

**Railway Group Standard**  
**GM/RT2100**  
**Issue Five**  
**Date June 2012**

## Requirements for Rail Vehicle Structures

### Synopsis

This document mandates requirements for the design and integrity of rail vehicle structures for both primary and secondary structures, including interior crashworthiness.

This document contains requirements that are amended under the Railway Group Standards Code (Issue Three) as a small scale change. Reference to the amended requirements is made in the 'Issue record'. All other parts of the document are unchanged from the previous issue.

Copyright in the Railway Group Standards is owned by Rail Safety and Standards Board Limited. All rights are hereby reserved. No Railway Group Standard (in whole or in part) may be reproduced, stored in a retrieval system, or transmitted, in any form or means, without the prior written permission of Rail Safety and Standards Board Limited, or as expressly permitted by law.

RSSB Members are granted copyright licence in accordance with the Constitution Agreement relating to Rail Safety and Standards Board Limited.

In circumstances where Rail Safety and Standards Board Limited has granted a particular person or organisation permission to copy extracts from Railway Group Standards, Rail Safety and Standards Board Limited accepts no responsibility for, and excludes all liability in connection with, the use of such extracts, or any claims arising therefrom. This disclaimer applies to all forms of media in which extracts from Railway Group Standards may be reproduced.

**Published by:**

**RSSB**  
**Block 2 Angel Square**  
**1 Torrens Street**  
**London EC1V 1NY**

© Copyright 2012  
Rail Safety and Standards Board Limited

 **Documents**  
Document Sharing Hub

**Railway Group Standard****GM/RT2100****Issue Five****Date** June 2012

# Requirements for Rail Vehicle Structures

## Issue record

| Issue | Date          | Comments                                                                                                                                                                                                                                                                                                                   |
|-------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| One   | July 1994     | Original document<br>Supersedes GM/TT0265                                                                                                                                                                                                                                                                                  |
| Two   | April 1997    | Supersedes issue one                                                                                                                                                                                                                                                                                                       |
| Three | October 2000  | Supersedes issue two as a result of review.<br>Incorporates and supersedes the requirements of GM/TT0179 and GM/TT0303                                                                                                                                                                                                     |
| Four  | December 2010 | Supersedes GM/RT2100 issue three, GM/RT2101 issue one, GM/RT2260 issue three, GM/RT2456 issue two, GM/RT2457 issue one, GM/RT2463 issue one, AV/ST9001 issue one and Part 3 of GM/RT2160 issue three, clauses 4.2, 5.5 and 5.7 of GM/RT2162 issue one and clauses 4.1 - 4.5 inclusive, 4.7 and 4.8 of GM/RT2190 issue two. |
| Five  | June 2012     | Supersedes issue four.<br>Small scale change amendment to include two new clauses in the standard at 8.1.1 and 8.1.2 re-instating a measure omitted at the previous revision but with two new measures and renumbering the existing clauses in 8.1.                                                                        |

Amended or additional parts of revised pages have been marked by a vertical black line in the adjacent margin.

## Superseded documents

The following Railway Group documents are superseded, either in whole or in part as indicated:

| Superseded documents                                                             | Sections superseded | Date when sections are superseded |
|----------------------------------------------------------------------------------|---------------------|-----------------------------------|
| GM/RT2100, issue four, December 2010<br>Requirements for Rail Vehicle Structures | All                 | 01 September 2012                 |

GM/RT2100, issue four, ceases to be in force and is withdrawn as of 01 September 2012.

## Supply

The authoritative version of this document is available at [www.rgsonline.co.uk](http://www.rgsonline.co.uk).  
Uncontrolled copies of this document can be obtained from Communications, RSSB, Block 2 Angel Square, 1 Torrens Street, London EC1V 1NY, telephone 020 3142 5400 or e-mail [enquirydesk@rssb.co.uk](mailto:enquirydesk@rssb.co.uk). Other Standards and associated documents can also be viewed at [www.rgsonline.co.uk](http://www.rgsonline.co.uk).

# Requirements for Rail Vehicle Structures

Railway Group Standard

GM/RT2100

Issue Five

Date June 2012

## Contents

| Section       | Description                                                               | Page      |
|---------------|---------------------------------------------------------------------------|-----------|
| <b>Part 1</b> | <b>Purpose and Introduction</b>                                           | <b>5</b>  |
| 1.1           | Purpose                                                                   | 5         |
| 1.2           | Introduction                                                              | 5         |
| 1.3           | Approval and authorisation of this document                               | 6         |
| <b>Part 2</b> | <b>Structural Requirements for Rail Vehicles</b>                          | <b>7</b>  |
| 2.1           | Common structural requirements                                            | 7         |
| <b>Part 3</b> | <b>Structural Requirements for Rail Vehicle Bodies</b>                    | <b>10</b> |
| 3.1           | Structural requirements for all vehicle types                             | 10        |
| 3.2           | Requirements for equipment attached to vehicle bodies                     | 10        |
| 3.3           | Requirements for vehicles carrying passengers, personnel or traincrew     | 11        |
| 3.4           | Requirements for freight vehicles                                         | 11        |
| <b>Part 4</b> | <b>Structural Elements for Bogies and Suspension</b>                      | <b>13</b> |
| 4.1           | Bogies and running gear                                                   | 13        |
| 4.2           | Body to bogie attachments                                                 | 14        |
| 4.3           | Equipment attached to bogie frames                                        | 15        |
| 4.4           | Equipment attached to axleboxes                                           | 16        |
| 4.5           | Lifeguards                                                                | 16        |
| <b>Part 5</b> | <b>Secondary Structural Elements</b>                                      | <b>18</b> |
| 5.1           | Common design requirements                                                | 18        |
| 5.2           | Windscreens                                                               | 18        |
| 5.3           | Bodyside windows                                                          | 18        |
| 5.4           | External vehicle doors                                                    | 21        |
| 5.5           | External steps, external grab rails and external handles                  | 21        |
| 5.6           | Inter-vehicle gangways                                                    | 22        |
| <b>Part 6</b> | <b>Rail Vehicle Elements Interfacing with Passengers and Traincrew</b>    | <b>24</b> |
| 6.1           | Vehicle interior design requirements                                      | 24        |
| 6.2           | Seats for passengers, personnel or traincrew                              | 27        |
| 6.3           | Fixed tables                                                              | 29        |
| 6.4           | Folding seat back tables                                                  | 30        |
| 6.5           | Interior doors, glazing and partitions                                    | 30        |
| 6.6           | Grab handles, poles, rails and hand holds                                 | 31        |
| 6.7           | Interior fixtures and fittings                                            | 32        |
| 6.8           | Luggage stowage                                                           | 33        |
| 6.9           | Cabs                                                                      | 33        |
| <b>Part 7</b> | <b>Aerodynamic Rail Vehicle Loads</b>                                     | <b>35</b> |
| 7.1           | Vehicle resistance to aerodynamic loads                                   | 35        |
| 7.2           | Generation of pressure pulses by vehicles                                 | 36        |
| 7.3           | Aerodynamic loads acting on traincrew and passengers                      | 36        |
| <b>Part 8</b> | <b>Mechanical Coupling of Rail Vehicles</b>                               | <b>37</b> |
| 8.1           | Design requirements for coupling systems                                  | 37        |
| 8.2           | Design requirements for drawgear                                          | 38        |
| 8.3           | Design requirements for buffers                                           | 38        |
| 8.4           | Design requirements for rescue and recovery coupling systems              | 39        |
| <b>Part 9</b> | <b>Lifting, Jacking, Recovery and Emergency Movement of Rail Vehicles</b> | <b>40</b> |

