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Railway Structures Derailment Risk Assessment: Guidance for Track Engineers

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Introduction

Train derailments can cause:

- Harm to people
- Railway operational delays and revenue impact
- Damage to rolling stock, railway infrastructure and 3rd party property
- Financial and legal penalties
- Reputational damage

Photo credit: R~P~M on VisualHunt

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Causes of derailments may include:

- S&C-specific causes – e.g. Potters Bar 2002 & Grayrigg 2007
- Train wheelset/bogie/suspension/loading issues – e.g. Ely Dock Jn. 2007
- Track geometry issues (e.g. twist faults, cyclic top, horizontal/vertical misalignments, etc.) – e.g. Willesden High Level Jn. 2019 & Foreign Ore Branch Jn. 2008
- Defective/broken rails – e.g. Hadfield 2000
- Defective/broken rail support systems (e.g. failures of fastenings, longitudinal timbers, baseplates, etc.) – e.g. Eastleigh 2020 & Wanstead Park 2020
- Obstructions of the track (e.g. landslips, fallen trees, 3rd party interventions, other rail/road vehicles, etc.) – e.g. Summit Tunnel 2010 & Carmont 2020
- Operational issues (e.g. train over-speeding, signaller error, etc.) – e.g. Watford Jn. Yard 2005 & Knaresborough 2015

<u>Derailment at Southsea</u>

Photo credit: Southsea_Matt on Visualhunt

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Statistics Alert!

According to the Rail Safety and Standards Board (RSSB):

- Seven train derailments occurred in the 2017-18 financial year, two involving passenger trains, two with empty coaching stock, and three involving freight trains
- In context, in the same financial year, there were 215,826 freight train movements and 1.71 billion passenger journeys

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Photo credit: foilman on Visualhunt

Definitions and inputs for consideration

The term ‘railway structure’ includes any structural element or building which could be adversely affected and potentially fail, as a result of being struck by a derailed train. Examples of railway structures include overbridges, underbridges, lineside or station buildings.

Track infrastructure enhancement related issues, which may trigger the potential increase in risk to railway structures include:

- Line speed increases
- The introduction of new S&C to a location, or the remodelling existing S&C
- Track layout remodelling, or significant realignment

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1. Derailment at lineside and overline structures

Key British Standards and RSSB guidance documents for derailment risk assessment include:

- BS EN 1991-1-7:2006+A1:2014 ‘*Eurocode 1: Actions on Structures Part 1-7: General Actions – Accidental Actions*’ *(plus UK National Annex)*
- BS EN 1991-2:2003 ‘*Eurocode 1: Actions on Structures Part 2: Traffic Loads on Bridges*’ *(plus UK National Annex)*
- GCGN5612 *‘Rail Traffic Loading Requirements for the Design of Railway Structures’*

BRITISH STANDARD

BS EN 1991-1-7:2006 +A1:2014

Incorporating corrigendum February 2010

Eurocode 1 — Actions on structures —

Part 1-7: General actions — Accidental actions

BRITISH STANDARD

BS EN 1991-2:2003

Incorporating Corrigenda December 2004 and February 2010

Eurocode 1: Actions on structures —

Part 2: Traffic loads on bridges

NA+A1:2020 to BS EN 1991-2:2003

Incorporating Corrigendum No. 1

BSI Standards Publication

UK National Annex to Eurocode 1: Actions on structures —

Part 2: Traffic loads on bridges

Rail Industry Guidance Note
GCGN5612
Issue: Two
Date: September 2018

Rail Traffic Loading Requirements for the Design of Railway Structures

Synopsis

This document gives guidance on the background and application of the rail traffic loading requirements for the design of railway structures set out in BS EN 1990:2002+A1:2005, BS EN 1991-2:2003 and BS EN 1991-1-7:2006+A1:2014, and their National Annexes.

