritised forward works programme either:

1) as standalone schemes; or,

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2) as part of maintenance or major works.

3.11 Existing parapets with remnant resistance, R_{CONT}, less than the minimum resistance, C_{MIN}, shall be:

1) assessed as high risk; and,
2) prioritised and planned for upgrading as standalone schemes.

3.11.1 Where parapets are assessed as high risk and planned for upgrading as standalone schemes, their upgrading should be undertaken as part of maintenance or major works where these provide the earliest reasonable opportunity.

3.12 For the purposes of works prioritisation and planning, existing parapets which are ALARP risk assessed in accordance with this Section shall be taken as medium risk:

1) where the remnant resistance, R_{CONT} is within the limits given in Table 3.12 for the structures listed;
2) for sites with a poor accident record;
3) for sites with a record of near misses;
4) for bridges or viaducts with spans exceeding 100 m; or,
5) based on engineering judgement.

Table 3.12 Remnant containment limits for medium risk parapets

Bridge/structure	Remnant containment limits for assessment as medium risk
Bridges over railways	$0.50\text{N2} < R_{CONT} \leq 0.67\text{N2}$
Bridges on 70mph roads	$0.33\text{N2} < R_{CONT} \leq 0.5\text{N2}$

3.12.1 Planned low-risk or medium-risk parapet upgrading may be undertaken as a standalone scheme rather than as part of maintenance or major works subject to influencing factors such as opportunity, local knowledge, priorities, funding and engineering judgement.

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4. Assessment of parapet remnant containment resistance

General

4.1 Existing parapets shall be assessed to determine their remnant containment resistance to applied impact vehicular loading.

4.1.1 The method of assessment to determine the remnant containment resistance may be influenced by factors such as age, material type, construction form, interaction/connection with superstructure, existing parapet condition, deterioration profile and engineering judgement.

NOTE A historical background on the containment characteristics of existing parapets is given in Appendix E.

Evaluation of remnant containment resistance

Masonry parapets

4.2 The remnant containment resistance of existing masonry parapets shall be assessed in accordance with the Department for Transport's guidance on the design, assessment and strengthening of masonry parapets on highway structures in Masonry Parapets Guidance [Ref 4.N].

Concrete and combined concrete/metal parapets

4.3 The resistance of existing concrete and combined metal/concrete parapets shall be verified in accordance with the requirements in this Section, CS 454 [Ref 1.N] and all other DMRB standards relevant for the materials being assessed including CS 455 [Ref 18.N], CS 456 [Ref 19.N] and CS 457 [Ref 17.N].

4.3.1 Remnant resistance may be verified by calculations using condition data, record information and testing.

4.4 Spalling resulting from vehicle impact to concrete and combined metal/concrete parapets shall be taken as representing a negligible safety risk, as both the probability of occurrence and the additional consequences are generally low.

4.4.1 The risk of a secondary accident occurring below the structure following impact should not increase since secondary spalling related to stringcourse damage occurs concurrently with possible incursion/debris from vehicle and parapet component.

NOTE The risk of secondary accident below a damaged structure can be ignored when assessing existing parapet sites for potential upgrading.

Parapet supporting members

4.5 The resistance of parapet supporting members shall be verified.

4.5.1 Parapet supporting members built since 1967 should generally be deemed as acceptable for assessment purposes, providing CS 450 [Ref 7.N] inspections and review of as-built records cannot attribute any defects observed to apparent errors in reinforcement detailing.

4.5.2 Supporting members for parapets installed before 1967 and any supporting members with apparent reinforcement detailing errors should be assessed to determine their resistance on the basis of engineering judgement.

4.5.3 Tests may be carried out occasionally and used to verify the resistance of parapet supporting members.

4.5.4 For metal parapets, assessment should be based on the absolute minimum resistance assessment criteria given in Appendix D.

4.5.5 For other types of parapets excluding metal parapets, parapet supporting members should be assessed in accordance with CS 454 [Ref 1.N] but assuming $\gamma_{fl} = 1.0$ and $\gamma_{f3} = 1.0$.

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Attachment and anchorage systems

4.6 The remnant resistance of attachment and anchorage systems shall be verified in accordance with any of the following:

1) the requirements in this section;
2) inspections in accordance with CS 450 [Ref 7.N];
3) testing in accordance with CS 463 [Ref 9.N] and MCHW Series 0400 [Ref 10.N]; or,
4) engineering judgement.

NOTE Cast-in cradles and drilled-in resin bonded anchors for parapets built since 1967 are generally reliable, whereas drilled-in expanding anchors are less likely to be reliable.

4.6.1 Socketed posts of parapets built since 1967 may be assessed to be reliable providing:

1) that embedment lengths are such that the impact loading can be resisted; and,
2) there are no signs of significant deterioration to the posts, sockets, or supporting members.

4.6.2 Attachment and anchorage systems to pre-1967 metal parapets should be assessed against the absolute minimum resistance assessment criteria given in Appendix D, assuming $\gamma_{\text{fl}} = 1.0$ and $\gamma_{\text{f3}} = 1.0$.

4.6.3 Other pre-1967 parapet types, should be assessed in accordance with the verification methods for the parapet construction materials, but assuming $\gamma_{\text{fl}} = 1.0$ and $\gamma_{\text{f3}} = 1.0$.

4.7 Where parapets with drilled-in expanded anchors are being assessed the maximum remnant containment levels shall be taken as follows:

1) $0.50\text{N}2$ for N2 parapets; and,
2) $0.25\text{N}2$ for N1 parapets.

4.8 Where the attachment and anchorage systems do not have the remnant resistance required for the assessed parapet containment level they shall be replaced, or the parapet system treated as substandard.

Protective safety barriers

4.9 Safety barriers providing protection to existing parapets shall be in accordance with either CD 377 [Ref 14.N] or NPSBS REV 1 [Ref 12.N].

4.9.1 Where parapets are protected by safety barriers which comply with either CD 377 [Ref 14.N] or NPSBS REV 1 [Ref 12.N], they should be deemed as acceptable for assessment purposes unless the parapet is not capable of providing pedestrian containment.

4.10 Parapet systems not capable of providing pedestrian resistance although protected by complying safety barriers shall be assessed as high risk, requiring upgrading to appropriate containment levels determined by ALARP.

4.11 Parapet protective safety barriers shall be classed as substandard where they are provided with working widths less than required by CD 377 [Ref 14.N] or the NPSBS REV 1 [Ref 12.N].

4.12 Substandard protective safety barriers shall be assessed using the ALARP-based risk assessment tool for substandard protective parapets included in Appendix A where:

1) the speed limit is $\geq$ 50 mph; or,
2) the two-way traffic flow is $\geq$ 7000.

4.12.1 Where the speed limit is, < 50 mph, or the two-way traffic flow is < 7000, the risk should generally be taken to be negligible.

4.13 Any upgrading work identified on the protective safety barriers shall be carried out as part of maintenance works or carriageway widening/realignment improvement scheme.

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Parapet connections and transitions

4.14 The assessment and upgrading of obsolete/substandard parapet connections and transitions shall be in accordance with Section 6.

Assessment remnant resistance of metal parapets

General

4.15 The remnant containment resistance of metal parapets shall be as given in this section verified by any of the following:

1) inspection in accordance with CS 450 [Ref 7.N];
2) testing in accordance with CS 463 [Ref 9.N] and MCHW Series 0400 [Ref 10.N]; or,
3) engineering judgement.

4.16 For as-built post-1967 parapets, the assessment remnant resistance shall be taken as given in this section, unless there are known faults, as listed below:

1) parapets demonstrated to be incorrectly designed or constructed; (Some early parapets were detailed without proper continuity in the longitudinal members.);
2) parapets designed to lower containment criteria than would be required by current standards;
3) parapets which have exhibited significant deterioration; This includes steel members which have corroded and parapet fixings, to the extent that there has been a significant loss of design resistance.);
4) parapets with other known material problems, including embrittlement in certain earlier aluminium parapet types; and,
5) parapets which have been damaged and have not been satisfactorily repaired, where there would be significant loss of design resistance.

4.16.1 For parapet systems with known faults built since 1967, the loss of as-built resistance caused by known faults and defects should be assessed by engineering judgement or testing.

4.17 Where the metal parapets show deterioration or defects which can affect performance under vehicle impact loads, the assessed effective remnant containment resistance shall be determined using reduced as-built containment resistance values.

Steel parapets

4.18 As-built post 1967 steel parapets shall be assumed to have effective remnant containment resistance of:

1) 0.75N2 for type N1 (except N1 vertical rod infill parapets); and,
2) 1.50N2 for type N2.

4.19 As-built post-1967 type N1 vertical rod infill parapets shall be assumed to have effective remnant containment resistance of 0.33N2 .

4.20 As-built steel normal containment parapets shall be assessed to have remnant resistance equivalent to H1/H2 containment, with regard to the potential to prevent incursion.

4.20.1 Where the loss of condition of normal containment parapets does not reduce the containment resistance by more than 20% from the as-built value, H1/H2 containment may be assumed where a RRRAP risk assessment is undertaken.

4.21 For pre-1967 steel parapets the remnant containment resistance shall be determined by engineering judgement and testing.

NOTE *Most pre-1967 metal parapets have either been replaced or protected.*

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Aluminium parapets

4.22 As-built post-1967 aluminium parapets shall be assumed to have effective remnant containment resistance of:

1) $0.50\mathrm{N2}$ for type N1; and,
2) 1.00N2 for type N2 except for HDA (102 and 208)

4.23 As built post-1967 type HDA (102 and 208) aluminium parapets shall be assumed to have an effective containment resistance of 0.85N2 for type N2.

4.24 As-built substandard BACO parapets shall be assumed to have effective containment resistance of:

1) 0.25N2 for type N1; and,
2) 0.50N2 for type N2 except for modified BACO 300 parapets.

4.25 As built and modified substandard BACO 300 parapets shall be assumed to have effective remnant resistance of 0.85N2 for type N2.

NOTE Appendix C provides guidance on the identification of substandard BACO parapets.

4.26 The Overseeing Organisation shall be notified where it is suspected that parapets have defective rails.

NOTE 1 BACO and Lindley parapets were known to have defective rails.

NOTE 2 Parapets supplied by Lindley and installed between 1994 and 1996 had rails from an unacceptable source (Hulett). These rails were known to be defective.

Assessment of vehicle parapets within carriageway widening/realignment schemes

4.27 Where carriageway widening/realignment schemes allow the possibility of retaining existing parapets, the parapets shall be assessed in relation to the proposed carriageway alignment.

4.28 Where carriageway widening/realignment schemes allow both the possibility of retaining existing parapets and their protective safety barriers, the following two options shall be assessed:

1) retain both parapet and protective safety barrier, and assess in relation to the proposed carriageway alignment (only viable where the safety barrier has significant residual life); and,
2) retain the parapet and remove the protective safety barrier, and assess in relation to the proposed carriageway alignment (only viable where the redundant resistance of the parapet satisfies the containment criteria for upgrading to high risk sites given in Section 5).

4.29 Where it is assessed that both the existing parapets and their protective barriers are to be retained, this shall only be done provided that reduced lane widths and/or setback are acceptable as departures from standards in accordance with CD 127 [Ref 3.N] by the TAA.

Temporary or interim protection of substandard parapets

4.30 Substandard parapets shall be upgraded in accordance with Section 5.

4.30.1 Temporary protection during road works or longer term interim protection of substandard parapets should only be proposed where there are exceptional circumstances subject to:

1) risk assessment; and,
2) agreement by the TAA.

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5. Upgrading of existing parapets

General principles

5.1 Any remedial work required for substandard parapets shall be appraised individually for each structure.

5.2 The execution of planned upgrading/replacement of substandard parapets either as standalone schemes or as part of maintenance or major works shall be based on a prioritisation in accordance with Section 3.

5.3 Where structures are listed or are of historic importance any remedial or upgrading work shall not adversely affect the character of these structures.

NOTE 1 Early consultation with the relevant planning authority, highway authority and the TAA is essential when planning works on structures which are listed or are of historic importance.

NOTE 2 Guidance on the procedures required for conservation of scheduled and listed highway structures can be found in CG 304 [Ref 2.N].

5.4 The methods of upgrading existing parapets shall be such that the upgraded parapets continue to provide vehicle containment with safe redirection.

5.4.1 The methods of upgrading existing parapets should include the following options without limitation:

1) remove old parapet and replace with a new one to current standard;
2) provide an additional independent containment facility; and,
3) strengthening existing systems by like-for-like replacement of existing faulty/deteriorated components (as examples, posts, rails, fixings).

NOTE Provision of an additional independent containment facility can only be a viable option where there is room available to allow for an installation that provides adequate set back and working width in accordance with CD 127 [Ref 3.N].

5.5 Where existing parapets are to be upgraded, the required level of containment shall be determined from the risk assessment process in Section 3, subject to:

1) the minimum containment levels for vehicle parapets in accordance with CD 377 [Ref 14.N]; and,
2) the additional requirements for containment levels given in this Section.

5.5.1 Where parapets are to be upgraded, containment levels of new parapets should not be less than the as-built containment level of the existing parapets for the following types of structures:

1) bridges over or retaining walls adjacent to railway lines;
2) bridges over or retaining walls adjacent to roads, where the two-way AADT values for the road above, and the road below, both exceed 25000; and,
3) viaducts longer than 100 m carrying roads with two-way AADT exceeding 25000.