**Railway Group Standard****GM/RT2100****Issue** Five**Date** June 2012**Requirements for Rail Vehicle Structures**

|                    |                                                                               |           |
|--------------------|-------------------------------------------------------------------------------|-----------|
| 9.1                | Design requirements for the safe lifting of rail vehicles                     | 40        |
| 9.2                | Lifting and jacking points                                                    | 40        |
| 9.3                | Wheelskates                                                                   | 42        |
| <b>Part 10</b>     | <b>Application of this document</b>                                           | <b>45</b> |
| 10.1               | Application - infrastructure managers                                         | 45        |
| 10.2               | Application - railway undertakings                                            | 45        |
| 10.3               | Health and safety responsibilities                                            | 45        |
| <b>Appendices</b>  |                                                                               | <b>46</b> |
| Appendix A         | Derivation of Load Cases from Test or Service Data                            | 46        |
| Appendix B         | Bodyside Windows - Small Missile Test Procedure                               | 47        |
| Appendix C         | Bodyside Windows - Passenger Containment Test Procedures                      | 49        |
| Appendix D         | Bodyside Windows - Pressure Pulse Test Procedure                              | 51        |
| Appendix E         | Dynamic Test Procedures for Passenger Seats or Tables                         | 54        |
| Appendix F         | Test Procedure for Cab Seat Zone                                              | 57        |
| Appendix G         | Preparation and Setting Up Procedures for Anthropomorphic Test Devices (ATDs) | 59        |
| Appendix H         | Injury Criteria and Survival Space                                            | 63        |
| Appendix J         | Symbols for Lifting / Jacking Points                                          | 68        |
| <b>Definitions</b> |                                                                               | <b>70</b> |
| <b>References</b>  |                                                                               | <b>75</b> |
| <b>Tables</b>      |                                                                               |           |
| Table 1            | Maximum speeds for vehicles fitted with wheelskates                           | 44        |

# Requirements for Rail Vehicle Structures

## Part 1 Purpose and Introduction

### 1.1 Purpose

- 1.1.1 This document mandates requirements for the design and integrity of rail vehicles structures for both primary and secondary structures, including interior crashworthiness.

### 1.2 Introduction

#### 1.2.1 Background

- 1.2.1.1 The implementation of the Technical Specifications for Interoperability (TSIs) mandated through a series of European Union Directives has resulted in a review of all requirements set out in Railway Group Standards.
- 1.2.1.2 Under the Strategy for Standards Management, RSSB has given a commitment to review all of its standards with a view to mandating only those requirements that define the interface and the need for co-operation between different categories of duty holder to manage risk safely.
- 1.2.1.3 A review of the requirements set out in a suite of standards associated with rail vehicle structures has resulted in a revised Railway Group Standard on this topic.
- 1.2.1.4 This document only mandates those requirements that satisfy one or more of the following:
- a) Requirements that define the interface and the need for co-operation between different categories of duty holder to manage risk safely.
  - b) Requirements that are necessary to support an open point in a TSI and meet an essential requirement of the relevant EU Directive.
  - c) Requirements that are necessary for interworking on non-TSI conforming GB infrastructure.

#### 1.2.2 Principles

- 1.2.2.1 This document is based on the principles set out in the Railway Safety Principles and Guidance Part 1, which states that railway vehicles shall be designed, manufactured and maintained to ensure that as far as reasonably practicable:
- a) The safety of occupants is maintained under both normal operating conditions and abnormal conditions such as heavy shunts, derailments and collisions.
  - b) The vehicle interior design controls the risk of injury to occupants in the event of a collision or derailment.
  - c) The containment of passengers and traincrew inside a vehicle in the event of a collision is maximised.
  - d) Structural integrity is maintained over the life of the vehicle and risks due to fatigue failure are controlled.
  - e) Equipment and components remain attached in the event of heavy shunts, derailments and collisions.
  - f) The vehicle can be safely coupled and for maintenance and recovery safely jacked or lifted.

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

# Requirements for Rail Vehicle Structures

**1.2.3 Support to essential requirements**

1.2.3.1 The EU Directives applicable to Interoperability mandate that each TSI is required to address a number of essential requirements. In supporting specific open points in Rolling Stock TSIs, in particular the as yet unpublished Conventional Rail Locomotives and Passenger Rolling Stock TSI, the following essential requirements are addressed.