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The British Standards and RSSB guidance previously mentioned, denote the requirements to be considered and mitigated against. These include:

1. Removing/reducing the risk to structures where people will congregate. (e.g. footbridges, overbridges, signal boxes, station buildings, etc.)
2. Consideration of the occupancy of adjacent buildings, pedestrians and vehicles using the structure and the occupancy of passing trains.
3. Designing of the structure to:
   a) Resist impact (i.e. in-built structural redundancy or protection of structural elements by deflection or absorption measures)
   b) Reduce the likelihood of impact (i.e. place structural elements away from harm)
   c) Reduce designed structure loadings (subject to specific risk assessment)
4. Understanding the category of the structure, which is usually categorised as either:
   a) Class A – occupied buildings (the highest risk structures, due to the potential damage and harm to people)
   b) Class B – bridges and unoccupied buildings
5. Identification of changes to the infrastructure which may increase the severity of damage to a structure and harm to people (e.g. a line speed increase, track layout remodelling, etc.)
6. Calculation of the cost of structure enhancement measures (i.e. as per Item 3 above), using risk assessment to support alternative risk mitigation measures, where these costs are deemed unreasonably high

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GCGN5612 lists the following risk factors:

G5.1.3 Risk factors

G5.1.3.1 In principle, wherever structures are adjacent to, or span above, the track they are vulnerable to impact from a derailed train. In practice, the vulnerability of a structure depends on a number of factors including the following:

a) Proximity of the structure's supports to the track.
b) Degree of support protection provided.
c) Robustness of the supports and the supported structure.
d) Structural redundancy.
e) Likelihood of a derailment.
f) Passing speed of the train.
g) Track alignment and features in the vicinity of the structure.
h) Ground topography adjacent to the track.

Photo credit: MTAPhotos on VisualHunt.com

<u>Excerpt from GCGN5612</u>

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GCGN5612 also provides guidance on how to assess the risks to railway structures, via a calculated risk assessment scoring process. This is achieved by taking formulae, statistics and values from UIC Code 777-2R ‘*Structures Built Over Railway Lines – Construction Requirements in the Track Zone*’.

General factors influencing the risks to structures include:

- The number of people on the structure
- The number of people on the train
- The permissible line speed
- The number of tracks
- The numbers and types of trains using the line (passenger or freight)
- The presence of S&C
- The track geometry
- The predicted rate of deceleration of a derailed train
- The predicted lateral distance of a derailed train from the structure
- The configuration of the structure and proximity of structural elements close to the tracks
- The presence of existing derailed train energy deflection or impact absorption measures

UIC CODE **777-2**

2nd edition, September 2002

Original

R

Structures built over railway lines - Construction requirements in the track zone

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Designated as the most critical structures, Class A structures have assigned danger zones, to assist risk assessment of structural elements.

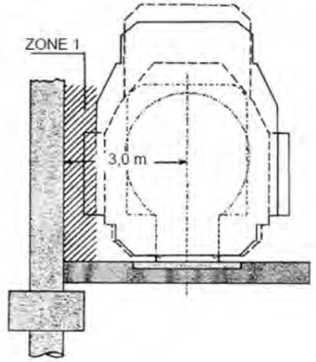


Fig. 1 - ZONE 1

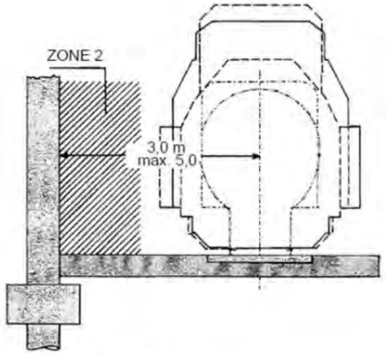
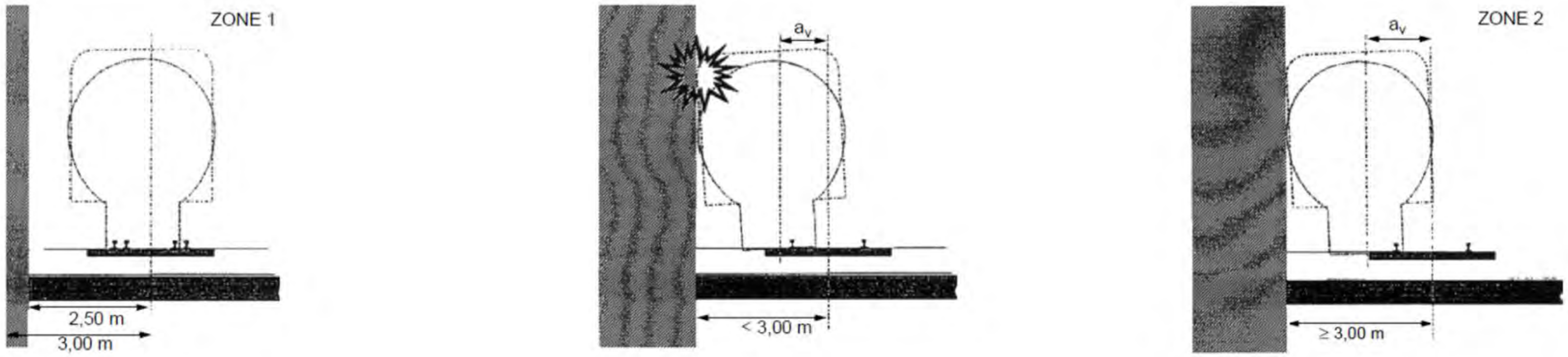