5.5.2 Where the existing parapets are steel N2 containment parapets, replacement parapets should have a minimum containment level of N2 for steel parapets or H1/H2 for other parapet types at the following types of structures:

1) bridges over or retaining walls adjacent to roads, where the two-way AADT values for the road above, and the road below, both exceed 25000; and,
2) viaducts longer than 100 m carrying roads with two-way AADT exceeding 25000.

5.6 Where parapets are to be upgraded, the existing approach and departure safety barriers shall be upgraded to ensure compliance with the:

1) requirements for permanent safety barriers in CD 377 [Ref 14.N]; and,
2) RRRAP User Guide [Ref 5.N].

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5.6.1 The length of need and P4 terminal requirements of safety barriers should be verified and upgraded to comply with CD 377 [Ref 14.N].

5.6.2 The containment level of the safety barrier should not exceed the required containment level of the parapet as determined by this document.

5.7 Obsolete/substandard parapet connections and transitions shall be upgraded in accordance with Section 6.

Parapet supporting members on existing bridges and retaining walls

5.8 Before upgrading existing parapets, the resistance of the parapet supporting member shall be verified in accordance with CS 454 [Ref 1.N], and any other applicable DMRB documents, including assessment for the effects of vehicle collision loading.

NOTE 1 The vehicle collision loading requirements applicable to upgrading are given in Appendix D.

NOTE 2 The DMRB standards for assessment of parapet supporting members include CS 455 [Ref 18.N], CS 456 [Ref 19.N], and CS 457 [Ref 17.N].

5.8.1 Where parapet supporting members are unable to satisfy the vehicle collision load criteria given in Appendix D, the following additional options should be investigated:

1) provide a continuous panel type safety barrier, near the edge of the deck or the face of the retaining wall, instead of a parapet;
2) provide an additional protective safety barrier with appropriate setback and working width; or,
3) allow a partial reduction of the Appendix D loading if agreed by the TAA.

5.8.2 The option to allow a partial reduction of the Appendix D loading requirements may be investigated only where the other two options given, which involve providing either an additional protective safety barrier or a continuous panel type safety barrier, prove impractical or disproportionately expensive.

5.9 Where a partial reduction of the Appendix D loading requirements is allowed the ALARP principle shall be satisfied by demonstrating that the costs and effort involved in verifying the resistance of the parapet supporting member including assessment for the effects of vehicle collision loading are grossly disproportionate to the benefits.

5.10 Where parapets are to be upgraded, the existing parapet supporting members shall be assessed for anchor-related concrete cone failure and concrete splitting failure.

5.10.1 Parapet supporting members that satisfy the minimum assessment resistance criteria should have a density and distribution of reinforcement in the parapet stringcourses (longitudinal bars and links) to make concrete cone failure or concrete splitting unlikely.

5.10.2 There should be no checks for concrete cone or concrete splitting failure where:

1) the existing parapet supporting member has been verified to satisfy the minimum assessment resistance; and,
2) there is a density and distribution of reinforcement in the parapet string course to make concrete cone failure or concrete splitting unlikely.

Safety barrier supporting members on existing bridges

5.11 Members supporting post and rail type safety barriers shall be assessed as acting as parapet supporting members in accordance with requirements given in this section for:

1) parapet supporting members on existing bridges and retaining walls;
2) members supporting chain-like safety barriers; and,
3) anchorage systems for parapets.

5.12 A safety barrier shall be deemed as chain-like where either of the following conditions apply:

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1) the safety barrier is not bolted to a supporting member; or,
2) the density of anchorage bolts provided along the barrier is less than 200 mm^2/m; (that is the cross-sectional area of bolts per metre length of barrier).

NOTE *Continuous panel type safety barriers often act as chains when impacted.*

5.12.1 Members supporting other continuous panel-type safety barriers should be assessed as members supporting post-and-rail type safety barriers.

Members supporting chain-like safety barriers

5.13 Members supporting chain-like safety barriers shall not be assessed for the local effects of vehicle collision.

NOTE *Safety barriers which rely on embedment are not suitable for use as chain-like safety barriers.*

5.14 Members supporting very high containment (H4a) safety barriers and higher containment (H1/H2) rigid concrete barriers shall be assessed for:

1) the global effects of vehicle collision given in D4 of Appendix D; and,
2) any specific assessment criteria recommended by the parapet manufacturer.

5.15 Where it is proposed to provide a safety barrier near the edge of a bridge deck the clearance from the back face of the barrier to the edge of the deck shall be in accordance with the safety barrier manufacturer's recommendations.

5.16 Where a safety barrier provided near the edge of a bridge deck results in a ledge 300 mm wide on the bridge deck, additional mitigation measures shall be required to prevent access to the ledge, subject to the approval of both the safety barrier manufacturer and the TAA.

5.17 The minimum height and infill requirements for parapets shall be in accordance with CD 377 [Ref 14.N].

5.18 Where anchorages are required for chain-like safety barriers, they shall be in accordance with

1) CD 377 [Ref 14.N]; and,
2) the anchorage manufacturer's requirements.

5.18.1 Where compliance with the manufacturer's requirement would require structural modifications to the existing structure, the highest level of anchorage resistance that does not necessitate structural modifications should be accepted subject to:

1) the minimum recommended requirements of the manufacturer being met; and,
2) the approval of the TAA.

Anchorage systems for parapets

5.19 Where parapets are upgraded, the existing anchorage systems shall only be reused where performance has been verified through:

1) inspections in accordance with CS 450 [Ref 7.N]; and,
2) testing in accordance with CS 463 [Ref 9.N] and MCHW Series 0400 [Ref 10.N]

NOTE *Reusing existing anchors can be more cost effective and less disruptive than installing new anchors although opportunities to do so are restricted by factors including:*

1) structure/element condition;
2) alignment/site restrictions; and,
3) manufacturer's requirements.

5.19.1 Where parapets are upgraded, existing drilled-in expanding anchors may be replaced by new cast-in cradle or drilled-in resin anchors that conform to current design standards, if agreed by the TAA.

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5.19.2 Where parapets are upgraded, existing drilled-in resin anchors or cast-in cradle anchorages may be reused, subject to:

1) satisfactory proof load testing; and,
2) recommendations and acceptance of the parapet manufacturer for modifications to the base plates and holding down bolts arrangements required to fit the cradles.

5.20 The modified components for parapet upgrades shall be in accordance with BS EN 1317-1 [Ref 16.N] and subject to the agreement of the parapet manufacturer.

5.21 Proof load testing of existing anchorages shall be accordance with the provisions of MCHW Series 0400 [Ref 10.N].

5.21.1 The number of anchors to be tested should be agreed with the TAA.

5.21.2 Where existing anchorages are unable to satisfy the proof loading criteria, it may be possible to accept a partial relaxation of the loading requirements in MCHW Series 0400 [Ref 10.N] if agreed by the TAA.

5.21.3 Partial relaxation of the loading requirements should demonstrate that the proposed solution:

1) satisfies the ALARP principle (that is by demonstrating that the costs and effort involved in complying with proof load testing of existing anchorages in accordance with the provisions of MCHW Series 0400 [Ref 10.N] would be grossly disproportionate to the benefit); and,
2) is supported by the parapet manufacturer.

NOTE *Further guidance on the requirements for the design of anchorages for vehicle can be found in CD 377 [Ref 14.N].*

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6. Obsolete/substandard parapet connections and transitions

General

6.1 This Section shall be used for the assessment of parapet-to-safety barrier connections approved for installation on the motorway and all-purpose trunk road network complying with, DD ENV 1317-4 [Ref 13.N], CD 377 [Ref 14.N], MCHW Series 0400 [Ref 10.N] or NPSBS REV 1 [Ref 12.N].

NOTE 1 Transition systems complying with DD ENV 1317-4 [Ref 13.N] are generally specific, in the sense that they enable connection from a particular parapet to a particular safety barrier.

NOTE 2 Transitions systems detailed in NPSBS REV 1 [Ref 12.N] have proven in-service use over many years and in some cases they have been successfully tested. These systems are generally generic in nature, enabling connections from a variety of parapet types to the old non-proprietary safety barrier systems.

6.1.1 Non-approved parapet connections complying with BS 6779-1 [Ref 3.I] may be assessed where they comprise one of the following two alternative options:

1) a connection between the safety barrier and the parapet able to transmit an ultimate tensile force of 330 kN, with a suitable safety barrier transition; or,
2) a full-height anchorage to the safety barrier, adjacent to the parapet end post, able to resist an ultimate tensile force of 330 kN, with a connection to the parapet able to transmit an ultimate tensile force of 50 kN, together with a suitable safety barrier transition.

NOTE BS 6779-1 [Ref 3.I] only permits option 2) of clause 6.1.1 where the speed limit is 50 mph or less.

6.2 The ultimate tensile force criterion to be used for assessment shall be 330 kN.

NOTE The 330 kN tensile force criterion has been accepted and used in approved standard details since 1974.

Assessment

6.3 Assessment and upgrading of substandard parapet connections shall be required where:

1) the speed limit is $\geq$ 50 mph; or,
2) the two-way traffic flow is $\geq$ 7000 AADT.

6.3.1 Existing parapet connections at sites where the speed limit is $\geq$ 50mph or the two-way traffic flow is $\geq$ 7000 AADT should not require assessment and upgrading where:

1) the transitions are approved for use on the motorway and all-purpose trunk road network in accordance with DD ENV 1317-4 [Ref 13.N] and NPSBS REV 1 [Ref 12.N];
2) the parapets are protected with road restraint systems in accordance with the requirements of CD 377 [Ref 14.N] or NPSBS REV 1 [Ref 12.N]; or,
3) the transitions are detailed in accordance with the original version of NPSBS.

6.3.2 Where road restraint systems have substandard working widths this should be seen as representing a separate safety risk rather than a parapet connection related risk and assessed in accordance with the requirements for protective safety barriers in Section 4.

6.4 Substandard parapet connections where the speed limit is less than 50 mph, or where the two-way traffic flow is less than 7000 AADT, shall be subject to a safety risk assessment to determine whether they require resistance assessment and upgrading.

NOTE Generally substandard parapet connections on the sites in clause 6.4 do not require upgrading unless the site has a higher than average accident rate.

6.5 Downstream or upstream of the parapet, the existing parapet and safety barrier connections shall not require assessment and upgrading where:

1) transitions are detailed in accordance with highway construction details issued by the Overseeing Organisation before the release of NPSBS REV 1 [Ref 12.N];

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2) parapet connections can transmit an ultimate tensile force of 330 kN between safety barrier and parapet, with or without compliant safety barrier transitions; and,
3) safety barriers have full height anchorages, within 5 m of the parapet end posts, with nominal connections between the parapet and safety barrier, regardless of speed limit.

6.6 Where there is no connection between a parapet and safety barrier with a full-height anchorage adjacent to the parapet end post, no assessment and upgrading shall be required for this type of arrangement, regardless of speed limit, except in any of the following circumstances:

1) the traffic face of the approach safety barrier is more than 30 mm behind the traffic face of the parapet;
2) the traffic face of the departure safety barrier is more than 30 mm in front of the traffic face of the parapet; or,
3) the longitudinal gap between parapet and safety barrier is more than 300 mm.

6.7 Safety barriers shall be programmed for replacement where the parapet and safety barrier have either of the following end arrangements:

1) the traffic face of the approach safety barrier is more than 30 mm behind the traffic face of the parapet; or,
2) the traffic face of the departure safety barrier is more than 30 mm in front of the traffic face of the parapet.

6.8 Where there is a longitudinal gap between the ends of the parapet and safety barrier of more than 300 mm, a compliant extension/connection shall be incorporated to close the longitudinal gap.

6.9 Substandard transitions on the upstream safety barrier approaches shall be assessed as requiring upgrading or modifications:

1) where there is no connection between the parapet and safety barrier; and,
2) whether or not assessment or upgrading is required for the arrangement.

6.10 Where parapet connections do not comply with any of the assessment criteria, they shall be classed as substandard and risk assessed using the ALARP-based risk assessment tool for substandard parapet connections included in Appendix A.

Upgrading

6.11 Mitigation works shall only be carried out on substandard parapet connections and transitions where the existing parapet has been assessed:

1) to provide full containment; and,
2) as suitable for retention with a minimum 10 years residual life.

6.11.1 Mitigation works should be carried out following the assessments where:

1) cost-effective modifications can be carried out to substandard transitions on the upstream barrier approaches;
2) it is appropriate to modify existing full-height anchorages to provide a suitable connection between parapet and safety barrier;
3) it is appropriate to replace safety barriers because of unacceptable detailing; and,
4) the ALARP-based risk assessment indicates that upgrading is justified.

6.11.2 Mitigation works should be carried out as part of maintenance works, or any other major works.

6.11.3 For upstream safety barrier approaches, the opportunity should be taken to rectify substandard lengths of need and provide P4 terminals at the upstream ends to comply with CD 377 [Ref 14.N], where this work can be done within the available traffic management.

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NOTE Also refer to the general principles for upgrading existing parapets given in Section 5.

6.12 Mitigation measures for substandard transitions and for full height anchorages with unacceptable transverse gaps shall be in accordance with the requirements given for their assessment in this Section.