1.2.3.2 Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the community contains within Annex 3, Essential Requirements, the following relevant essential requirement:

*2.4.1 paragraph 1*

*The rolling stock structures and those of the links between vehicles must be designed in such a way as to protect the passenger and driving compartments in the event of collision or derailment.*

**1.2.4 Supporting documents**

1.2.4.1 The following Railway Group documents support this Railway Group Standard:

|           |                                                                                     |
|-----------|-------------------------------------------------------------------------------------|
| GM/GN2685 | Guidance on Lifting, Jacking, Recovery and Emergency Movement of Rail Vehicles      |
| GM/GN2686 | Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements                   |
| GM/GN2687 | Guidance on Rail Vehicle Interior Structure and Secondary Structural Elements       |
| GM/GN2688 | Guidance on the Structural Design of Rail Freight Wagons including Rail Tank Wagons |
| GM/GN2689 | Guidance on Mechanical Coupling of Rail Vehicles                                    |

**1.3 Approval and authorisation of this document**

1.3.1 The content of this document was approved by Rolling Stock Standards Committee on 17 February 2012.

1.3.2 This document was authorised by RSSB on 19 March 2012.

# Requirements for Rail Vehicle Structures

## Part 2 Structural Requirements for Rail Vehicles

### 2.1 Common structural requirements

#### 2.1.1 Vehicle condition and loading

- 2.1.1.1 Vehicles shall meet the requirements of this document over the full range of variations in vehicle condition that are likely to be experienced.
- 2.1.1.2 Account shall be taken of variations due to vehicle dimensional and mass tolerances, variations and asymmetries in payload, variations in vehicle maintenance condition, potential for corrosion, effects due to material ageing and any other relevant variables.
- 2.1.1.3 It is permissible for load cases derived from test, service or simulation data in accordance with Appendix A to be used to support or to replace the loads specified in this document where technically justified.
- 2.1.1.4 Railway vehicle structures shall be designed, manufactured and maintained using materials suitable for an external temperature range of -20°C to +40°C.
- 2.1.1.5 The general criteria set out in this section shall apply unless specific criteria are set out elsewhere in this document.

#### 2.1.2 Structural material properties

- 2.1.2.1 The suitability of structural materials (for example, the suitability of properties such as yield stress, tensile strength and elongation) shall be demonstrated by conformity with the requirements for structural material properties set out in the Euronorms mandated by this document. Where no requirements are set out in the Euronorms mandated by this document, the suitability of structural material properties shall be demonstrated by, in order of preference:
  - a) Conformity with an applicable Euronorm (EN).
  - b) Conformity with a British Standard (BS).
  - c) Conformity with another applicable national or international standard available in English (for example a Deutsches Institut für Normung (DIN) standard or an International Organization for Standardization (ISO) standard).
  - d) Evidence of established and successful use in other comparable railway vehicle structures.
  - e) Test data, evidence from other applications or a combination to demonstrate that the structural properties are sufficiently well understood to allow reliable predictions to be made of performance under fatigue, proof and ultimate load conditions.

#### 2.1.3 Structural failure

- 2.1.3.1 Structures shall be designed to ensure that, as far as is reasonably practicable, catastrophic failure does not occur, for example by rupture or gross instability, until the proof load conditions are exceeded by a significant margin. This shall be demonstrated by achieving the proof and ultimate load reserve factors set out 2.1.5 and 2.1.6.
- 2.1.3.2 Structures shall be designed to achieve their required fatigue life with a survival probability of at least 97.5%, when subjected to the cyclical loads associated with normal operation.

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

# Requirements for Rail Vehicle Structures

**2.1.4 Demonstration of structural integrity**

- 2.1.4.1 The satisfactory performance of railway vehicle structures and structural elements shall be demonstrated by calculation, testing, comparison with documented established practice on other vehicles or a combination of these methods.
- 2.1.4.2 In order to allow for uncertainties associated with methods of calculation and also for the consequences of failure, all proof or service load calculations or test results shall achieve the proof and ultimate load reserve factors as set out in 2.1.5 and 2.1.6.
- 2.1.4.3 Where an ultimate load is directly specified, an additional ultimate load reserve factor as set out in 2.1.6 shall not be applied.

**2.1.5 Proof load reserve factor**

- 2.1.5.1 The proof load reserve factor is defined as the allowable material proof stress divided by the calculated or measured stress for a given proof load case. The following requirements shall be satisfied:
  - a) Where there is to be no experimental verification, the proof load reserve factor shall not be less than 1.15.
  - b) Where there is to be experimental verification, it is permissible to reduce the proof load reserve factor to 1.0.
  - c) For glass or materials with similar characteristics the proof load reserve factor shall be equal to the ultimate load reserve factor and shall not be less than 1.5.
- 2.1.5.2 When determining the proof load reserve factor, where calculations predict relatively high localised stresses or 'hot spots', it is permissible for these stresses to be partially or fully discounted where it can be demonstrated that there will be no significant permanent deformation when the load is removed.
- 2.1.5.3 A localised proof load reserve factor less than 1.15 but greater than 1.0 shall be acceptable if it can be demonstrated that the required ultimate load reserve factor is achieved by means of detailed non-linear calculations or localised testing to validate the predicted structural performance.
- 2.1.5.4 Where structural elements, such as bodyside windows of glass or similar material, can be considered to form part of a primary structure, these elements shall not be included in the determination of the proof load capacity.

**2.1.6 Ultimate load reserve factor**

- 2.1.6.1 The ultimate load reserve factor is defined as the material ultimate tensile stress divided by the calculated or measured elastic stress for a given proof load case. Either of the following requirements shall be satisfied:
  - a) The ultimate load reserve factor shall not be less than 1.5 for calculated or measured elastic stresses.

Or

  - b) It is demonstrated by means of detailed non-linear calculations, testing or a combination of these that material rupture or failure shall not occur under the application of the applicable proof load case factored by 1.5.