Fig. 2 - ZONE 2



Minimum distance to wall according to clearance-gauge requirements a = 2,50 m

Contact with the wall occurs if the track distance is < 3,00 m. The wall serves to check the derailed vehicles; this function is fulfilled satisfactorily if there are no major protections, thus allowing the accident consequences to be reduced to a minimum.

a_v = 1,40 m displacement factor. From a wall distance of ≥ 3,0 m upwards the rail situated nearest to the wall will act as check rail.

Excerpts from UIC 777-2R

Notes:

1. BS EN 1991-1 shows Zone 2 ‘d’ for distance beyond the track centreline where 0kN force is encountered as 5m; however for GB railways (with 1435mm gauge), the UK National Annex defines the ‘hazard zone’ as 4.5m from the cess rail, therefore ‘d’ =5.2m from the track centreline.
2. Zone 3 is classified as the area behind a buffer stop, which is discussed in Section 3 of this presentation.

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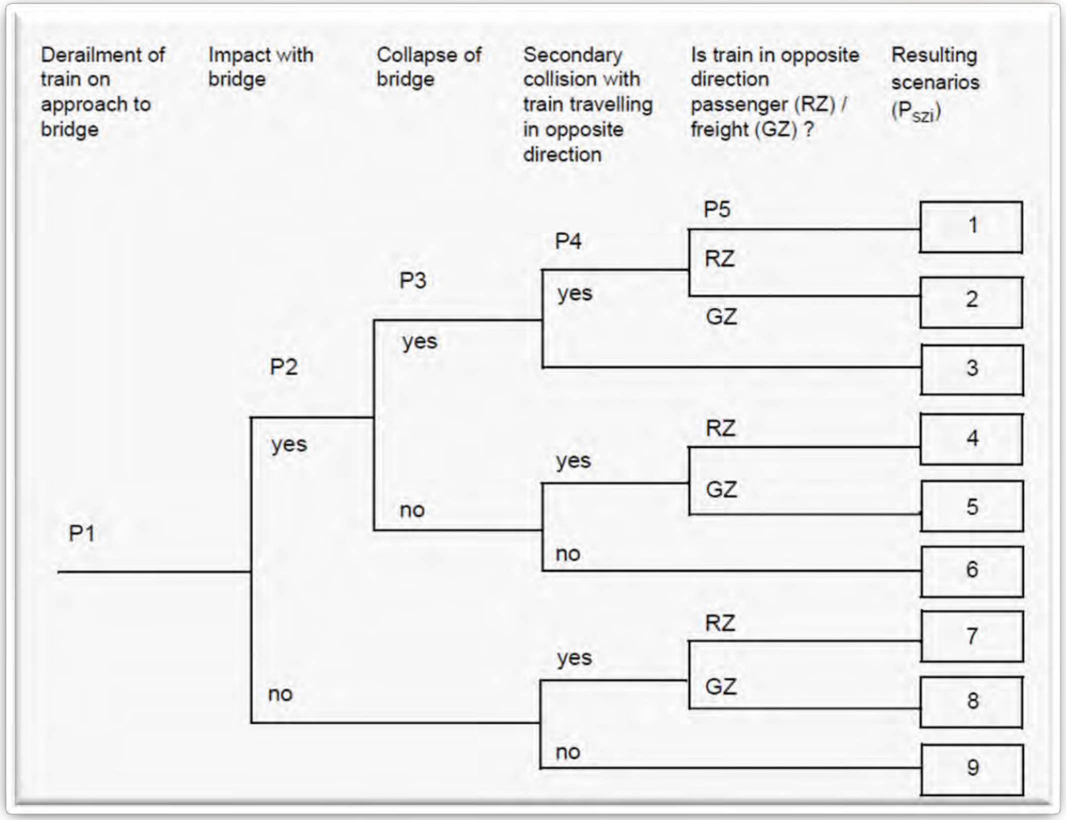
The risk assessment process may be undertaken using the equations and tabulated values listed in GCGN5612, from RSSB statistics and in UIC777-2R to calculate values for:

- Likelihood of a train becoming derailed on the approach to a bridge
- Likelihood of the train colliding with the bridge
- Likelihood of the bridge collapsing as a result of the impact
- Likelihood of a train travelling on another track colliding with the derailed train
- Type of train travelling in the opposite direction
- Likelihood of the resulting scenarios (with resultant event tree).
- The annual risk of derailment

N.B. the calculated likelihood/risk values are expressed as ‘1 in X’.



Excerpt from UIC 777-2R of Event Tree

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Risk mitigation measures cost assessment

If further supporting evidence is required to decide on the appropriate risk mitigation measures, additional cost calculations may be produced. From the likelihood of derailment and theoretical number of worst-case fatalities calculations, costs for implementing structural improvements can be assessed, based upon the equations noted in GCGN5612, namely:

- The annual cost of preventing fatalities, based upon industry-defined values
- The theoretical annual discounted cost of providing preventative measures, including installation and maintenance

The effectiveness of the risk reduction measures is then obtained by comparing the ratio of the two values. Where the ratio is less than 1, the measures may be considered appropriate. However, further guidance is available from the RSSB via the 'Taking Safe Decisions' guidance document, or through additional specialist consultation.

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Once the risk assessment process is completed, it can be discussed with key stakeholders. NR/L2/TRK/2102 *'Design and Construction of Track'* requires the provision of guard rails to be discussed between the Network Rail Regional Engineers for Track, Civils and Geotech, as noted below.

6.5.3 Guard rails on viaducts or other at risk structures and locations to provide protection from a derailed vehicle – design

When track is to be renewed adjacent to parapets and the edges of embankments with a vertical face or other at risk locations where the consequence of a derailment is high the Regional Engineer (Track) shall consult the Regional Engineer (Civils) and Regional Engineer (Geotech), and any other affected asset owner on what derailment or containment system is to be provided.

The following factors should be taken into account in the review:

a) line speed;

b) curvature;

c) height of structure;

d) dead load on the structure;

e) clearances to structural members;

f) ballast depth;

g) consequential risk;

h) type and frequency of traffic;

i) existence of derailment-containment kerbs; and

j) condition of the structure and parapet.

At the approach end, the parallel portion of guard rails shall extend 18 m beyond the face of the abutment (or the location at risk) and include a set of gathering rails.

Where guard rails already exist and they are removed, the justification for their removal shall be recorded by the Regional Engineer (Track) in consultation with the Regional Engineer (Civils).

A derailment containment kerb should extend at least 300 mm above rail level. It should comprise:

k) a structural metallic member; or

l) not less than 450 mm width of brickwork; or

m) not less than 300 mm width of reinforced concrete.

Guard rails should be designed and installed so they do not increase the risk of track buckling.

10.11 Provision of continuous check rails

Consider whether to provide a check rail on curves with radii in the range of 201 m to 300 m where high volumes of traffic can be expected. When assessing these locations take into account:

a) the requirements for the provision of effective lubrication;

b) current and future operations and usage of the route;

c) deterioration history for the curve;

d) likely consequences of any derailment; and

e) surrounding environment.