6.13 In cases other than for substandard transitions and for full height anchorages with unacceptable transverse gaps, possible mitigation measures shall be as listed (in order of preference):

1) transitions complying with DD ENV 1317-4 [Ref 13.N];
2) modified connections able to transmit an ultimate tensile force of 330 kN between safety barrier and parapet in accordance with BS 6779-1 [Ref 3.I] together with safety barrier transitions, complying with DD ENV 1317-4 [Ref 13.N]; and,
3) safety barriers with full-height anchorages able to resist an ultimate tensile force of 330 kN, with connections to the parapets able to transmit an ultimate tensile force of 50 kN, together with safety barrier transitions, complying with DD ENV 1317-4 [Ref 13.N].

NOTE The options for mitigation measures given in 2) and 3) of clause 6.13 require departures from standards.

6.13.1 Complete parapet replacement may be the preferred solution where:

1) the existing parapets have a limited residual life; and,
2) the costs of mitigation are uneconomical.

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7. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref.	**Document**
Ref 1.N	National Highways. CS 454, 'Assessment of highway bridges and structures'
Ref 2.N	Highways England. CG 304, 'Conservation of highway structures'
Ref 3.N	Highways England. CD 127, 'Cross-sections and headrooms'
Ref 4.N	HMSO for Department for Transport. Masonry Parapets Guidance, 'Guidance on the Design, Assessment and Strengthening of Masonry Parapets on Highway Structures'
Ref 5.N	Highways England. RRRAP User Guide, 'Guidance on the use of the Road Restraint Risk Assessment Process (RRRAP) associated with CD 377'
Ref 6.N	Highways England. CD 109, 'Highway link design'
Ref 7.N	Highways England. CS 450, 'Inspection of highway structures'
Ref 8.N	National Highways. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 9.N	Highways England. CS 463, 'Load testing for bridge assessment'
Ref 10.N	Highways England. MCHW Series 0400, 'Manual of Contract Documents for Highway Works, Volume 1 Specification for Highway Works, Series 400 Road Restraint Systems'
Ref 11.N	Highways England. MCHW Series NG 0400, 'Manual of Contract Documents for Highway Works, Volume 2 Notes for Guidance on the Specification for Highway Works, Series 400 Road Restraint Systems'
Ref 12.N	Highways England. NPSBS REV 1, 'Non-Proprietary Safety Barrier Systems'
Ref 13.N	BSI. DD ENV 1317-4, 'Performance classes, impact test acceptance criteria and test methods for terminals and transitions of safety barriers'
Ref 14.N	Highways England. CD 377, 'Requirements for road restraint systems'
Ref 15.N	BSI. BS EN 1317-2, 'Road restraint systems. Performance classes, impact test acceptance criteria and test methods for safety barriers including vehicle parapets '
Ref 16.N	BSI. BS EN 1317-1, 'Road restraint systems. Terminology and general criteria for test methods.'
Ref 17.N	Highways England. CS 457, 'The assessment of composite highway bridges and structures'
Ref 18.N	National Highways. CS 455, 'The assessment of concrete highway bridges and structures'
Ref 19.N	Highways England. CS 456, 'The assessment of steel highway bridges and structures'

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8. Informative references

The following documents are informative references for this document and provide supporting information.

Ref.	Document
Ref 1.I	Highways England. BE 5, 'Design of highway bridge parapets 1967'
Ref 2.I	UKPGA 1974/37 (HASAWA), 'Health and Safety at Work etc. Act 1974'
Ref 3.I	BSI. BS 6779-1, 'Highway parapets for bridges and other structures. Specification for vehicle containment parapets of metal construction. 1998'
Ref 4.I	DfT. Managing incursion , 'Managing the incursion of road vehicles from trunk road overbridges onto lower roads'
Ref 5.I	Department for Transport on www.gov.uk. Traffic Advisory Unit. TAL 6/03, 'Traffic Advisory Leaflet 6/03 - Managing the accidental obstruction of the railway by road vehicles'

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Appendix A. ALARP-based risk ranking tools

A1 General

ALARP-based risk assessment tools are provided for the following three situations:

1) assessment of substandard parapets; (Refer to Appendix A2)

1) assessment of substandard parapet connections; (Refer to A3)
2) assessment of substandard protective safety barriers. (Refer to A4)

For all of these situations, the ALARP-based risk ranking score, R_{ALARP}, is expressed in Equation A.1.

Equation A.1 ALARP-based risk ranking score

$$R_{ALARP} = \frac{AADT \cdot F_1 \cdot F_2 \cdot F_3}{10000}$$

where AADT is the average two-way daily traffic flow on the road adjacent to the parapet (or twice the AADT on one-way traffic roads), and the three factors, F_1 to F_3, are defined in Appendix A (A2, A3 and A4), for substandard parapets, protective safety barriers and parapet connections respectively.

The value of AADT should be obtained from existing data where available. The Overseeing Organisation can provide information on where available existing data can be sourced. Where data is not available, the value of AADT should be estimated, using local knowledge of the motorway and all-purpose trunk road maintenance service provider, and the local highway authority if appropriate.

Table A.1 provides typical AADT values for different types of roads which may be used as a basis for estimating.

Table A.1 Typical AADT values

Road type	Typical range of two-way AADT
Green Lane or Farm Access Road	Less than 200
Unclassified road	200 to 2000
Class B or C road	2000 to 7000
Single carriageway class A or trunk road	7000 to 20000
Dual carriageway class A or trunk road	15000 to 40000
Motorway	Greater than 35000

A2 ALARP assessment of substandard parapets

For the assessment of substandard parapets, the three factors, F_1 to F_3 are defined as follows:

F_1 = Parapet containment factor (Refer to A2.1)

F_2 = Site features factor (Refer to A2.2)

F_3 = Ease of upgrading factor (Refer to A2.3)

Upgrading is justified, as part of maintenance or major works, when, $R_{ALARP} 1.0$.

A2.1 Parapet containment factor, F_1

The value for the parapet containment factor, F_1 is derived from Table A.2 and Table A.3.

The parapet containment factor, F_1 is determined from Table A.3 using the required containment resistance, C_{REQ} (expressed as a proportion of $N2$) obtained from Table A.2.

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Table A.2 Required containment resistance

Bridge/structure over or adjacent to:	Speed limit (mph) and corresponding C_{REQ} values				
	70	60	50	40	30[2]
Railway	1.00N2 at all speed limits				
Road or other[1]	1.00N2	0.73N2	0.50N2	0.33N2	0.20N2

Notes:

1) Other refers to river, canal, WCH/agricultural access routes, open land, etc.
2) Speed limit restrictions apply for accommodation bridges and roundabouts in accordance with clauses 3.6.1 and 3.6.2.

Table A.3 Parapet containment factor

Remnant resistance, R_{CONT} (as % of Required containment resistance, C_{REQ})		
0% — 33%	34% — 66%	67% — 100%
5.00	1.00	Upgrading not required

Notes:

1) The remnant resistance R_{CONT} should generally be assessed on the basis of engineering judgement. (Refer to Section 4).
2) Parapets within containment $C_{REQ} \geq 75\%$ do not need to be upgraded unless at a site with a very poor accident record.

A2.2 Site features factor, F_2

The value for the site features factor, F_2 is taken from Table A.4.

Although this factor is mostly dependent on clearance, allowances are also to be made for proximity to junctions and poor accident record.

Table A.4 Site features factor

Clearance to parapet from the edge of the nearest permanent running lane (m)						
0.0	1.0	2.0	3.0	4.0	5.0	6.0
1.50	1.50	1.25	1.00	0.75	0.50	0.50

Notes:

1) Intermediate values should be derived by linear interpolation.
2) If within the standard sight stopping distance of a junction/interchange/sharp bend add 0.25 to the value for F_2 .
3) If at a location with a poor accident record add 0.50 to the value of F_2 .

A2.3 Ease of upgrading factor, F_3

The value for the ease of upgrading factor, F_3 is taken from Table A.5

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Table A.5 Ease of upgrading factor

Method of upgrading		
Use existing anchors	New drilled anchors	Modify supporting member
1.5	1.00	0.50

Note:

1) Upgrading should be undertaken as part of maintenance or major works. The above values reflect this assumption. Significantly lower values would apply otherwise.

A3 ALARP assessment of substandard parapet connections

For the assessment of substandard parapets, the three factors, F_1 to F_3 , are defined as follows:

F_1 = Connection factor (Refer to A3.1)

F_2 = Site features factor (Refer to A2.2 as for substandard parapets)

F_3 = Ease of upgrading factor (Refer to A2.3)

Upgrading is justified, as part of maintenance or major works, when, $R_{ALARP} > 2.0$

A3.1 Connection factor, F_2, derived from Tables A.6 and A.7

The value for the connection factor, F_2 is derived from Table A.6 and Table A.7

Table A.6 Required ultimate tensile resistance of connection

Speed limit (mph)		
70	60	50
330 kN	240 kN	165 kN

Notes:

1) Upgrading is not required where the speed limit is less than 50 mph.
2) A speed limit of 30 mph should be assumed for accommodation bridges.
3) Speed limits on roundabouts should be assumed not to exceed 40 mph.

Table A.7 Connection factor

Remnant capacity, R_{CONT} (as % of Required connection resistance)		
0% — 33%	34% — 66%	67% — 100%
3.00	1.00	Upgrading not required

Note:

1) The remnant capacity R_{CONT} should be assessed on the basis of engineering judgement.
2) Connection factor, F_1 .

A4 ALARP assessment of substandard protective safety barriers

For the assessment of substandard parapets, the three factors, F_1 , F_2 and F_3 , are defined as follows:

F_1 = Overall containment factor (Refer to A4.1)

F_2 = Site features factor (Refer to A2.2 as for substandard parapets)

F_3 = Working width factor (Refer to A4.2)

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Upgrading is justified, as part of maintenance or major works, when, $R_{ALARP} > 2.0$

A4.1 Overall containment factor, F_1

The overall containment factor, F_1 is derived from Appendix A2.1 by considering the combined remnant capacity of parapet and protective safety barrier (that is, by adding the respective remnant capacities). However, where the combined remnant capacity is above 66%, F_1 is taken as 1.0.

A4.2 Working width factor, F_3

Value for the working width factor F_3 is derived from Table A.8 and Table A.9.

The working width factor, F_3 is determined from Table A.9, taken as a percentage of the required working width from Table A.8.

Table A.8 Required working width (proportion of full working width)

Speed limit (mph)		
70	60	50
1.0W	0.73W	0.50W

Notes:

1) Upgrading is not required where the speed limit is less than 50 mph.
2) A speed limit of 30 mph should be assumed for accommodation bridges.
3) Speed limits on roundabouts should be assumed not to exceed 40 mph.
4) W is the full working width.

Table A.9 Working width factor

Working width provided (as % of required working width)		
0% — 33%	34% — 66%	67% — 100%
3.00	1.00	Upgrading not required

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Appendix B. Incursion risk ranking tools

B1 Background

The guidance contained within this Appendix uses incursion risk ranking tools to simplify the assessment process.

The guidance combines the tools from available sources including DfT Report "Managing the accidental obstruction of the railway by road vehicle" TAL 6/03 [Ref 5.I] to avoid unnecessary duplication, whilst updating to be consistent with CD 377 [Ref 14.N].

Road-rail and road-road incursion risk ranking tables are provided in B7, for both single carriageway and motorway/dual carriageway road-over situations.

Guidance on the relevant factors is provided in B3 to B6 as shown in the Table B.1.

Table B.1 Risk factor information

Appendix B	Risk factor	
B3	f1 to f11	road over factors (single carriageway)
B4	f1 to f11	road over factors (motorway/dual carriageway)
B5	f12 to 14	rail under factors
B6	f12 to 14	road under factors

B2 Instructions: overall scoring and methodology

The overall score for a bridge is obtained by adding all 14 factors together.

As a guide, an increase of two in a score for any of the factors or for an overall risk score implies a doubling of the risk, so 6 is twice as bad as 4, and 12 is eight times worse than 6. This gives a wide range of risk values. A score of 90 implies that the risk is approximately a million times bigger than a score of 50.

The scoring regime assumes that no factor needs a score of zero, as even the best protection still allows a slim chance of a vehicle or debris, reaching the line.

Assessors are to rank bridges according to score, assessing the highest scoring bridges in more detail to see how they can be improved. As a guide, scores of 100 or more are significant and scores of 70 or more would suggest that highway authorities should at least consider the practicability of improvements. This does not rule out simple and cost-effective improvements at bridges that score less than 70. Mitigation action is not strictly required when:

1) for bridges carrying single carriageway roads that either score one for factor 1 (road approach containment) or score of 1 for factor 5 (site topography); and,
2) for bridges carrying motorway and dual carriageway roads that score one for factor 1 (road approach containment) combined with a score of 1 for factor 5 (site topography), and a score of two or less for factor 8 (vehicle parapet resilience).

B3 Factors: single carriageway road over rail or road

B3.1 f1: Road approach containment on upper road

The factor is used to consider the possibility of a road traffic accident (RTA) resulting in a vehicle or debris continuing along the road approach side slope and then onto the railway track or road below. It is also used to consider a vehicle or debris gaining access either side of the parapets in a cutting.

Where containment varies on each approach side slope, (that is, at each of the four corners), the worst case has to be assessed, in particular, containment immediately adjacent to parapet ends and score the factor accordingly. For example, good containment on a road approach up to 3 m from the parapet, but with no protection in the 3m section, would be marked 24.

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Table B.2 gives scores to be used for factor f1.