# Requirements for Rail Vehicle Structures

- 2.1.6.2 Where controlled structural deformation or post-yield energy absorption is required to satisfy particular structural (see Part 3) or interior crashworthiness requirements (see Part 6), an ultimate load reserve factor is not required for a collapse zone or collapsible component provided that:
- a) It can be demonstrated that the proof load criteria are satisfied taking account of material and manufacturing tolerances.
  - b) Post-yield performance against the requirements for the collapse zone or collapsible component is demonstrated by detailed non-linear calculations, testing or a combination of these.
- 2.1.6.3 Where structural elements such as bodyside windows of glass or similar material, can be considered to form part of a primary structure, these elements shall not be included in the determination of the ultimate load capacity.
- 2.1.6.4 Where an ultimate loadcase is specified, an ultimate load reserve factor is not required.

## 2.1.7 Vehicle repair

- 2.1.7.1 Any structural damage shall be repaired in such a way that the overall structural integrity is restored to:
- a) The same level as for an otherwise identical undamaged vehicle. (It is permissible for this reference vehicle to be the same vehicle before the damage occurred.)
- Or
- b) A level which complies fully with this document.
- 2.1.7.2 In the event that the original design condition cannot be fully replicated, the repair shall result in an equivalent level of structural integrity consistent with the requirements of 2.1.7.1.

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

# **Requirements for Rail Vehicle Structures**

## **Part 3 Structural Requirements for Rail Vehicle Bodies**

### **3.1 Structural requirements for all vehicle types**

- 3.1.1 Rail vehicle body structures shall comply with the requirements of BS EN 12663-1:2010 or BS EN 12663-2:2010, BS EN 15227:2008 and the specific requirements set out in Part 3 of this document.
- 3.1.2 Vehicle payload shall be calculated in accordance with BS EN 15663:2009. As permitted by BS EN 15663:2009, it is permissible for the vehicle load to be defined as functions of the reference cases in the standard to accurately represent actual service conditions appropriate for design purposes.
- 3.1.3 In accordance with 2.1.1.3 above, it is permissible for alternative load cases to be used to support or to replace specified loads where this is permitted by BS EN 12663-1:2010 or BS EN 12663-2:2010.
- 3.1.4 The fatigue design life for rail vehicle structures or substructures shall be determined and shall be at least equal to either the design life of the vehicle or a predetermined maintenance interval at which point the structure shall be considered to be life expired.

### **3.2 Requirements for equipment attached to vehicle bodies**

- 3.2.1 Equipment attached to vehicle bodies shall be designed according to the inertia load values set out in BS EN 12663-1:2010 or BS EN 12663-2:2010 for the relevant vehicle category unless otherwise set out in this document.
- 3.2.2 The ultimate strength of the equipment attachments shall be consistent with the inertia load values set out in BS EN 12663-1:2010 or BS EN 12663-2:2010 or the maximum mean deceleration levels for the collision scenarios set out in BS EN 15227:2008, whichever is the greater.
- 3.2.3 The equipment attachment strength shall be formally assessed unless, for minor items of equipment, it can be demonstrated that:
  - a) For a given type or method of attachment, items at or below a given mass will be securely retained for the acceleration loads specified.
  - Or
  - b) A minor item is sufficiently contained or enclosed to prevent it becoming a potential hazard if detached in the event of a collision or derailment or for any other reason.
  - Or
  - c) Service experience in an equivalent or more demanding environment has shown the installation to be satisfactory.
- 3.2.4 Where the failure of an individual mounting could lead to the overload and the potential sequential failure of adjacent mountings, or where a single mounting is used and a resulting failure will create a hazardous situation, secondary fasteners, retention devices or some other equivalent means shall be provided, taking into account the likelihood of detection of an initial failure when in service or during maintenance inspections.
- 3.2.5 Locally generated accelerations, forces and resonances acting within and on equipment shall be accounted for as well as the specified proof and fatigue inertia loads.

# Requirements for Rail Vehicle Structures

- 3.2.6 Sources of locally generated accelerations, forces and resonances to be considered for proof and fatigue loads shall include, but not be limited to:
- a) Engines, gearboxes, cooler groups and hydrostatic drives.
  - b) Body mounted traction motors.
  - c) Transmission units.
  - d) Suspension elements (for example dampers, anti-rollbars, traction linkages).
  - e) Air compressors.
  - f) Door operating equipment.
  - g) Gangways.
  - h) Air conditioning systems.
- 3.2.7 The fatigue design life for equipment attachments shall be determined. If the fatigue design life is less than the design life of the vehicle, this shall be accounted for in inspection, maintenance and overhaul procedures, whereby life expired items are replaced.

## 3.3 Requirements for vehicles carrying passengers, personnel or traincrew

### 3.3.1 Structural collapse and prevention of overriding

- 3.3.1.1 The structural crashworthiness requirements of BS EN 15227:2008 shall apply. The collision scenarios set out in section 5 of BS EN 15227:2008 shall be applied in accordance with the crashworthiness design categories set out in section 4 of BS EN 15227:2008.

### 3.3.2 Obstacle deflectors

- 3.3.2.1 The requirements of BS EN 15227:2008 for obstacle deflectors shall apply in accordance with the crashworthiness design categories set out in section 4 of BS EN 15227:2008.

### 3.3.3 Missile protection

- 3.3.3.1 To resist penetration into the vehicle of missiles or other objects:
- a) Forward facing surfaces of vehicles occupied by people shall have an equivalent impact resistance to that required for the vehicle cab windscreens (see 5.2).
  - b) Roofs over areas which are freely accessible to passengers, personnel or traincrew during normal service shall withstand, without penetration, the impact of a 100 kg concrete cube with an edge length of 0.36 m dropped from a height of 3.0 m above the roof. The cube shall be dropped so that a flat surface hits the roof.

## 3.4 Requirements for freight vehicles

### 3.4.1 Applicable standards for freight vehicles

- 3.4.1.1 The Conventional Rail Freight Wagons TSI (CR WAG TSI) sets out requirements for freight vehicles intended for operation over the conventional rail Trans-European Network (TEN).

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

# **Requirements for Rail Vehicle Structures**

---

- 3.4.1.2 In the case of freight vehicles for operation exclusively on other routes, these shall also be designed to comply with the requirements of the CR WAG TSI.