Excerpts from NR/L2/TRK/2102 Issue 9

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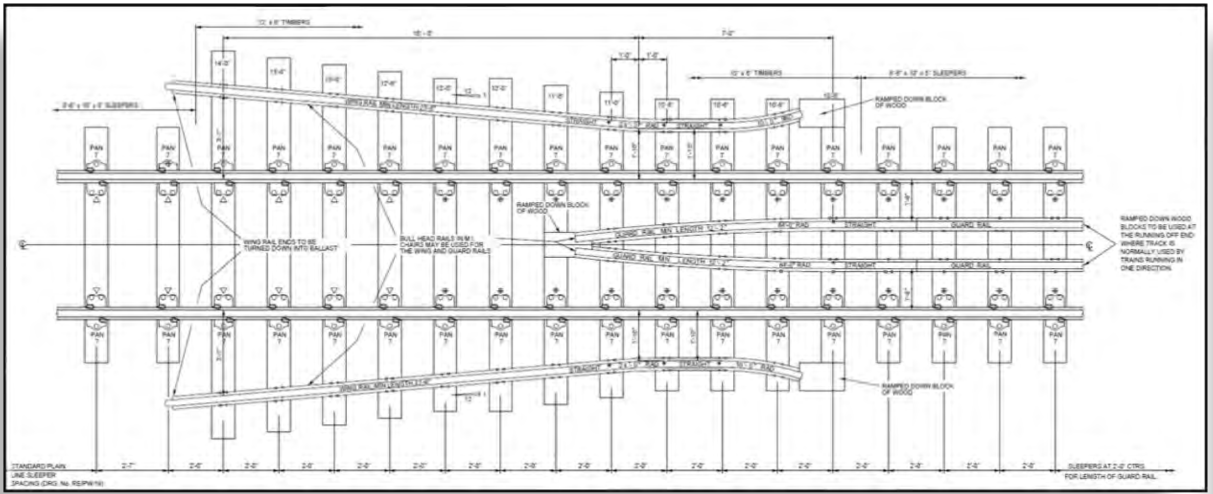
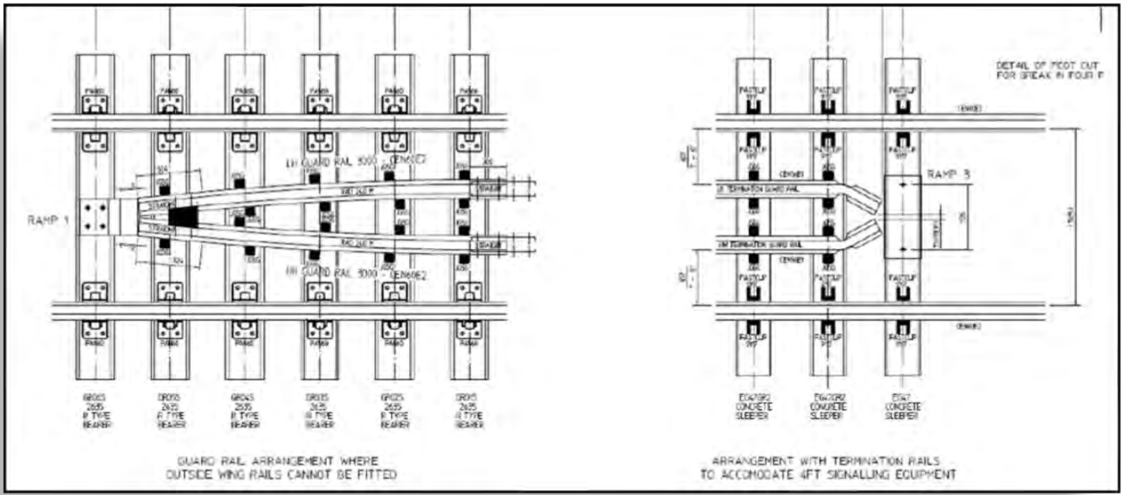
Track works which could reduce the impact from a derailment include inside and outside guard rails, or check rails.

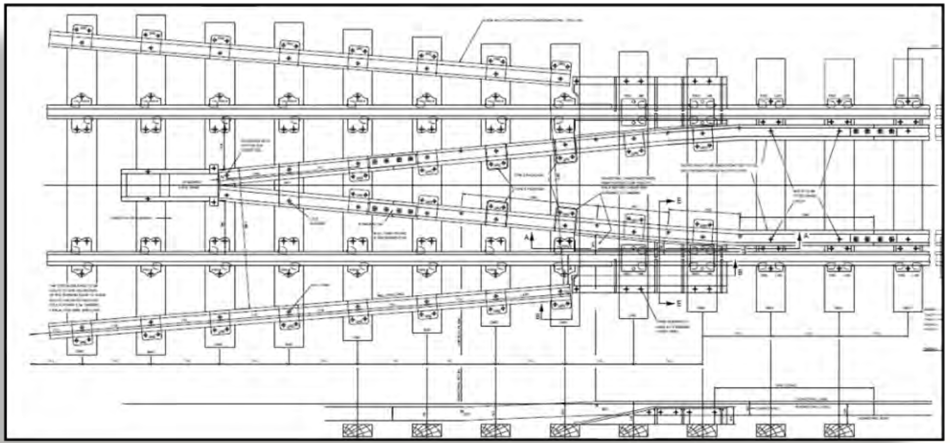


Extract from RE/PW/077



Extract from RE/PW/1210

Photo credit: chooyutshing on Visualhunt



Extract from RE/PW/086

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Trap points and derailer devices may also help to reduce the impact of a potential derailment, by deliberately derailing an unauthorised train movement in a strategically low risk area.