Table B.2 f1 scores for single carriageway road over rail or road

Sc-ore	**Containment**	**Notes**
1	For acceptable containment (safety fence, heavily wooded road approach slopes, buildings or brickwork walls 450 mm or thicker)	The scorer assesses whether a fence takes account of normal design parameters. For instance, a safety fence is not designed to resist perpendicular loading at a Z-bend over a railway bridge. "Heavily wooded" means trees of more than 5 00 mm girth at spacing of less than 2 m. Buildings on approaches or brickwork/masonry walls in good condition, 45 0 mm or greater in thickness, to be scored as 1. Where the road speed is not greater than 30 mph, the scorer may include Trief safety kerb in this category. Virtually zero chance of a road vehicle penetrating the containment, or evading the end of it.
12	For inadequate containment (inadequate safety fence, lightly wooded road approach slopes or brickwork minimum 225 mm thick)	At this score, the safety fence is being expected to provide containment perpendicular to its face, or it meets a standard now superseded, or it is a non-standard type. Trees are of less than 500 mm girth and/or spacing of 2 m or more. Brick/masonry walls in good condition are a minimum of 225 mm thick. Some sites have several layers of protection, each of which would be inadequate on its own, but which together offer a reasonable level of containment. For example, a pedestrian safety barrier at the kerb edge combines with a close-boarded fence on concrete posts at the boundary. Perceived chance of vehicle evading or penetrating a fence or trees.

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Table B.2 f1 scores for single carriageway road over rail or road (continued)

Sc-ore	Containment	Notes
24	For non-existent containment (including post rail/wire fencing)	At this score, road approach slopes have no fencing or only post/wire or post/rail fencing. There is no significant vegetation (trees or bushes less than 250 mm girth and/or at centres greater than 2 m). High chance of a vehicle that leaves the highway continuing at undiminished speed.

B3.2 f2: Upper road alignment (horizontal)

Road width and horizontal alignment are important, as a wide straight road with passing clearance for two oncoming vehicles is an obviously lower risk than a narrow road where one vehicle has to give way. The curved approaches increase the chance of an accident due to reduced sighting distance and reaction time.

"Road width" is the width taken as the width of road surface, disregarding any footpath or verge.

B3.3 f3: Upper road alignment (vertical)

Blind summits reduce the sighting and reaction distance for two oncoming vehicles meeting at a bridge with restricted clearance. Assessors should determine visibility on straight road hump backs in accordance with CD 109 [Ref 6.N].

B3.4 f4: Actual speed of approaching road traffic on upper road

The faster approaching road traffic is going, the greater the risk of an accident. Speed also contributes to the effect of the incident. The faster a vehicle is travelling, the further it (and any debris) may travel afterwards.

If possible assessors are to use actual speed figures, measured on site. Where these are not available, speeds are evaluated during the site visit. Assessors should disregard signed and designed speeds. Experience indicates that actual speeds may be much higher.

B3.5 f5: Site topography

This factor involves subjectively assessing the likelihood of a vehicle, or substantial parts of it, or its load, reaching the railway track or road below following a RTA that breaches any containment in factor f1. The assessor considers how far an errant vehicle leaving a high-speed road would travel. This may be affected by the:

1) gradient of the side slope;
2) distance from toe of cutting slope to the nearest point on the railway track or road below;
3) height of the railway track bed or road below in relation to the field level next to the approach slopes;
4) proximity of railway track or road below to ends of the vehicle parapets;
5) increased risk of incursion due to skew effects at obtuse corners;
6) height of the deck above railway track or road below;
7) likelihood of the vehicle becoming airborne;
8) skid resistance of the ground between the upper road, and the railway track or road below; and,
9) presence of shrubbery between the carriageway upper road, and the railway track or road below.

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This factor is not intended to include any assessment of the risk associated with parts of the vehicle parapet or safety fence being displaced onto the rail track or road below. We consider this in factor f8.

B3.6 f6: Site specific hazards increasing the likelihood of a RTA on upper road

Because it is not practicable to have a simple risk ranking which considers all possible hazards, we decided to include a factor so that the assessor can take account of additional hazards that may increase the risk of a RTA. These include (but are not limited to):

1) farm access/field gates;
2) road junctions;
3) private driveways;
4) schools, hospitals, and the like;
5) factory entrances;
6) steep descent on upper road approach and adjacent access tracks;
7) lay-bys;
8) bus stops;
9) car parking; and,
10) cafes and shops.

All of these may lead to conflicting or unusual traffics movements.

Table B.3 gives scores to be used for factor f6.

Table B.3 f6 scores for single carriageway road over rail or road

Score	Hazard
1	for no obvious hazard.
5	for a single minor hazard, such as a field gate, lay-by or bus stop.
9	for multiple minor hazards or a single major hazard, such as a school, hospital or factory entrance, leading to conflicting traffic movements.

Assessors consider upper road traffic speeds, and the distance of hazards from parts of bridge approaches susceptible to road vehicle incursion. A frequently used field gate 10 m from a relatively unprotected wall on a narrow high-speed road would score higher than one 100 m away on a lightly used, wider road.

B3.7 Site specific hazards increasing the consequences of the event (between the upper road and railway track or road below)

Again, due to the difficulty of including all possible hazards, we have included a factor so that the assessor can take account of them. These include, but are not limited to; exposed gas or chemical pipelines, water mains, communication cabinets, and similar that are:

1) attached to the bridge structure;
2) adjacent to the bridge approaches; or,
3) parallel with the railway tracks or road below.

Risk increases where there is more than one pipeline or hazard.

Some railway infrastructure is likely to worsen the effects of an accident. Some, such as switch and crossing work or junctions, are a derailment hazard. Others are likely to increase the severity of an accident if hit by a derailed vehicle. These include station platforms, bridge piers and abutments and tunnel portals within 800 m (half a mile) of the bridge site. Disregard overhead line masts within this factor.

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Road infrastructure likely to increase severity of incident to include bridge piers and abutments and tunnel portals etc within 800m (1/2 mile) of structure.

Table B.4 gives scores to be used for factor f7.

Table B.4 f7 scores for single carriageway road over rail or road

Score	Hazard
1	for no obvious hazard.
3	for a single hazard, such as a gas main, oxygen pipe and so on.
5	for multiple hazards and/or railway or highway infrastructure likely to increase the severity of an accident.

B3.8 f8: Vehicle parapet resilience on upper road

Parapet resilience (containment) is important because the effect of an accident will be less if the parapet can keep crashed vehicles on the bridge deck. On multitrack railway routes a parapet may limit the effects of any RTA to outer tracks.

Modern welded steel half through bridge decks offer containment to at least H4a standard. Earlier riveted steel/wrought iron half through decks score higher, due to the possibility of rivet or deck corrosion.

Where the parapet is in poor condition due to age, corrosion or existing accident damage, assessors should raise the score to at least the next category.

Table B.5 gives scores to be used for factor f8

Table B.5 f8 scores for single carriageway road over rail or road

Score	Containment
1	for H4a parapet, or welded steel half through bridge deck.
2	for N2 parapet, or riveted steel/wrought iron half through bridge deck.
5	for 450 mm thick brickwork parapet.
7	for 340 mm thick brickwork parapet.
11	for cast iron or corrugated sheet parapet.

B3.9 f9: Upper road verges & footpaths

Road approaches and bridge decks with wide footpaths or verges reduce the risk of RTAs, as they give drivers extra width to take avoiding action and offer the psychological comfort of a wider gap to steer through. At sites where pedestrian safety barriers have been provided, the factor should be marked on the distance between barrier and kerb edge.

B3.10 f10: Upper road signage and markings

Adequate road signage and markings help to warn strangers to an area that a hazard exists, but their effects are limited and the consensus view is that regular road users may ignore signage and markings. This makes locals more likely to crash. For this reason signage is generally considered to be of lower importance in the ranking procedure.

Table B.6 gives scores to be used for factor f10

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Table B.6 f10 scores for single carriageway road over rail or road

Score	Signage and markings
1	for signage/markings considered fit for purpose and which are clean and clearly visible, or are not considered to be needed at the location.
4	for non-existent, inadequate, or obscured signage/markings, at a location where they are considered necessary.

Note: Assessors are to notify the highway authority of a score of 4 for early action, regardless of the perceived risk at the location based on the total score from all factors.

B3.11 f11: Volume of road traffic on upper road

Road traffic volume increases the probability of a RTA. This model was developed using the number of HGVs per day, but assessors can apply any measure of recorded traffic flow, subject to similar weighting. HGVs and farm traffic are more likely to be involved in an accident on narrow roads, as they reduce the passing space for oncoming traffic.

This factor can need upwards adjustment to the next higher category where local conditions such as the presence of a quarry increase traffic, and are not reflected in the original survey figures.

Equivalent traffic flows for all vehicle types can be substituted, depending upon the units of measurement used by the relevant highway authority.

Assessors can use the following vehicles per day figures where the highway authority cannot provide traffic volumes in HGVs.

Table B.7 gives scores to be used for factor f11.

Table B.7 f11 scores for single carriageway road over rail or road

Score	Volume of traffic on upper road
1	For 0 to10 HGVs per day (<200 vehicles per day).
2	For 11 to 100 HGVs per day (<2000 vehicle per day).
3	For 101 to 500 HGVs per day (<7150 vehicle per day).
4	For 501 to 1000 HGVs per day (<12500 vehicle per day).
5	For over 1000 HGVs per day (>12500 vehicle per day).

The highway authority will provide traffic figures.

B4 Factors: motorway or dual carriageway road over rail or road

B4.1 f1: Upper road approach containment

This factor is used to consider the possibility of a road traffic accident (RTA) resulting in a vehicle or debris continuing along the road approach side slope and then onto the railway track or road below. It is also used to consider a vehicle or debris gaining access either side of the safety barriers and transitions prior to the vehicle parapet in a cutting.

This factor is to be considered in conjunction with factor f5 (site topography) to determine the "length of need".

Where containment varies on each approach, (that is, at each corner of the bridge) the worst case has to be assessed.

Table B.8 gives scores to be used for factor f1.

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Table B.8 f1 scores for motorway or dual carriageway road over rail or road

Score	Containment	Notes
1	for very high containment	This means that there is a very high containment barrier (H4a) of adequate length with appropriate transition to normal containment safety barrier (N2), in accordance with CD 377 [Ref 14.N]. This should either be continuous or used in conjunction with a very high containment level vehicle parapet. See factor 8. Assessors are to consider, in particular, the "length of need" for high containment safety barriers and/or vehicle parapets on high-speed roads. The "length of need" is the length reasonably required to prevent a vehicle from reaching the railway or lower road. Road engineers are likely to meet "the length of need" either by using a very high containment level parapet and transition or continuous high containment barriers. Assessors are to include only sites in this category where the length of high containment protection is reasonably likely to prevent most vehicles reaching the road below from either a wide approach angle (such as hitting the containment at an angle of more than 20 degrees) or a shallow approach angle (leaving the road before the containment begins and continuing behind the barrier towards the hazard).
6	for normal containment	This score covers sites with normal containment safety barriers of adequate length, fully complying with CD 377 [Ref 14.N], and connected to a normal containment level parapet in accordance with the requirements for non-proprietary and proprietary safety barriers.
12	for approach safety barriers of normal containment that are sub- standard, defective, damaged or too short	These sites have safety barriers that do not comply with current standards. This is either as a result of poor original installation, deterioration, damage, settlement or any other significant defect, or because they are too short.
24	for no effective vehicle restraint system or very low containment, non- standard walls, fences or barriers	Here there is a high probability of an errant vehicle continuing at the same speed and/or angle.

B4.2 f2: Upper road alignment (horizontal and vertical)

Road width, and horizontal and vertical alignments are important, but are unlikely to be a significant feature of high-speed major roads. Length of sight lines are important, as blind summits and bends can reduce sighting and reaction times. Assessors should determine intervisibility on straight road humpbacks and bends in accordance with CD 109 [Ref 6.N].

Assessors should consider using the single carriageways ranking tool for major roads with speed restrictions or with narrow widths and poor alignments.

B4.3 f3: Sleep-related vehicle accidents (SRVAs) on upper road

Recent research has identified a number of RTAs caused by drivers falling asleep. These are known as sleep-related vehicle accidents or SRVAs. The study found that SRVAs are relatively common on high-speed major roads. Proportions ranged from 16 percent to 30 percent of all reported fatal, injury and damage only accidents.

In a recent study of SRVAs, the highest proportion was found on a featureless, unlit stretch of the M40 in rural Warwickshire. The research indicated that SRVAs are independent of traffic density, but there are some identifiable characteristics that lead to clusters of these accidents.

Availability of service areas did not seem to affect SRVAs but the study found clusters of SRVAs on slow right hand bends and towards the end of a long route. For example, run-off accidents were found clustered on the eastbound carriageway of the eastern end of the M180 and B180, but there was no such cluster on the westbound carriageway.

SRVAs were also found to occur on slow left hand bends. Most major roads have a central reservation safety fence, which heavy goods vehicles (HGVs) may broach thereby posing a particular risk of incursion on to railway lines.

B4.4 f4: Actual speed of approaching road traffic on upper road

This ranking tool is intended for use on fast roads where higher traffic speeds increase both the likelihood and the effect of an accident. This is due to the distance over which the vehicle and debris can travel after the accident, and/or the capability of the vehicle restraint system.