**3.4.2 Tank wagons**

- 3.4.2.1 Where a clearance of at least 920 mm from the uncompressed buffer face to the end of the tank does not exist, tank wagons designed to carry dangerous goods shall be provided with additional end protection against overriding in the event of a collision or derailment. Such protection shall:

- a) Extend upwards from the buffer centreline for at least 500 mm.
- b) Minimise the risk of puncturing or damaging the tank end by the provision of smooth surfaces without sharp edges or corners in areas likely to contact the tank if the end protection is deflected or deformed in the event of a collision or derailment.

**3.4.3 Barrier and translator vehicles**

- 3.4.3.1 It is permissible for barrier vehicles or translator vehicles, intended solely for the purpose of permitting trains or units to be hauled by otherwise incompatible vehicles or locomotives, to be designed to the same structural design criteria as the hauled vehicles with which they interface.
- 3.4.3.2 It is permissible for structural criteria permitted by 3.4.3.1 to apply to either the complete vehicle or locally where required for non-standard or incompatible drawgear attachment points and associated interfaces on translator vehicles.
- 3.4.3.3 Compliance with the crashworthiness requirements set out in 3.3 shall not be required for barrier or translator vehicles, intended solely for the purpose of permitting trains or units to be hauled by otherwise incompatible vehicles or locomotives.

# Requirements for Rail Vehicle Structures

## Part 4 Structural Elements for Bogies and Suspension

### 4.1 Bogies and running gear

#### 4.1.1 Bogie structures

- 4.1.1.1 The bogie design load cases shall be consistent with both the extreme and normal service conditions under which the vehicle is required to operate.
- 4.1.1.2 Bogie design load cases for items of equipment and their attachments that are of sufficient mass to affect the dynamic behaviour of the bogie shall be determined from previous experience, testing, simulation, or by a combination of these techniques.
- 4.1.1.3 It is permissible to use bogie design load cases used for previous vehicles where it can be demonstrated that:
  - a) The new application is directly comparable.
  - b) Performance in service has been satisfactory in terms of no failures or unscheduled maintenance.
- 4.1.1.4 The bogie design load cases set out in 4.3 and 4.4 represent established values of inertia load for items of equipment outside the scope of 4.1.1.2 and which have resulted in satisfactory performance for typical conditions. However it shall be demonstrated that the general requirements have been met for any particular application.

#### 4.1.2 Proof load cases

- 4.1.2.1 Bogie structures shall withstand as proof loads all peak forces imposed on them in service taking full account of the full range of operational conditions likely to be encountered. Proof load cases to be considered, taking into account the layout and suspension characteristics of the bogie, shall include, but not be limited to:
  - a) Maximum dynamic vertical load due to track input.
  - b) Maximum dynamic vertical load due to low speed derailment.
  - c) Maximum dynamic vertical load due to abrupt application of payload for relevant freight vehicles.
  - d) Maximum lateral load at point of wheel lifting due to overspeeding on a curve.
  - e) Loads due to lifting a vehicle / bogie on its side in recovery situations.
  - f) Maximum dynamic longitudinal load due to shunt / buffing operations.
  - g) Maximum twist load input.
  - h) Maximum steering load (shear across the frame).
- 4.1.2.2 Bogie structures shall withstand as proof loads all reaction forces imposed on them by the proof load cases for bogie mounted and axle mounted equipment.
- 4.1.2.3 Bogie structures shall withstand as proof loads all reaction forces imposed on them by the vehicle body and bogie retention proof load cases.

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

# Requirements for Rail Vehicle Structures

**4.1.3 Fatigue load cases**

4.1.3.1 Bogie structures shall achieve their required fatigue life with a survival probability of at least 97.5%, when subjected to loads representative of operating conditions when in service. Fatigue load cases to be considered, taking into account the layout and suspension characteristics of the bogie, shall include, but not be limited to:

- a) Vertical dynamic loads.
- b) Lateral dynamic loads.
- c) Repeated twist load inputs.
- d) Dynamic steering loads (shear across the frame).

4.1.3.2 Each fatigue load case shall be considered as acting separately and the damage from the individual cases shall be summed.

4.1.3.3 The fatigue design life for bogie structures or substructures shall be determined and shall be at least equal to either the design life of the vehicle or a predetermined maintenance interval at which point the structure shall be considered to be life expired.

**4.1.4 Derivation of bogie proof and fatigue load cases from test data**

4.1.4.1 It is permissible for load cases derived from test or service data in accordance with Appendix A to be used to support or to replace the bogie equipment loads set out in 4.3 and 4.4.

**4.2 Body to bogie attachments****4.2.1 Proof load cases**

4.2.1.1 As far as is reasonably practicable, bogies shall remain attached to vehicle bodies during a collision or derailment. To achieve this objective, in addition to loads resulting from the requirements of 4.1.2, the body to bogie attachments shall withstand as proof loads the following conditions:

- a) The bogie mass subject to a longitudinal acceleration of  $\pm 5$  g. The relevant proportion of the maximum vertical body proof load at the secondary suspension shall be applied simultaneously.
- b) The relevant proportion of the fully laden body mass, together with the associated bogie mass, subject to a lateral acceleration sufficient to lift the wheels from the rail at one side or the bogie mass subject to a lateral acceleration of 1 g, whichever is the greater.
- c) A compressive vertical load of the fully laden body mass subject to an acceleration of 2 g.
- d) A tensile vertical load of the bogie mass subject to an acceleration of 2 g.

4.2.1.2 For locomotives and vehicles in rigidly coupled rakes the longitudinal load shall be the bogie mass subject to an acceleration of  $\pm 3$  g.

**4.2.2 Ultimate load case**

4.2.2.1 The body to bogie attachment shall withstand as ultimate loads the longitudinal decelerations and forces imposed by the collision scenarios set out in 3.3.1.1.

# Requirements for Rail Vehicle Structures

- 4.2.2.2 Body to bogie connection arrangements shall ensure that failure due to overload occurs in a predictable manner and that the structural integrity of the vehicle body structure is not reduced.