Photo credit: Derell Licht on VisualHunt

Photo credit: Kecko on VisualHunt

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Risk assessment example from the Gatwick Station Project:

GSP Derailment Report.pdf

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2. Derailment at underline structures and embankments

As previously mentioned, the British Standards and RSSB guidance provides information on the key parameters to be considered within the bridge design.

For underline structures, they should be able to resist derailment and support a derailed train.

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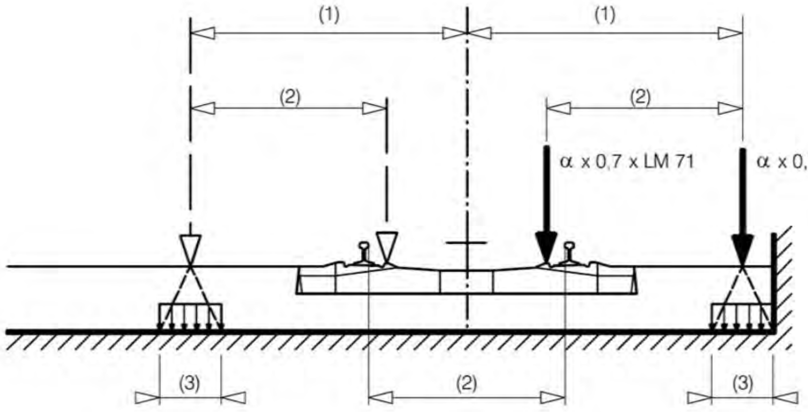
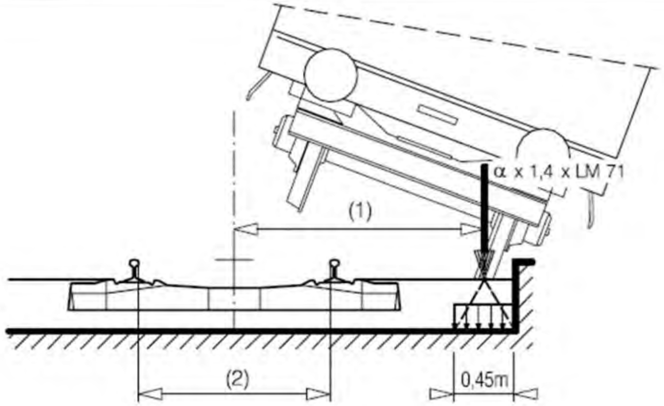
Background information: The bridge design is to consider derailment in two scenarios, as shown below.



Key
(1) max. 1,5*s* or less if against wall
(2) Track gauge *s*
(3) For ballasted decks the point forces may be assumed to be distributed on a square of side 450mm at the top of the deck.

Figure 6.26 - Design Situation I - equivalent load Q_{A1d} and q_{A1d}



Key
(1) Load acting on edge of structure
(2) Track gauge *s*

Figure 6.27 - Design Situation II - equivalent load q_{A2d}

6.7 Derailment and other actions for railway bridges

(1)P Railway structures shall be designed in such a way that, in the event of a derailment, the resulting damage to the bridge (in particular overturning or the collapse of the structure as a whole) is limited to a minimum.

<u>Excerpts from BS EN 1991-2-2003</u>

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Structure protection and derailed train deflection examples include:

- Robust kerbs (concrete, masonry or metallic elements)
- Concrete, masonry or metallic bridge pier protective elements

Image credit: ProjectMapper

Robust Kerbs

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3. <u>Derailment at terminal tracks</u>

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The requirements and risk management processes are noted within the following RSSB documents:

- GIGN5633 *'Recommendations for the Risk Assessment of Buffer Stops and End Impact Walls'*
- RIS-7016-INS *'Interface Between Station Platforms, Track, Trains and Buffer Stops'*

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Statistics Alert!