If possible, assessors are to use actual speeds taken from site measurements. If these are not available, they estimate the speed at medium traffic density and note it on the scoring sheet. Assessors consider traffic density when measuring traffic speed, as these two factors can be interdependent, producing an unreliable figure as a result.

B4.5 f5: Site topography

This factor involves subjectively assessing the likelihood of a vehicle, or substantial parts of it, or its load, reaching the railway track or road below following a RTA which breaches any containment in factor f1. The assessor considers how far an errant vehicle leaving a high-speed road will travel. This can be affected by the:

1) gradient of the side slope;
2) distance from toe of cutting slope to the nearest point on the railway track or road below;
3) height of the railway track bed or road below in relation to the field level next to the approach slopes;
4) proximity of railway track or road below to ends of the vehicle parapets;
5) increased risk of incursion due to skew effects at obtuse corners;
6) height of the deck above railway track or road below;
7) likelihood of the vehicle becoming airborne;
8) skid resistance of the ground between the upper road, and the railway track or road below; and,
9) presence of shrubbery between the carriageway upper road, and the railway track or road below.

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This factor is not intended to include any assessment of the risk associated with parts of the vehicle parapet or safety fence being displaced onto the rail track or road below. We consider this in factor f8.

B4.6 f6: Site-specific hazards increasing the likelihood of a RTA on upper road

Analysis of accident data suggests that RTAs on major, high-speed roads are clustered near junctions or other areas, which can lead to conflicting or unusual traffic movements or vehicles changing lanes. The following are all likely to increase the frequency of RTAs:

1) interchanges;
2) road junctions;
3) lane drops;
4) emergency service vehicle recesses;
5) no hard shoulders;
6) service areas; and,
7) lay-bys.

Assessors generally consider the distance of a hazard from the bridge approach when scoring this factor. Raise the score by one band for sites prone to long periods of bad weather, such as exposed moorland. Consideration is to be given to increasing the score by two if there is no adequate carriageway lighting.

B4.7 f7: Site-specific hazards increasing the consequences of the event (between the upper road and railway track or road below)

These include, but are not limited to, exposed pipelines, water mains, communication cabinets etc, that are:

1) attached to the bridge structure;
2) adjacent to the bridge approaches; or,
3) parallel with the railway tracks or road below.

Risk increases where there is more than one pipeline or hazard.

Some railway infrastructure is likely to worsen the consequence of an accident. Some, such as switch and crossing work or junctions, are a derailment hazard. Others are likely to increase the severity of an incident if hit by a derailed vehicle. These include station platforms, bridge piers and abutments and tunnel portals within 800 m (1/2 mile) of the bridge site. Disregard overhead line masts within this factor.

Road infrastructure likely to increase severity of incidents to include bridge piers and abutments and tunnel portals etc within 800 m (1/2 mile) of structure.

B4.8 f8: Vehicle parapet resilience on upper road

Parapet resilience (containment) is important because the effect of an accident will be less if the parapet can contain and redirect crashed vehicles on the bridge deck. On multi-track railway routes a parapet can limit the effects of any RTA to the outer tracks. Refer to CD 377 [Ref 14.N] for details of parapet types.

The type of parapet will also, by definition, specify the height and the infill. This will, in turn, determine the likelihood of debris from the bridge fouling the railway track or road below.

B4.9 f9: Hard shoulders, edge strips, road verges and footpaths on upper road

Road approaches and bridge decks with hard shoulders, edge strips and/or wide footpaths or verges reduce the risk of RTAs, as they give drivers extra width to take avoiding action and to regain control of an their vehicles.

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B4.10 f10: Quality and effectiveness of edge markings and raised rib markings on upper road

Edge markings include raised rib markings (sometimes called "rumble strips") and reflective road studs (sometimes called "cats eyes") on the nearside edge of a major road alert drivers to their position. They can help to reduce the risk of vehicles leaving the nearside of major roads. There is some evidence that adequate, well-maintained raised rib markings can be particularly effective in overcoming run-off accidents where fatigue is a factor. However, assessors need to check their condition.

Note: Assessors should notify the highway authority of a score of 4 for early action, regardless of the perceived risk at the location based on the total score from all factors.

B4.11 f11: Combined volume of road traffic on both carriageways of upper road

Heavy road traffic has been shown to increase the likelihood of a RTA. We measure traffic flow for major high-speed roads with high volumes of traffic in vehicles per day (vpd). On average HGVs make up about 10 percent of the traffic on motorways and all-purpose trunk roads and are involved in about 7 per cent of RTAs. However, the mix of traffic may add to the risk of vehicle incursion, particularly in relation to containment (see f1: upper road approach containment). Assessors are to increase the score by one band if HGVs form 12 percent or more of total traffic.

B5 Factors: rail under road

B5.1 f12: Permissible line speed and track alignment

We consider this to be important because derailments are more likely on high-speed routes. We have included the curve factor due to the increased chance of derailment on curves, and the reduced braking distance if the curve obscures the vehicle and/or debris on the track from the train driver's view.

Scoring reflects the increased chance of derailment with increased speed, or track curvature, and also that the consequences of the event can increase with speed.

For bridges carrying single carriageway roads, on routes with more than two tracks and where the vehicle parapet resilience in factor f8 scores 2 or less, it is considered that, unless other circumstances indicate otherwise, assessors are to consider only the speed of the outer lines. The assumption is that the parapets will contain any crashed vehicle and only the outer tracks be affected.

The operating speed categories allow assessors to use the model for the Channel Tunnel Rail Link and other high-speed routes, and where speed enhancement schemes are being considered.

Details of line speeds are available from the railway infrastructure authority. This may be for example Network Rail, London Underground Ltd, NEXUS (Tyne & Wear PTE), a preserved railway operator or other infrastructure authority.

The site inspection will establish the existence of curvature.

B5.2 f13: Type of rail traffic

The type of rail traffic can affect the severity of a railway incident following a RTA in a number of ways. The five categories used are a development of work to assess the risk from signals passed at danger (SPADS). This includes the likelihood of derailment and the crash resistance of different rolling stock types.

Though a route can be considered to be used primarily by one of the lower risk categories below, if more than five higher risk trains use the route each day, assessors are to include it in the higher scoring group. For example, the East Coast Mainline north of York, is principally a loco-hauled passenger route for high speed trains and IC225s, but it also carries sliding door 'Sprinters' and some dangerous goods traffic, so it scores 5.

For bridges carrying single carriageway roads, if f8 (vehicle parapet resilience) scores 2 or less, score f13 on the basis of outermost tracks of a multi-track railway

Table B.9 gives scores to be used for factor f13

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Table B.9 f13 scores for rail under road

Score	Rail traffic
1	for freight only routes, not carrying dangerous goods such as petrol. These are considered the least risk, as generally there is a reduced chance of derailment. Also substantially fewer casualties are possible.
3	for loco-hauled passenger trains, to include push-pull services such as high speed trains, I C225s and similar. These have a reduced risk of derailment, as they are loco-hauled and have better crash resistance than lighter rolling stock. The possible number of injuries, however, increases the risk.
5	for sliding-door multiple units (maximum speed 100 mph), and/or dangerous goods freight trains. Modern diesel and electric sliding-door multiple units (Sprinters, EMU's) and trains carrying dangerous goods increase risk. This is due to the high number possible casualties following any explosion or fire.
7	for 'slam-door' multiple units and sliding door multiple units (maximum speed greater than 100 mph). This is because older slam-door trains have less structural integrity than modern ones and passengers in the leading vehicles of modern higher speed multiple units are at greater risk of death or injury.
11	for light rail. Lightweight passenger trains, as operated by NEXUS (Tyne & Wear Metro) are at greatest risk. This is due to the high number of possible casualties and the increased chance of derailment of a light train, when compared with a conventional multiple unit or loco-hauled service.

Light rail does not include preserved railways operating under a Light Railway Order. These are to be assessed against the types of vehicle they normally operate.

The railway infrastructure controller will confirm the types of traffic likely to use a route.

B5.3 f14: Volume of rail traffic

The more trains use a route, then obviously the greater the chance of one being involved in the aftermath of a RTA. The railway infrastructure authority will provide usage figures for a particular route.

Network Rail will provide figures from its NETRAFF system. NETRAFF will give information for each track at a location, split into passenger/freight movements. Assessors are to first score the total for the location, even at multitrack locations.

This also applies to bridges over single carriageway roads at multitrack sites, where the assessor is only looking at the outer tracks in factor f12, due to acceptable parapet containment in factor f8. The information by track, split into passenger/freight movements, can be useful later, when carrying out a more detailed risk assessment

B6 Factors: road under road

B6.1 f12: Actual speed of traffic on lower road

The higher the traffic speeds on the lower roads the greater the likelihood and consequences of an accident. The fastest lower road drivers will have less time to react to, and avoid, a hazard ahead. In addition, the faster the vehicle is travelling at impact, the greater the kinetic energy on impact. If possible, assessors should use actual speeds taken from site measurements. If these are not available, they should estimate the mean speed of all traffic at medium traffic density and note it on the scoring sheet. Assessors are to consider traffic density when measuring traffic speed, as these two factors can be interdependent, producing an unreliable figure.

B6.2 f13: Site specific hazards increasing consequences of event on lower road

Assessors should consider anything within a 100-m zone of influence (100 m beyond each end of the bridge parapet) that may pose additional hazards. These include, but are not limited to, the presence of:

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1) pedestrians, especially if stationary (such as at bus stops or crossing);
2) narrow road width and/or verge width (inability to avoid a vehicle blocking the road);
3) poor or no lighting, particularly with low bridges;
4) reduced sight lines (such as due to bends or vegetation);
5) adjacent land use (including housing, schools); and,
6) queuing traffic (traffic signals, junctions).

Table B.10 gives scores to be used for f13

Table B.10 f13 scores for road under road

Score	Site specific hazard
1	for sites with no site-specific hazards on the lower road. For sites with site specific hazards, a doubling of risk is assumed for 2-way roads because of the increased likelihood of more vehicles and casualties being involved
3	for a 1-way lower road (or 5 for a 2-way lower road) with a single site-specific hazard
5	for a 1-way lower road (or 7 for a 2-way lower road) with two site-specific hazards
7	for a 1-way lower road (or 9 for a 2-way lower road) with queuing, or with 3 or more site-specific hazards. These should include sites which commonly have pedestrian or vehicle queuing zone of influence around the bridge.

B6.3 **f14: Combined volume of road traffic on both carriageways of lower road**

The greater the volume of traffic on the lower road the harder it will be for vehicles to avoid a vehicle or debris falling from the road above and the greater the number of vehicles (and so casualties) to be at risk of involvement in the accident. As for factor f11, we measure traffic flow in vehicles per day (vpd). On average HGVs make up about 10 percent of the traffic on motorways and all-purpose trunk roads and are involved in about 7 per cent of RTAs. (Considering all roads, HGVs make up about 6 per cent of the traffic and are involved in about 6 per cent of RTAs.) The mix of traffic may add to the risk of the consequences so assessors should increase the score by one band if HGVs form 12 per cent or more of total traffic.

B7 Incursion risk ranking tables

Road-rail and road-road incursion risk ranking tables are provided for the following four situations given in Table B.11.

Table B.11 Incursion risk ranking table for four road situations

Road situation	Associated risk ranking table in Appendix B
single carriageway over rail (Appendix B3 and B5 for guidance)	Table B13
motorway/dual carriageway over rail (Appendix B4 and B5 for guidance)	Table B14
single carriageway over road (Appendix B3 and B6 for guidance)	Table B15
motorway/dual carriageway over road (Appendix B4 and B6 for guidance)	Table B16

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Table B.12 Inter-releationship matrix for Road-Rail and Road-Road incursion risk ranking tables

Infrastructure under	**Infrastructure over**	
	Single carriageway Appendix B3 (f1 to f11)	Motorway/dual carriageway Appendix B4 (f1 to f11)
railway Appendix B5 (f12 to f14)	Table B13	Table B14
trunk road Appendix B6 (f 12 to f14)	Table B15	Table B16

Table B.13 Single carriageway over rail incursion risk ranking (DfT form 1a)

Factor		**Options**	**Scor-e**
f1 (See Note A. 1)	Road approach containment	Score 1	
		for acceptable (safety fence and/or heavily wooded side approaches, buildings or brick wall thicker than 450 mm)	
		Score 12	
		for inadequate (imperfect fencing and/or medium/lightly wooded approaches, 225 mm thick brick wall)	
		Score 24	
		for non-existent (no fencing, or only post & rail/wire, no significant vegetation)	
f2	Road alignment (horizontal)	Score 1	
		for straight road with at least 7.3 m carriageway	
		Score 3	
		for straight less than 7.3 m carriageway or curved at least 7.3 m carriageway	
		Score 7	
		for curved road less than 7.3 m carriageway	
		Score 10	
		for reverse curves less than 7.3 m carriageway	

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Table B.13 Single carriageway over rail incursion risk ranking (DfT form 1a) (continued)

Factor		Options	Scor-e
f3	Road alignment (vertical)	Score 1	
		for level or constant grade	
		Score 2	
		for slight hump back	
		Score 3	
		for hump back where vehicles are inter-visible	
		Score 5	
		for hump back where vehicles are not inter-visible	
f4	Actual speed of approaching road traffic	Score 1	
		for <10 mph	
		Score 3	
		for <30 mph	
		Score 5	
		for <50 mph	
		Score 7	
		for <70 mph	
		Score 9	
		for >70 mph	
f5	Site topography	Score 1	
		if vehicle/debris very unlikely to foul track	
		Score 4	
		if vehicle/debris unlikely to foul track	
		Score 6	
		if vehicle/debris can be reasonably expected to foul track	
		Score 8	
		if vehicle/debris likely to foul track	
		Score 10	
		if vehicle/debris very likely to foul track	