## 4.2.3 Fatigue load cases

- 4.2.3.1 Fatigue loads for body to bogie connections shall be determined in accordance with Appendix A.
- 4.2.3.2 The fatigue design life for body to bogie connections shall be determined and be at least equal to either the design life of the vehicle or a predetermined maintenance interval at which point the items affected shall be considered to be life expired.

## 4.3 Equipment attached to bogie frames

### 4.3.1 Proof load cases

- 4.3.1.1 Except for items of equipment in the scope of 4.1.1.1, items of equipment and their mountings shall withstand as proof loads, the inertia forces associated with the following accelerations:
- a) Vertical  $\pm 20.0$  g at the wheelset centreline,  $\pm 10.0$  g at the bogie centreline. Values at other positions shall be obtained by linear interpolation or extrapolation.
  - b) Transverse  $\pm 10.0$  g at the wheelset centreline,  $\pm 5.0$  g at the bogie centreline. Values at other positions shall be obtained by linear interpolation or extrapolation.
  - c) Longitudinal  $\pm 5.0$  g or  $\pm 3.0$  g according to the criteria set out in 4.2.1.

### 4.3.2 Fatigue load cases

- 4.3.2.1 Except for items of equipment in the scope of 4.1.1.1, items of equipment and their mountings shall be assessed assuming a fatigue life of not less than  $10^7$  cycles with a survival probability of at least 97.5 %, under the inertia forces associated with the following accelerations:
- a) Vertical  $\pm 6.0$  g at the wheelset centreline,  $\pm 3.0$  g at the bogie centreline. Values at other positions shall be obtained by linear interpolation or extrapolation.
  - b) Transverse  $\pm 5.0$  g at the wheelset centreline,  $\pm 2.5$  g at the bogie centreline. Values at other positions shall be obtained by linear interpolation or extrapolation.
  - c) Longitudinal  $\pm 2.5$  g.
- 4.3.2.2 The fatigue design life for items of equipment and their mountings shall be determined and be at least equal to either the design life of the vehicle or a predetermined maintenance interval at which point the items affected shall be considered to be life expired.

### 4.3.3 Locally generated accelerations, forces and resonances

- 4.3.3.1 The accelerations set out in 4.3.1 and 4.3.2 do not include the effects of locally generated accelerations, forces and resonances acting within and on equipment. Special provision shall be made to withstand such additional forces or means provided to avoid their occurrence.

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

# Requirements for Rail Vehicle Structures

4.3.3.2 Locally generated accelerations, forces and resonances to be considered shall include, but not be limited to, the effects of:

- a) Traction motors.
- b) Traction gearboxes, final drive units or drive couplings.
- c) Brake equipment.
- d) Suspension components or actuators.
- e) Shoe gear (if applicable).

## 4.4 Equipment attached to axleboxes

### 4.4.1 Proof load cases

4.4.1.1 Items of equipment attached to axleboxes, together with their mountings, shall withstand, as proof loads, the inertia forces associated with the following accelerations acting at the axle centreline. Values at other positions shall be derived using the characteristics of the suspension system:

- a) Vertical  $\pm 70.0$  g.
- b) Transverse  $\pm 10.0$  g.
- c) Longitudinal  $\pm 10.0$  g.

### 4.4.2 Fatigue load cases

4.4.2.1 Items of equipment attached to axleboxes, together with their mountings, shall be assessed assuming a fatigue life of not less than  $10^7$  cycles with a survival probability of at least 97.5%, under the inertia forces associated with the following accelerations acting at the axle centreline. Values at other positions shall be derived using the characteristics of the suspension system:

- a) Vertical  $\pm 25.0$  g.
- b) Transverse  $\pm 5.0$  g.

4.4.2.2 The fatigue design life for items of equipment attached to axleboxes, together with their mountings shall be determined and be at least equal to either the design life of the vehicle or a predetermined maintenance interval at which point the items affected shall be considered to be life expired.

### 4.4.3 Locally generated accelerations, forces and resonances

4.4.3.1 The accelerations set out in 4.4.1 and 4.4.2 do not include the effects of locally generated accelerations, forces and resonances acting within and on equipment. Special provision shall be made to withstand such additional forces or means provided to avoid their occurrence.

4.4.3.2 The accelerations specified shall be factored if necessary to take into account any force variation effects due to the particular primary suspension arrangement.

## 4.5 Lifeguards

4.5.1 All leading bogies shall be fitted with lifeguards, as stipulated below, with the aim of reducing as far as is reasonably practicable the risk of derailment due to impact by small obstacles on the rails.

# Requirements for Rail Vehicle Structures

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

- 
- 4.5.2 A lifeguard shall be:
- a) Made of a ductile material.
  - b) Able to resist a sustained concentrated proof load of at least 20 kN applied at its bottom edge horizontally and in a longitudinal direction towards the adjacent wheel, and during deformation beyond the proof load, able to resist an ultimate load of at least 35 kN.
  - c) Able to resist the proof load set out in b) combined with a transverse load, in either direction, of at least 10 kN.
  - d) Designed so that, as the load in b) or c) is increased up to the ultimate or maximum dynamic load that it can sustain during impact with the obstacle, it deforms plastically to absorb as much additional energy as reasonably practicable.
  - e) Designed so that, during and after deformation due to the loads specified, it does not foul the track or running gear and that contact with the wheel tread, if it occurs, does not pose the risk of derailment.
  - f) Designed so that, under the conditions described above, it remains securely attached to the bogie.
- 4.5.3 The bogie and the attachment of the lifeguard to the bogie shall not be damaged or suffer significant permanent deformation under the loads set out above.
- 4.5.4 If mounted on a bogie frame or mounted on an axlebox, the lifeguard and its attachments shall be:
- a) Capable of withstanding the applicable proof loads.
  - b) Capable of withstanding without failure the inertia forces associated with all applicable fatigue accelerations.
- 4.5.5 The accelerations specified shall be factored if necessary to take into account any force magnification due to the particular primary suspension arrangement.
- 4.5.6 Lifeguards shall be positioned as close as reasonably practicable to the rail head taking into account wheel wear, suspension movements, suspension wear and assembly tolerances.