Between 1945 and 2007 there were 47 buffer stop collisions resulting in HMRI reports on the British Rail network. This resulted in:

- 11 Fatalities
- Over 960 injuries

However, from 2007 to 2017, there have been eight buffer stop collisions on the Main Line Network, five of which resulted in RAIB reports with:

- No fatalities
- 35 – 40 injuries

Photo credit: R~P~M on Visualhunt

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The objective of the assessment is to prevent or reduce (as far is as reasonably practicable) the harm to people and sensitive structural elements.

Recommended mitigation measures include:

- Provision of buffer stops
- Provision of end impact walls
- Provision of sand drags

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GIGN5633 provides a method of assessing the risks (UIC 777-2R also includes provision), including a spreadsheet-based collision risk proforma, which is commonly used on GB railways.

Some of the key criteria required for the risk assessment include:

[GIGN5633-Iss1 Buffer Stop Risk Assessment.xlsx]()

Factors affecting buffer stop risk

- History of buffer stop collisions
- Normal stopping position distance from buffer stop
- Gradient on approach to buffer stop
- Permissible speed on approach to buffer stop
- Visibility
- Countdown markers
- Driver distractions
- Rail head conditions

Factors affecting buffer stop risk

- Type of buffer stop
- Condition of buffer stop
- Type of track
- Condition of track

Factors affecting buffer stop risk

- Interface compatibility of rolling stock with buffer top
- Energy compatibility of rolling stock with buffer top
- End impact wall 1.3m above rail level

Factor affecting buffer stop risk

- Number of people in area A
- Number of people in area B
- Number of people in area C
- Obstruction factor
- Which part of the overrun area is the structure located?
- Number of passengers, public or staff that will be affected by structural failure

Factor affecting buffer stop risk

- Which part of the overrun area is the structure located
- Probability of collapse if struck by a train overrun
- Number of passengers, public or staff that will be affected by structural collapse
- Distance from buffer stop to decking

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If the risks are deemed unacceptable, additional safety measures which may be employed include:

- Improved illumination
- Countdown marker boards
- Permanent speed restrictions on the approach to the buffer stop
- Screening or the removal of driver distractions