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Table B.13 Single carriageway over rail incursion risk ranking (DfT form 1a) (continued)

Factor		**Options**	**Scor-e**
f6 (See Note 2)	Site-specific hazards increasing likelihood of RTA on upper road	Score 1	
		for no obvious hazards	
		Score 5	
		for single site-specific hazard	
		Score 9	
		for multiple minor hazards, or single major hazard (such as a school, hospital or major factory access)	
f7 (See Note 3)	Site-specific hazards increasing consequences of event (between upper and lower road)	Score 1	
		for no obvious hazards	
		Score 3	
		for single site-specific hazard	
		Score 5	
		for multiple site-specific hazards and/or highway infrastructure likely to increase severity of an incident	
f8	Vehicle parapet resilience	Score 1	
		for very high containment (H4a) parapet or welded steel half-through type	
		Score 2	
		for normal containment (N2) parapet or riveted steel/wrought iron half-through type	
		Score 5	
		for 450 mm brickwork/masonry parapet	
		Score 7	
		for 340 mm brickwork/masonry parapet	
		Score 11	
		for cast iron or corrugated sheet parapet	
f9	Road verges and footpaths	Score 1	
		for at least 2 m both sides	
		Score 2	
		for at least 1 m both sides	
		Score 3	
		for one or both verges less than 1 m	

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Table B.13 Single carriageway over rail incursion risk ranking (DfT form 1a) (continued)

Factor		Options	Scor-e
f10 (See Note 4)	Road signage/carriageway markings	Score 1	
		for signage/markings fit for purpose and clearly visible, or not needed	
		Score 4	
		for unfit, non-existent or obscured signage/markings, where considered to be required	
f11 (See Note 5)	Combined volume of road traffic on both carriageways	Score 1	
		for 0 to 10 HGVs per day (generally green lane or farm access)	
		Score 2	
		for 11 to 100 HGVs per day (generally unclassified)	
		Score 3	
		for 101 to 500 HGVs per day (generally C or B class)	
		Score 4	
		for 501 to 1,000 HGVs per day (generally 'Other Strategic' roads)	
		Score 5	
		for over 1,000 HGVs per day (generally 'Primary Routes')	

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Table B.13 Single carriageway over rail incursion risk ranking (DfT form 1a) (continued)

Factor		Options	Scor-e
f12 (See Note 6)	Permissible line speed and track alignment	Score 1	
		for straight track up to 45 mph	
		Score 4	
		for straight track up to 75 mph or curved up to 45 mph	
		Score 8	
		for straight track up to 90 mph or curved up to 75 mph	
		Score 12	
		for straight track up to 100 mph or curved up to 90 mph	
		Score 16	
		for straight track up to 125 mph or curved up to 100 mph	
		Score 20	
		for straight track up to 140 mph or curved up to 125 mph	
		Score 24	
		for straight track above 140 mph or curved above 125 mph	
f13 (See Note 7)	Type of rail traffic	Score 1	
		for non-dangerous goods freight	
		Score 3	
		for loco-hauled stock	
		Score 5	
		for sliding door multiple units (up to 100 mph) or dangerous goods freight	
		Score 7	
		for slam door multiple unit or sliding door multiple units (over 100 mph)	
		Score 11	
		for light rail (see definition in guidance notes)	

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Table B.13 Single carriageway over rail incursion risk ranking (DfT form 1a) (continued)

Factor		**Options**	**Scor-e**
f14 (See Note 8)	Volume of rail traffic	Score 1	
		for seldom used route (fewer than 500 trains per year)	
		Score 3	
		for lightly used route (501 to 3,000 trains per year)	
		Score 5	
		for medium used route (3,001 to 10,000 trains per year)	
		Score 8	
		for heavily used route (10,001 to 50,000 trains per year)	
		Score 12	
		for very heavily used route (more than 5 0,000 trains per year)	
		Total score	
Note 1	Score f1 on the basis of the corner of the bridge with the least containment during stage 1 or for each corner during the detailed stage 2 assessment.		
Note 2	Site specific hazards increasing the likelihood of an RTA include the following features in proximity to the bridge: farm access, road junction, private driveway, lay-by, bus stop, school, hospital.		
Note 3	Site specific hazards increasing the consequences of the event include the following features in proximity to the bridge: exposed gas or chemical pipelines, etc. Railway infrastructure likely to increase severity of incident to include pointwork, platforms, bridge piers and abutments and tunnel portals within 800 m (1/2 mile) of structure.		
Note 4	If Score = 4, sign/road marking deficiencies to be brought to attention of the Overseeing Organisation.		
Note 5	Equivalent traffic flows for all vehicle types may be substituted, depending upon the units of measurement used by the relevant highway authority.		
Note 6	If factor f8 scores 2 or less, score factor f12 on the basis of outermost tracks of a multi-track railway.		
Note 7	If factor f8 scores 2 or less, score factor f12 on the basis of outermost tracks of a multi-track railway.		
Note 8	Volume of rail traffic is to be provided by Railway Infrastructure Controller. See guidance notes.		

Table B.14 Motorway and dual carriageway over rail incursion risk ranking (DfT form 1b)

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Factor		**Options**	**Scor-e**
f1 (See Note 1)	Road approach containment	Score 1	
		for very high containment (H4a) vehicle restraint system (safety barrier or extended vehicle parapet as examples) of adequate length.	
		Score 6	
		for normal containment (N2) vehicle restraint system of adequate length or compliant with "length of need".	
		Score 12	
		for sub-standard, defective or damaged or inadequate length approach safety barriers (See Note 1)	
		Score 24	
		for non-existent or significantly sub-standard vehicle restraint system.	
f2	Road alignment (horizontal & vertical)	Score 1	
		for full standard sight stopping distance (SSD), full width lanes, straight & constant grade	
		Score 3	
		for full standard SSD, some curves and undulations but standard horizontal and vertical alignments	
		Score 7	
		for sub-standard SSD or narrow, sub-standard vertical and horizontal alignments	

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Table B.14 Motorway and dual carriageway over rail incursion risk ranking (DfT form 1b) (continued)

Factor		Options	Scor-e
f3	Sleep-related vehicle accidents	Score 1	
		for no obvious risk factor	
		Score 3	
		for site on featureless rural road with the minimal services and/or minimal distractions for drivers at the side of the road	
		Score 5	
		for a bridge on a sweeping right hand bend, sweeping left hand bend with no central reserve safety barriers or a site at the end of a long route (for example, the eastbound of eastern end of the M20)	
		Score 9	
		for a combination of any of the above factors	
f4	Actual speed of approaching traffic	Score 1	
		for 50 – 60	
		Score 3	
		for 61 – 70	
		Score 6	
		for > 70	
f5	Site topography	Score 1	
		if vehicle/debris very unlikely to foul track from the bridge approach	
		Score 4	
		if vehicle/debris unlikely to foul track from the bridge approach	
		Score 6	
		if vehicle/debris can be reasonably expected to foul track from the bridge approach	
		Score 8	
		if vehicle/debris likely to foul track from the bridge approach	
		Score 10	
		if vehicle/debris very likely to foul track from the bridge approach	

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Table B.14 Motorway and dual carriageway over rail incursion risk ranking (DfT form 1b) (continued)

Factor		**Options**	**Scor-e**
f6 (See Note 2)	Site-specific hazards increasing likelihood of RTA	Score 1	
		for no obvious hazards	
		Score 5	
		for single site-specific hazard	
		Score 7	
		for multiple minor hazards, or single major hazard (such as. junctions, steep slopes, sharp bends)	
		Score 9	
		for multiple major hazards	
f7 (See Note 3)	Site specific hazards increasing consequences of event	Score 1	
		for no obvious hazards	
		Score 3	
		for single site-specific hazard	
		Score 5	
		for multiple site-specific hazards and/or railway infrastructure likely to increase severity of an incident	

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Table B.14 Motorway and dual carriageway over rail incursion risk ranking (DfT form 1b) (continued)

Factor		Options	Scor-e
f8	Vehicle parapet resilience	Score 1	
		for very high containment (H4a) vehicle parapet or equivalent	
		Score 2	
		for a normal containment (N2) parapet (of either 1.25 or 1.5 m height) or a sub-standard parapet protected by a normal containment safety barrier	
		Score 3	
		for a normal containment (N2) parapet (of 1 m height)	
		Score 5	
		for an unprotected 450-mm brickwork/masonry vehicle parapet	
		Score 7	
		for an unprotected 340-mm brickwork/masonry vehicle parapet	
		Score 11	
		for an unprotected defective or sub-standard vehicle parapet	
f9	Hard shoulders, edge strips, road verges and footpaths	Score 1	
		for full width hard shoulder (>3.0 m) and 1.5-m or greater verge	
		Score 2	
		for reduced hard shoulder (3.0 m <2.5 m) or 1-m edge strip and 1.5-m or greater verge/footpath measured at the narrowest point	
		Score 3	
		for narrow hard shoulder (< 2.5 m) or edge strip and verge/footpath less than 2 m measured at the narrowest point	

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Table B.14 Motorway and dual carriageway over rail incursion risk ranking (DfT form 1b) (continued)

Factor		Options	Scor-e
f10 (See Note 4)	Carriageway markings	Score 1	
		for edge markings, rumble strips and "cats eyes" in accordance with current standards	
		Score 4	
		for non-existent, inadequate or obscured markings, worn, buried or over painted rumble strips at a location where considered to be required	
f11 (See Note 5)	Combined volume of road traffic on both carriageways	Score 1	
		for < 20,000 vehicles per day (vpd)	
		Score 2	
		for 20,000 - 40,000 vpd	
		Score 3	
		for 40,000 - 60,000 vpd	
		Score 5	
		for 61,000 - 120,000 vpd	
		Score 8	
		for Over 120,000 vpd	

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Table B.14 Motorway and dual carriageway over rail incursion risk ranking (DfT form 1b) (continued)

Factor		Options	Scor-e
f12 (See Note 6)	Permissible line speed and track alignment	Score 1	
		for straight track up to 45 mph	
		Score 4	
		for straight track up to 75 mph or curved up to 45 mph	
		Score 8	
		for straight track up to 90 mph or curved up to 75 mph	
		Score 12	
		for straight track up to 100 mph or curved up to 90 mph	
		Score 16	
		for straight track up to 125 mph or curved up to 100 mph	
		Score 20	
		for straight track up to 140 mph or curved up to 125 mph	
		Score 24	
		for straight track above 140 mph or curved above 125 mph	
f13	Type of rail traffic	Score 1	
		for non-dangerous goods freight	
		Score 3	
		for Loco-Hauled Stock	
		Score 5	
		for sliding door multiple units (up to 100 mph) or dangerous goods freight	
		Score 7	
		for slam door multiple unit or sliding door multiple units (over 100 mph)	
		Score 11	
		for light rail (see definition in guidance notes)	

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Table B.14 Motorway and dual carriageway over rail incursion risk ranking (DfT form 1b) (continued)

Factor		Options	Scor-e
f14	Volume of rail traffic	Score 1	
		for seldom used route (fewer than 500 trains per year)	
		Score 3	
		for lightly used route (501 to 3,000 trains per year)	
		Score 5	
		for medium used route (3,001 to 10,000 trains per year)	
		Score 8	
		for heavily used route (10,001 to 50,000 trains per year)	
		Score 12	
		for very heavily used route (more than 50,000 trains per year)	
		Total score	
Note 1	This factor is to be considered in conjunction with factor f5 Site Topography to determine the "length of need".		
Note 2	Site-specific hazards increasing the likelihood of an RTA include the following features in proximity to the bridge: interchange, road junction, lay-by, emergency service vehicle recesses, lane drops and no hard shoulder. Consideration is to be given to increasing the score by two if there is no adequate carriageway lighting.		
Note 3	Site-specific hazards increasing the consequences of the event include the following features in proximity to the bridge: exposed gas or chemical pipelines, etc, railway infrastructure likely to increase severity of incident to include pointwork, platforms, bridge piers and abutments and tunnel portals etc within 800 m (1/2 mile) of structure.		
Note 4	If factor f10 score = 4 road marking deficiencies to be brought to attention of Overseeing Organisation.		
Note 5	The percentage of HGVs on major roads is typically about 10%. Assessors should increase the score by one band if HGVs form 12% or more of the total traffic.		
Note 6	Line speed, volume and type of rail traffic to be provided by Railway Infrastructure Controller, see guidance notes.		