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

# **Requirements for Rail Vehicle Structures**

## **Part 5 Secondary Structural Elements**

### **5.1 Common design requirements**

- 5.1.1 All secondary structural elements, together with all mounting attachments, fixings and surrounding vehicle structure shall, in addition to the particular loads set out below, comply with the proof, ultimate and fatigue load requirements specified for vehicle body mounted equipment (see 3.2).

### **5.2 Windscreens**

#### **5.2.1 Windscreen structural requirements**

- 5.2.1.1 Any predominantly forward facing window which in normal service operation may be positioned at the leading end of a train behind which traincrew, personnel or passengers may be located shall satisfy the structural requirements for windscreens.
- 5.2.1.2 At intermediate ends of fixed formation units, any predominantly forward or rear facing window, behind which passengers, personnel or traincrew may be located in normal service, shall be considered to be a bodyside window.
- 5.2.1.3 The strength of windscreen fixings and the complete windscreen installation shall be consistent with the strength and impact requirements for the windscreen.

#### **5.2.2 Impact resistance for vehicle windscreens**

- 5.2.2.1 The requirements for impact resistance and spalling set out in BS EN 15152:2007 shall apply for all vehicle windscreens.

#### **5.2.3 Windscreen aerodynamic loads**

- 5.2.3.1 A windscreen together with all mounting attachments, fixings and surrounding vehicle structure shall withstand without failure the aerodynamic loads set out in Part 7.

### **5.3 Bodyside windows**

#### **5.3.1 Bodyside window requirements**

- 5.3.1.1 All bodyside windows for vehicles carrying passengers, personnel or traincrew, in areas which are freely accessible during normal service, shall have at least one pane of laminated safety glass, or other material with equivalent or superior structural properties. The requirements for sleeper vehicles are set out in 5.3.1.3.
- 5.3.1.2 For refurbishment of existing vehicles where due to limitations imposed by the window frame design or the underlying vehicle structure it is not possible to achieve full compliance, the requirements of 5.3 shall be applied as far as it is reasonably practicable.
- 5.3.1.3 For dedicated sleeper vehicles the following requirements shall apply:
- Means shall be provided to allow compartment and corridor windows to be safely removed or opened in an emergency to allow passenger escape from the vehicle.
  - For existing vehicles it is permissible, even if otherwise subject to the requirements of 10.2.1.3, for the windows to be breakable using a suitable hammer or other device to allow passenger escape in an emergency.

# Requirements for Rail Vehicle Structures

5.3.1.4 Where double glazed units are fitted, it is permissible for one pane to be of toughened safety glass. When installed in the vehicle the laminated safety glass pane shall always be fitted on the side of the unit forming part of the vehicle interior.

5.3.1.5 Where double glazed units incorporate toughened glass either:

- a) A means of easily recognisable identification in English shall be provided on both the interior and exterior of the window to distinguish between laminated or toughened safety glass in order to show that windows are correctly fitted along the bodyside of the vehicle.

Or

- b) The double glazed unit and its mounting to the vehicle shall be designed to prevent incorrect installation.

## 5.3.2 Window design requirements

5.3.2.1 Glass shall be manufactured in accordance with BS 857:1967 or an equivalent specification.

5.3.2.2 Bodyside window fixings and the complete bodyside window installation shall be consistent with the strength and impact requirements for the bodyside window set out in 5.3.3 to 5.3.5.

5.3.2.3 Bodyside window systems representative of production quality and construction shall be tested as required below (see 5.3.4 to 5.3.6). Where a vehicle or unit is fitted with a number of different sized windows to an otherwise common design, it is permissible for impact, containment and pressure pulse testing required in accordance with Appendices B, C and D to be undertaken on only the largest window unit.

5.3.2.4 Impact, containment and pressure pulse testing required in accordance with Appendices B, C and D of this document is not required where either the height or width is less than 300 mm for window units or window unit subassemblies if the Bodyside window is subdivided.

5.3.2.5 Where a window unit or window unit type has already been tested in accordance with Appendices B, C and D of this document, additional testing for a new installation shall not be required if it can be demonstrated that the following conditions are satisfied:

- a) The window unit design and mounting arrangements are mechanically equivalent to those for which test data has been obtained.
- b) The window unit installation and corresponding vehicle structure can satisfactorily resist all structural loads from the series of tests for which data has been obtained.

## 5.3.3 Bodyside window structural requirements

5.3.3.1 Bodyside windows, when installed in a vehicle, shall remain fully serviceable after the application over the full surface area of the following loads:

- a) The aerodynamic loads set out in Part 7.
- b) For all windows in areas accessible to passengers, personnel or traincrew, with the exception of cabs, a sustained pressure of 6 kPa from inside the vehicle.

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

# Requirements for Rail Vehicle Structures

c) For external door windows, the sustained pressure loads specified for the door assembly (see 5.4.2).

d) For cab side windows, a sustained pressure of 3 kPa from inside the vehicle.

5.3.3.2 If a bodyside window pane is damaged by impact, the risk of injury to vehicle occupants from any spalling of the inner surface shall be controlled. This objective shall be deemed to be satisfied by demonstrating that, when windows are tested in accordance with Appendices B and C:

a) For the small missile tests (see Appendix B), the total amount of spall does not exceed 40 g.

b) For the sequence of containment tests (see Appendix C), the total amount of spall for the steel ball impact test (see Appendix C.5) does not exceed 10 g.

5.3.3.3 If a bodyside window pane is damaged by impact, the risk of detachment from the outer surface of pieces, with the consequent risk of injury for people outside the vehicle, shall be controlled. For double glazed bodyside window units, this shall be demonstrated by satisfactory testing in accordance with the requirements of Appendix D.

## 5.3.4 Laminated safety glass bodyside window and window unit loads and impact resistance

5.3.4.1 To demonstrate resistance to small missiles, a laminated safety glass bodyside window pane or a double glazed window unit incorporating laminated safety glass shall resist without penetration into the vehicle, the impact of a solid steel ball weighing 0.25 kg travelling at a speed of 100 km/h when tested in accordance with the requirements of Appendix B.