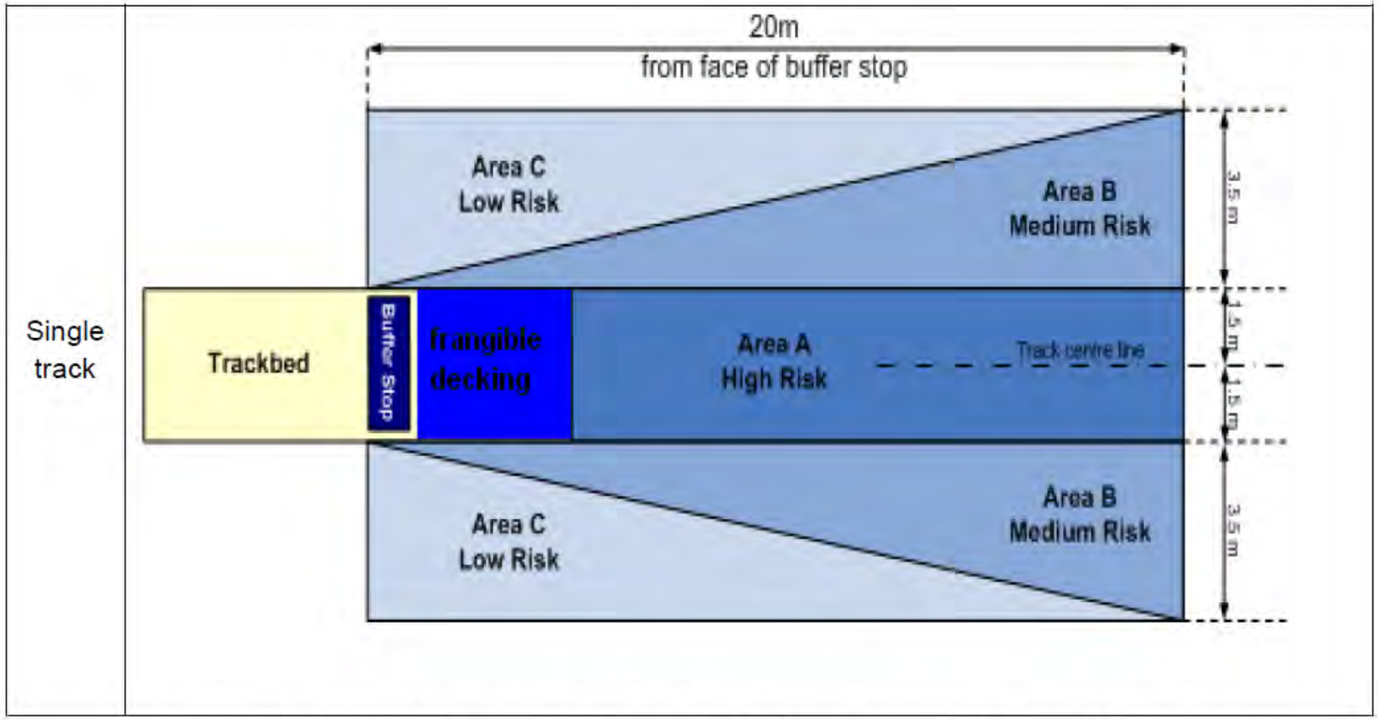

Figure G 3 The overrun risk zone divided into risk areas A, B, C and the frangible decking (not to scale)

Example of the overrun risk zone for an energy absorbing buffer stop

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4. Additional Considerations

Derailment impact reduction measures and risk assessment initiatives are currently being investigated by RSSB, including:

a. Research project 'Devices to Guide Derailed Trains (T1143), published in April 2021, which discusses the employment of:
   - Robust kerbs
   - Guard rails/check rails
   - Rolling stock solutions (e.g. axle box-mounted L-shape brackets, central bogie-mounted stoppers)

b. An enhanced route risk assessment tool (a prototype spread sheet-based calculation of risks)

RSSB Derailment
‹ Based Tool_stalyt

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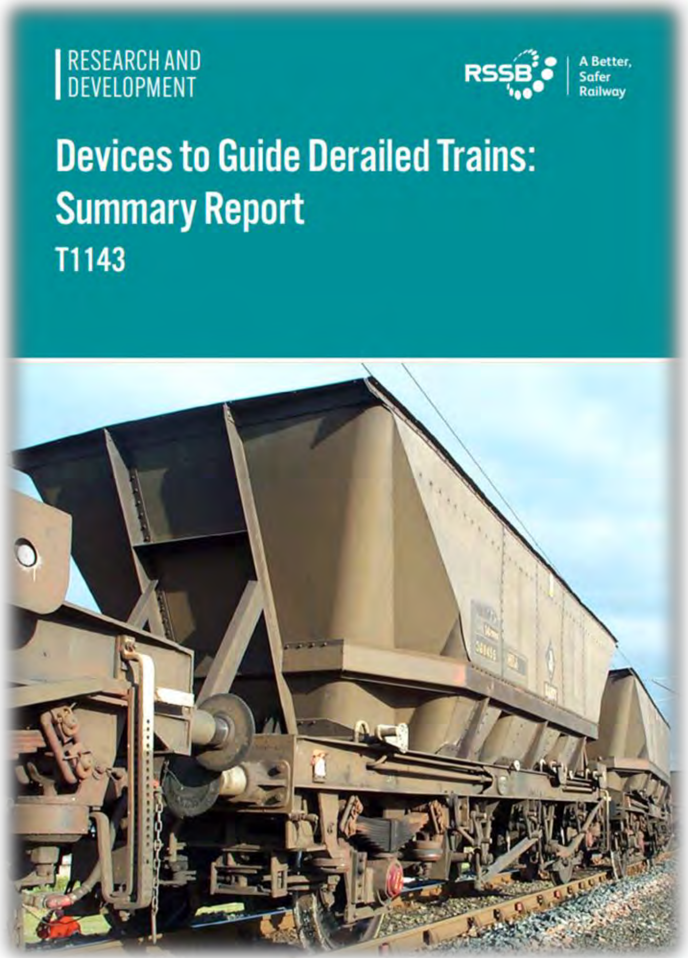

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Acknowledgements and Clarifications

The content is intended for information only, expressing the views of the author and is not intended as a definitive guide.

Thank you for your participation.

Any Questions?

Photo credit: Unknown