Table B.15 Single carriageway over road incursion risk ranking (from DfT and TRL forms)

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Factor		Options	Sco-re
f1 (See Note 1)	Upper road approach containment	Score 1	
		for acceptable (safety fence and/or heavily wooded side approaches, buildings or brick wall thicker than 450 mm)	
		Score 12	
		for inadequate (imperfect fencing and/or medium/lightly wooded approaches, 225 mm thick brick wall)	
		Score 24	
		for non-existent (no fencing, or only post & rail/wire, no significant vegetation)	
f2	Upper road alignment (horizontal)	Score 1	
		for straight road with at least 7.3 m carriageway	
		Score 3	
		for straight less than 7.3 m carriageway or curved at least 7.3 m carriageway	
		Score 7	
		for curved road less than 7.3 m carriageway	
		Score 10	
		for reverse curves less than 7.3 m carriageway	
f3	Upper road alignment (vertical)	Score 1	
		for level or constant grade	
		Score 2	
		for slight hump back	
		Score 3	
		for hump back where vehicles are inter-visible	
		Score 5	
		for hump back where vehicles are not inter-visible	

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Table B.15 Single carriageway over road incursion risk ranking (from DfT and TRL forms) (continued)

Factor		Options	Sco-re
f4	Actual speed of approaching road traffic on upper road	Score 1	
		for <10 mph	
		Score 3	
		for <30 mph	
		Score 5	
		for <50 mph	
		Score 7	
		for <70 mph	
		Score 9	
		for >70 mph	
f5	Site topography	Score 1	
		if vehicle/debris very unlikely to foul lower road	
		Score 4	
		if vehicle/debris unlikely to foul lower road	
		Score 6	
		if vehicle/debris can be reasonably expected to foul lower road	
		Score 8	
		if vehicle/debris likely to foul lower road	
		Score 10	
		if vehicle/debris very likely to foul lower road	
f6 (See Note 2)	Site-specific hazards increasing likelihood of RTA	Score 1	
		for no obvious hazards	
		Score 5	
		for single site-specific hazard	
		Score 9	
		for multiple minor hazards, or single major hazard (such as a school, hospital or major factory access)	

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Table B.15 Single carriageway over road incursion risk ranking (from DfT and TRL forms) (continued)

Factor		Options	Sco-re
f7 (See Note 3)	Site specific hazards increasing consequences of event (between upper and lower road)	Score 1	
		for no obvious hazards	
		Score 3	
		for single site-specific hazard	
		Score 5	
		for multiple site-specific hazards and/or lower road infrastructure likely to increase severity of an incident	
f8	Vehicle parapet resilience on upper road	Score 1	
		for very high containment (H4a) parapet or welded steel half-through type	
		Score 2	
		for normal containment (N2) parapet or riveted steel/wrought iron half-through type	
		Score 5	
		for 450 mm brickwork/masonry parapet	
		Score 7	
		for 340 mm brickwork/masonry parapet	
		Score 11	
		for cast-iron or corrugated sheet parapet	
f9	Road verges and footpaths on upper road	Score 1	
		for at least 2 m both sides	
		Score 2	
		for at least 1 m both sides	
		Score 3	
		for one or both verges less than 1 m	
f10 (See Note D)	Road signage/carriageway markings on upper road	Score 1	
		for signage/markings fit for purpose and clearly visible, or not needed	
		Score 4	
		for unfit, non-existent or obscured signage/markings, where considered to be required	

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Table B.15 Single carriageway over road incursion risk ranking (from DfT and TRL forms) (continued)

<table>
<tr><th>Factor</th><th></th><th colspan="3">Options</th><th>Sco-re</th></tr>
<tr><td rowspan="10">f11 (See Note 5)</td><td rowspan="10">Volume of road traffic on upper road</td><td colspan="3">Score 1</td><td rowspan="10"></td></tr>
<tr><td colspan="3">for 0 to 10 HGVs per day (generally green lane or farm access)</td></tr>
<tr><td colspan="3">Score 2</td></tr>
<tr><td colspan="3">for 11 to 100 HGVs per day (generally unclassified)</td></tr>
<tr><td colspan="3">Score 3</td></tr>
<tr><td colspan="3">for 101 to 500 HGVs per day (generally C or B class)</td></tr>
<tr><td colspan="3">Score 4</td></tr>
<tr><td colspan="3">for 501 to 1,000 HGVs per day (generally 'Other Strategic' roads)</td></tr>
<tr><td colspan="3">Score 5</td></tr>
<tr><td colspan="3">For over 1,000 HGVs per day (generally 'Primary Routes')</td></tr>
<tr><td rowspan="10">f12</td><td rowspan="10">Actual speed of traffic on lower road</td><td colspan="3">Score 1</td><td rowspan="10"></td></tr>
<tr><td colspan="3">for < 10 mph</td></tr>
<tr><td colspan="3">Score 4</td></tr>
<tr><td colspan="3">for < 30 mph</td></tr>
<tr><td colspan="3">Score 8</td></tr>
<tr><td colspan="3">for < 50 mph</td></tr>
<tr><td colspan="3">Score 10</td></tr>
<tr><td colspan="3">for < 70 mph</td></tr>
<tr><td colspan="3">Score 12</td></tr>
<tr><td colspan="3">for > 70 mph</td></tr>
<tr><td rowspan="5">f13 (See Note 6)</td><td rowspan="5">Site specific hazards increasing consequences of event on lower road</td><td></td><td>One-way roads</td><td>Two-way roads</td><td rowspan="5"></td></tr>
<tr><td>No hazards</td><td>Score 1</td><td>Score 1</td></tr>
<tr><td>Single hazard</td><td>Score 3</td><td>Score 5</td></tr>
<tr><td>Two hazards</td><td>Score 5</td><td>Score 7</td></tr>
<tr><td>3 or more hazards/ queuing</td><td>Score 7</td><td>Score 9</td></tr>
</table>

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Table B.15 Single carriageway over road incursion risk ranking (from DfT and TRL forms) (continued)

Factor		Options	Sco-re
f14 (See Note 7)	Combined volume of road traffic on both carriageways of lower road	Score 1	
		for < 20,000 vehicles per day (vpd)	
		Score 5	
		for 20,000 - 40,000 vpd	
		Score 7	
		for 40,000 - 60,000 vpd	
		Score 9	
		for 61,000 - 120,000 vpd	
		Score 11	
		for over 120,000 vpd	
		Total score	
Note 1	Score factor f1 on the basis of the corner of the bridge with the least containment during stage 1 or for each corner during the detailed stage 2 assessment		
Note 2	Site-specific hazards increasing the likelihood of an RTA include the following features in proximity to the bridge: farm access, road junction, private driveway, lay-by, bus stop, school, hospital, etc.		
Note 3	Site-specific hazards increasing the consequences of the event include the following features in proximity to the bridge: exposed gas or chemical pipelines, and similar. highway infrastructure likely to increase severity of incident to include bridge piers, abutments and tunnel portals etc within 800 m (1/2 mile) of structure.		
Note 4	If factor f10 score = 4 sign/road marking deficiencies to be brought to attention of Overseeing Organisation.		
Note 5	Equivalent traffic flows for all vehicle types may be substituted, depending upon the units of measurement used by the relevant highway authority.		
Note 6	The percentage of HGVs on major roads is typically about 10%. Assessors should increase the score by one band if HGVs form 12% or more of the total traffic.		
Note 7	The hazards on the lower road leading to increased consequences could include the presence of pedestrians, road and/or verge width (inability to avoid a vehicle blocking the road), poor or no lighting, reduced sight lines (e.g. bends or vegetation) and adjacent land use (e.g. housing, schools). likelihood of queues, etc.		

Table B.16 Motorway and dual carriageway-over road incursion risk ranking (TRL Figure 2.1)

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Factor		Options	Score
f1 (See Note 1)	Upper road approach containment	Score 1	
		for very high containment (H4a) vehicle restraint system (safety barrier or extended vehicle parapet etc.) of adequate length.	
		Score 6	
		for normal containment (N2) vehicle restraint system of adequate length or compliant with "length of need".	
		Score 12	
		for sub-standard, defective or damaged or inadequate length approach safety barriers (See Note 1)	
		Score 24	
		for non-existent or significantly sub-standard vehicle restraint system.	
f2	Upper road alignment (horizontal & vertical)	Score 1	
		for full standard sight stopping distance (SSD), full width lanes, straight & constant grade	
		Score 3	
		for full standard SSD, some curves and undulations but standard horizontal and vertical alignments	
		Score 7	
		for sub-standard SSD or narrow, sub-standard vertical and horizontal alignments	

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Table B.16 Motorway and dual carriageway-over road incursion risk ranking (TRL Figure 2.1) (continued)

Factor		Options	Score
f3	Sleep-related vehicle accidents on upper road	Score 1	
		for no obvious risk factor	
		Score 3	
		for site on featureless rural road with the minimal services and/or minimal distractions for drivers at the side of the road	
		Score 5	
		for a bridge on a sweeping right hand bend, sweeping left hand bend with no central reserve safety barriers or a site at the end of a long route (for example eastbound of eastern end of M20)	
		Score 9	
		for a combination of any of the above factors	
f4	Actual speed of approaching traffic on upper road	Score 1	
		for 50 – 60	
		Score 3	
		for 61 – 70	
		Score 6	
		for > 70	
f5	Site topography	Score 1	
		if vehicle/debris very unlikely to foul lower road from the bridge approach	
		Score 4	
		if vehicle/debris unlikely to foul lower road from the bridge approach	
		Score 6	
		if vehicle/debris can be reasonably expected to foul lower road from the bridge approach	
		Score 8	
		if vehicle/debris likely to foul lower road from the bridge approach	
		Score 10	
		if vehicle/debris very likely to foul lower road from the bridge approach	

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Table B.16 Motorway and dual carriageway-over road incursion risk ranking (TRL Figure 2.1) (continued)

Factor		Options	Score
f6 (See Note 2)	Site specific hazards increasing likelihood of RTA on upper road	Score 1	
		for no obvious hazards	
		Score 5	
		for single site specific hazard	
		Score 7	
		for multiple minor hazards, or single major hazard (such as junctions, steep slopes, sharp bends)	
		Score 9	
		for multiple major hazards	
f7 (See Note 3)	Site specific hazards increasing consequences of event (between upper and lower road)	Score 1	
		for no obvious hazards	
		Score 3	
		for single site-specific hazard	
		Score 5	
		for multiple site-specific hazards and/or lower road infrastructure likely to increase severity of an incident.	
f8	Vehicle parapet resilience on upper road	Score 1	
		for very high containment (H4a) vehicle parapet or equivalent	
		Score 2	
		for a normal containment (N2) parapet (of either 1.25 or 1.5 m height) or a sub-standard parapet protected by a normal containment safety barrier	
		Score 3	
		for a normal containment (N2) parapet (of 1 m height)	
		Score 5	
		for an unprotected 450-mm brickwork/masonry vehicle parapet	
		Score 7	
		for an unprotected 340-mm brickwork/masonry vehicle parapet	
		Score 11	
		for an unprotected defective or sub-standard vehicle parapet	

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Table B.16 Motorway and dual carriageway-over road incursion risk ranking (TRL Figure 2.1) (continued)

Factor		Options	Score
f9	Hard shoulders, edge strips, road verges and footpaths on upper road	Score 1	
		for full width hard shoulder (>3.0 m) and 1.5 m or greater verge	
		Score 2	
		for reduced hard shoulder (3.0 m<2. 5 m) or 1 m edge strip and 1.5 m or greater verge/footpath measured at the narrowest point	
		Score 3	
		for narrow hard shoulder (< 2.5 m) or edge strip and verge/footpath less than 2m measured at the narrowest point	
f10 (See Note 4)	Carriageway markings on upper roads	Score 1	
		for edge markings, rumble strips and "cats eyes" in accordance with current standards	
		Score 4	
		for non-existent, inadequate or obscured markings, worn, buried or over painted rumble strips at a location where considered to be required	
f11 (See Note 5)	Combined volume of road traffic on both carriageways of upper road	Score 1	
		for < 20,000 vehicles per day (vpd)	
		Score 2	
		for 20,000 - 40,000 vpd	
		Score 3	
		for 40,000 - 60,000 vpd	
		Score 5	
		for 61,000 - 120,000 vpd	
		Score 8	
		for over 120,000 vpd	

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Table B.16 Motorway and dual carriageway-over road incursion risk ranking (TRL Figure 2.1) (continued)

Factor		Options			Score
f12	Actual speed of traffic on lower road	Score 1			
		for < 10 mph			
		Score 4			
		for < 30 mph			
		Score 8			
		for < 50 mph			
		Score 10			
		for < 70 mph			
		Score 12			
		for > 70 mph			
f13 (See Note 6)	Site specific hazards increasing consequences of event on lower road		One-way roads	Two-way roads	
		No hazards	1	1	
		Single hazards	3	5	
		Two hazards	5	7	
		3 or more hazards/ queuing	7	9	
f14 (See Note 5)	Combined volume of road traffic on both carriageways of lower road	Score 1			
		for < 20,000 vehicles per day (vpd)			
		Score 5			
		for 20,000 - 40,000 vpd			
		Score 7			
		for 40,000 - 60,000 vpd			
		Score 9			
		for 61,000 - 120,000 vpd			
		Score 11			
		for over 120,000 vpd			
				Total score	
Note 1	Factor f1 is to be considered in conjunction with factor f5 Site Topography to determine the "length of need".				
Note 2	Site-specific hazards increasing the likelihood of an RTA include the following features in proximity to the bridge: interchange, road junction, lay-by, emergency service vehicle recesses, lane drops and no hard shoulder etc. Consideration to be given to increasing the score by two if there is no adequate carriageway lighting.				

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Table B.16 Motorway and dual carriageway-over road incursion risk ranking (TRL Figure 2.1) (continued)

Factor		Options	Score
Note 3	Site-specific hazards increasing the consequences of the event include the following features in proximity to the bridge: exposed gas or chemical pipelines, etc. Highway infrastructure likely to increase severity of incident to include bridge piers, abutments and tunnel portals etc within 800 m (1/2 mile) of structure.		
Note 4	If factor f10 score = 4 road marking deficiencies to be brought to attention of Overseeing Organisation.		
Note 5	The percentage of HGVs on major roads is typically about 10%. Assessors are to increase the score by one band if HGVs form 12% or more of the total traffic.		
Note 6	The hazards on the lower road leading to increased consequences could include the presence of pedestrians, road and/or verge width (inability to avoid a vehicle blocking the road), poor or no lighting, reduced sight lines (such as due to bends or vegetation) and adjacent land use (as examples housing, schools). likelihood of queues.		

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Appendix C. Identification of substandard BACO parapets

C1

Following the adoption of BS 6779-1 [Ref 3.I], a series of tests were undertaken on BACO normal containment parapets. Consultants were then commissioned by Highways Agency (now Highways England) to provide an independent review of the testing.

C2

The conclusions reached were that the normal containment BACO 300/400 series parapets (without RF 158/01B modifications) do not, in many respects, meet the normal containment standards of BS 6779-1 [Ref 3.I], but do meet the requisite standards for low containment systems. BACO low containment parapets were not tested, but the review concluded that it is likely, based on the evidence of testing on normal containment parapets, that low containment parapets of similar design would not meet the requirements of BS 6779-1 [Ref 3.I].

(Note that the designations "normal containment" and "low containment" used in this Appendix when relating to the substandard BACO parapets relate to the BS 6779-1 [Ref 3.I] containment levels.)

C3

The retesting of BACO parapets following the adoption of BS 6779-1 [Ref 3.I] had shown that a number of types do not comply with the standard. These parapets are ones supplied prior to 1994 and are:

1) normal containment parapets - Series 300 and 400, P1(113), P2(113) and P5; and,
2) low containment parapets - P2(80).

The only exception to the above is in the parapet design which uses vertical posts supplied from January 1988 and with water-cooled (as opposed to pre-1986 air-cooled) extrusions. These may be satisfactorily modified in accordance with Amendment No 1: December 1993 to BS 6779-1 [Ref 3.I]. Any BACO 300/400 Series parapets installed after 31 March 1993 should have been modified either during fabrication or on site prior to acceptance.

C4

Parapets with vertical posts and manufactured entirely from water-cooled alloy may be modified in situ in accordance with Amendment No 1: December 1993 to as an alternative to replacement. The modification consists of cutting slots in the rear of the posts and fitting additional post-to-rail clips. Modification is acceptable on technical grounds as an alternative to replacement provided the parapet is in good condition. However, as it is often difficult to provide the slots in the posts without removing them from the structure. Consequently, the overall cost of modification may be similar to full parapet replacement.

C5

Despite various attempted modifications to the posts and post-rail connections and further retesting, it had not proven possible to find a practical way of modifying the substandard designs to make them compliant with BS 6779-1 [Ref 3.I]

There are two basic configurations for the 300/400 Series of:

1) parapets with inclined posts angled towards the traffic face; and,
2) parapets with vertical posts.

C6

In 1993, Highways Agency (now Highways England), identified that BACO aluminium parapet standard designs, which had been in accepted between 1967 and 1993, required modifications to their designs to meet the requirements of the fourth revision to BE 5 [Ref 1.I] and BS 6779-1 [Ref 3.I].

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BACO revised their details and issued updated drawings. Parapets fabricated to earlier issues of the revised drawings were prohibited from use on the trunk road network after 31 March 1993.

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Appendix D. Assessment of parapet supporting members

D1 Background

This appendix provides criteria for the assessment of parapet-supporting members relating to the local effects and global effects of vehicle collision loading. These criteria differ from the assessment requirements of CS 454 [Ref 1.N].

D2 Local effects of vehicle collision

D2.1 Background

A fundamental principle in the design of new structures is that impact destruction of a parapet does not cause damage to parapet supporting members. This principle ensures that impact destructed parapets can be replaced relatively readily.

D2.2 Local effects of vehicle collision

For the assessment or upgrading of parapets to existing structures, the 'do-nothing' option is generally preferred. This option accepts the impact damage to the supporting structure when it occurs, and repairs would then be undertaken, preferably at the same time as replacing/repairing the parapet. Therefore the assessment of parapet supporting members is to be governed by the absolute minimum strength requirement, covered in D3.

D2.3 Absolute minimum resistance assessment criteria

In exceptional cases, where damage to the supporting member could lead to global consequence (that is collapse of a bridge, or full closure of a highway bridge in the period before repairs are completed), the verification of parapet supporting members is to be governed by the requirements of CS 454 [Ref 1.N] and other relevant standards applicable for the assessment of the structure and parapet supporting member as agreed with the TAA.

D3 Absolute minimum resistance assessment criteria

The absolute minimum resistance requirement for a parapet supporting member is the resistance necessary to ensure the containment level requirement for the parapet is provided. The relevant assessment criteria are given below:

1) single impact force and force height obtained from Table D1. The force is applied normal to the line of the parapet and at a height measured above the level of the supporting member.;
2) single wheel load obtained from Table D2. The load is applied in a position which produces the most severe effect, and should be distributed over a circular or square contact area, assuming an effective pressure of 1.1 N/mm^2.; and,
3) $\gamma_{\text{fl}} = 1.00$ and $\gamma_{\text{f3}} = 1.00$ at the ultimate limit state.

Simple methods of assessment tend to yield conservative results. Should an initial simplified assessment indicate member failure, more refined techniques should be considered, subject to agreement with the TAA.

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Table D.1 Assessment impact force dynamic deflection

Containment level	Dynamic deflection of road restraint system (m)											Force height (m)
	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00	
N1	69	52	42	35	30	27	24	21	19	18	17	0.60
N2	130	99	79	67	57	50	45	40	37	34	31	
L1	101	87	77	68	62	56	52	48	44	42	39	0.75
L2	139	127	117	108	100	94	88	83	79	74	71	
H4a	329	295	268	245	225	209	195	182	171	162	153	0.90

Notes:
1) Dynamic deflection is as defined in BS EN 1317-2 [Ref 15.N].
2) Guidance on dynamic deflections for approved parapets can be obtained from the parapet manufacturers.
3) For older N1 or N2 containment metal parapets, dynamic deflection may be assumed to be 0.6 m.
4) Force height is measured above the level of the parapet supporting member.

Table D.2 Vertical wheel load (kN) versus containment level

Containment level				
N1	N2	L1	L2	H4a
25	25	60	60	100

D4 Global effects of vehicle collision

D4.1

Global effects need not be considered for bridges where the superstructure is fully integral with the substructure.

D4.2

Normal (N1/N2) and higher containment (L1/L2) parapets and safety barriers do not generally require consideration of global effects, except for L1/L2 containment rigid concrete barriers.

D4.3

All very-high containment (L4a) parapets/safety barriers and L1/L2 containment rigid concrete barriers require consideration of the following global assessment criteria:

1) Single 500 kN horizontal force. The force is applied at the top of and normal to the line of the parapet, over a length of 3 m;
2) $\gamma_{\text{fl}} = 1.00$ and $\gamma_{\text{f3}} = 1.00$ at serviceability limit state; and,
3) $\gamma_{\text{fl}} = 1.25$ and $\gamma_{\text{f3}} = 1.00$ at ultimate limit state.

The force should only be considered in relation to possible destabilisation of the structure, typically caused by failure of bearings or other deck restraint features for bridges, and geotechnical failure for retaining walls.

D4.4

Assessment failure of bearings/restraint features are generally considered acceptable, provided that such failure is not likely to lead to global consequence (that is the collapse or full closure of a bridge/retaining wall in the period before repairs are completed).

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Appendix E. Historical background for assessment of parapet remnant containment resistance

Parapets may be classified fundamentally into those which were built before the advent of design criteria based on containment in 1967, and those which have been built since that date. Most pre-1967 parapets have since been replaced or protected.

Pre-1967 parapets include a large number of masonry and brick parapets, generally associated with masonry arch bridges. These rely principally on their mass to keep the stresses in the mortar layers compressive under light-to-moderate impact loadings. They cannot be relied on to contain heavier vehicles travelling at speed, and secondary incidents may be initiated by falling debris. Many masonry parapets have been upgraded by providing a reinforced concrete stem which may have been integral with a horizontal slab spanning all or part of the way transversely across the bridge. Such reinforced concrete parapets may have been clad with masonry or brick slips to retain their original appearance.

Pre-1967 bridges, other than arches, often had a variety of parapet types, including wrought iron, cast iron, steel, timber, masonry, and in situ and precast concrete. The superstructures of these bridges may not have sufficient capacity to transmit the impact forces from parapets of modern containment standards, and, unlike arch bridges, may not have sufficient reserves of dead load capacity to allow additional strengthening members to be added to the structure. Consequently, upgrading has often comprised provision of protective safety barriers, or, more rarely, modifications to the structure.

Parapets built since 1967 (or earlier parapets known to be designed to BE 5 [Ref 1.I] were designed to standards which may be considered as broadly equivalent to current standards in terms of containment characteristics. Such parapets should be considered as acceptable unless there are known faults, as listed below:

1) parapets demonstrated to be incorrectly designed or constructed, (for example some early parapets were detailed without proper continuity in the longitudinal members);
2) parapets designed to lower containment criteria than would be required by current standards;
3) parapets which have exhibited significant deterioration. This includes steel members which have corroded and parapet fixings, to the extent that there has been a significant loss of design capacity.;
4) parapets with other known material problems, including embrittlement in certain earlier aluminium parapet types; and,
5) parapets which have been damaged and have not been satisfactorily repaired, where there would be significant loss of design capacity.

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Highway Structures & Bridges
Inspection & Assessment

CS 461 - ENAA
England National Application Annex for Assessment and upgrading of in-service parapets

(formerly BA 37/92, IAN 97/07)

Version 0.0.1

Summary
There are no specific requirements for National Highways supplementary or alternative to those given in CS 461.

Feedback and Enquiries
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Latest release notes

Document code	Version number	Date of publication of relevant change	Changes made to	Type of change
CS 461 - ENAA	0.0.**1**	January 2023	Core document, England NAA, Northern Ireland NAA	Incremental change to notes and editorial updates
England National Application Annex to CS 461.				

Previous versions

Document code	Version number	Date of publication of relevant change	Changes made to	Type of change
CS 461	0	March 2020		

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Highway Structures & Bridges
Inspection & Assessment

CS 461 - NINAA
Northern Ireland National Application Annex for Assessment and upgrading of in-service parapets

(formerly BA 37/92, IAN 97/07)

Version 0.0.1

Summary
This National Application Annex contains the Department for Infrastructure Northern Ireland specific requirements related to assessment and upgrading of in-service parapets.

Feedback and Enquiries
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Document code	Version number	Date of publication of relevant change	Changes made to	Type of change
CS 461 - NINAA	0.0.**1**	January 2023	Northern Ireland NAA	Incremental change to notes and editorial updates
Department for Infrastructure Northern Ireland National Application Annex to CS 461.				

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Document code	Version number	Date of publication of relevant change	Changes made to	Type of change
CS 461	0	March 2020		

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Foreword

Publishing information

This document is published by National Highways on behalf of Department for Infrastructure, Northern Ireland.

This document supersedes BA 37/92 and IAN 97/07, which are withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

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Introduction

Background

This National Application Annex gives the Department for Infrastructure, Northern Ireland requirements related to the implementation of DMRB document CS 461 [Ref 1.N].

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 2.N] apply to this document.

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Abbreviations and symbols

Abbreviations

Abbreviation	Definition
DMRB	Design Manual for Roads and Bridges

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NI/1. Special requirements for Northern Ireland (CS 461, 1.2 & 1.7)

Requirements

NI/1.1 The following text shall apply with reference to clauses 1.2 and 1.7 in the scope of CS 461 [Ref 1.N].

NI/1.2 In Northern Ireland, this document shall be applicable for all maintenance (excluding routine maintenance) and improvement works on the motorway and all-purpose trunk road network.

NI/1.2.1 For all other roads in Northern Ireland which are maintainable by the Department for Infrastructure, the Overseeing Organisation should be contacted for further guidance.

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NI/2. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref.	Document
Ref 1.N	National Highways. CS 461, 'Assessment and upgrading of in-service parapets'
Ref 2.N	National Highways. GG 101, 'Introduction to the Design Manual for Roads and Bridges'

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Design Manual for Roads and Bridges

Highway Structures & Bridges
Inspection & Assessment

CS 461
Scotland National Application Annex to CS 461 Assessment and upgrading of in-service parapets

(formerly BA 37/92, IAN 97/07)

Revision 0

Summary
There are no specific requirements for Transport Scotland supplementary or alternative to those given in CS 461.

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Release notes

Version	Date	Details of amendments
0	Mar 2020	Transport Scotland National Application Annex to CS 461.

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Design Manual for Roads and Bridges

Llywodraeth Cymru
Welsh Government

Highway Structures & Bridges
Inspection & Assessment

CS 461
Wales National Application Annex to CS 461 Assessment and upgrading of in-service parapets

(formerly BA 37/92, IAN 97/07)

Revision 0

Summary
There are no specific requirements for Welsh Government supplementary or alternative to those given in CS 461.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Welsh Government team. The email address for all enquiries and feedback is: Standards_Feedback_and_Enquiries@gov.wales

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Release notes

Version	Date	Details of amendments
0	Mar 2020	Welsh Government National Application Annex to CS 461.

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