5.3.4.2 When tested in accordance with Appendix C, a bodyside window or window unit, with the exception of cab bodyside and cab door windows, using laminated safety glass shall demonstrate acceptable containment performance by withstanding the following sequence of loads:

a) The external impact of a solid steel ball weighing 5 kg travelling at a speed of 34 km/h.

This shall be followed by:

b) A 50 kg pendulum internal impact from a height of 1200 mm.

And then it shall be followed by:

c) A concentrated perpendicular internal load of 0.8 kN applied over an area of 0.1 m x 0.1 m on the surface at the window centre.

5.3.4.3 For cab bodyside and cab door windows acceptable performance shall be demonstrated only against the requirements of 5.3.4.2 a) when tested in accordance with the applicable parts of Appendix C.

## 5.3.5 Toughened safety glass bodyside window impact resistance

5.3.5.1 Where these are permitted, toughened safety glass bodyside window units shall withstand without penetration the impact of a solid steel ball weighing 0.25 kg travelling at a speed of 50 km/h when tested in accordance with the requirements of Appendix B.

# Requirements for Rail Vehicle Structures

## 5.3.6 Bodyside window emergency access

- 5.3.6.1 Testing shall be undertaken to demonstrate that the time to create an opening suitable for access shall not exceed 2 minutes, using tools typically available to rescue services.
- 5.3.6.2 Test samples shall be mounted at a height corresponding to the nominal relative height of the installed bodyside window from a standard station platform.

## 5.4 External vehicle doors

### 5.4.1 External vehicle door design requirements

- 5.4.1.1 The strength of door frames, door locks and associated equipment shall be compatible with the strength of the doors.

### 5.4.2 External vehicle door loads

- 5.4.2.1 External vehicle doors and their mountings shall withstand the following separate proof load cases without significant permanent deformation or loss of normal function:
  - a) A concentrated perpendicular load of 2.5 kN applied over an area of 0.1 m x 0.1 m, acting from within the vehicle. The structure shall be capable of withstanding this load at any position on the surface of the door.
  - b) An external surface pressure load of 2.5 kPa.
  - c) The inner surface pressure load of 2.5 kPa, applied over the internal surface of the door plus a concentrated perpendicular load, acting from within the vehicle, of 0.8 kN applied over an area of 0.1 m x 0.1 m. The structure shall be capable of withstanding the concentrated load at any position on the surface of the door.
- 5.4.2.2 In the case of vehicles with a maximum speed in excess of 125 mile/h or pressure sealing, an appropriate quasi-static aerodynamic pressure load shall be determined according to the requirements set out in Part 7.
- 5.4.2.3 External doors shall withstand as an ultimate load case a sustained pressure of 6 kPa over its internal surface. It shall not be necessary for the door and associated components to remain operational after the application of this load.
- 5.4.2.4 Direct access external doors exclusively for use by traincrew or personnel for access and egress and only accessible by them in normal operation shall withstand as an ultimate load case a sustained pressure of 3 kPa over its internal surface. It shall not be necessary for the door and associated components to remain operational after the application of this load.
- 5.4.2.5 External doors shall withstand without significant permanent deformation or loss of normal function the transient aerodynamic load requirements set out in Part 7.

## 5.5 External steps, external grab rails and external handles

### 5.5.1 Structural requirements

- 5.5.1.1 A step shall withstand a concentrated downward vertical proof load of 2 kN, applied over an area of 100 mm x 200 mm. The structure shall be capable of withstanding the concentrated load at any position on the step surface.
- 5.5.1.2 A step shall withstand a uniformly distributed downward vertical proof load of 4 kN per metre over its length, without significant permanent deformation.

**Railway Group Standard****GM/RT2100****Issue** Five**Date** June 2012

# Requirements for Rail Vehicle Structures

- 5.5.1.3 External grab rails or handles shall withstand a perpendicular proof load of 1.7 kN applied at any point along its length without significant permanent deformation.
- 5.5.1.4 External handles on external doors shall withstand a downward vertical proof load of 1.7 kN without significant permanent deformation. For external handles which rotate, the proof load shall be applied with the handle in the worst case position(s).
- 5.5.1.5 Step materials and surfaces shall be slip resistant.

## 5.6 Inter-vehicle gangways

### 5.6.1 Structural requirements

- 5.6.1.1 A gangway, including all its flexible elements, shall remain stable and provide a safe passageway between vehicles. Compliance with the following requirements of 5.6.1 shall be deemed to satisfy these objectives for conventional gangways. Requirements for open wide gangways are an 'open point'.
- 5.6.1.2 In service, gangway movement shall not expose any gaps, crevices or openings where passengers or traincrew could be caught, trapped or become injured by crushing or pinching.
- 5.6.1.3 Gangway loads, and where appropriate combinations of loads, shall be identified taking full account of the following conditions:
  - a) Kinematic and dynamic movements due to operation in passenger service taking account of:
    - i) Vehicle speed.
    - ii) Vehicle loads.
    - iii) Relative displacement between vehicles, including where applicable variations due to inflated and deflated suspensions on adjacent vehicles.
    - iv) Combinations of horizontal and vertical curvature.
    - v) Cant deficiency and cant excess conditions, including where applicable effects due to tilt systems.
    - vi) Differences between vehicles due to wheel wear or vehicle set up or vehicle and suspension tolerances.
  - b) Kinematic and dynamic movements due to low speed operation in sidings and depots.
  - c) Aerodynamic forces due to pressure transients created by other trains, by lineside structures and by passage through tunnels.
- 5.6.1.4 A gangway shall withstand without significant permanent deformation the following proof loads:
  - a) A pressure load of 6 kPa on the standing floor area.
  - b) A concentrated perpendicular load, acting from within the gangway, of 0.8 kN applied over an area of 0.1 m x 0.1 m acting on the surface of the side walls. The gangway structure shall be capable of withstanding the concentrated load at any position.

# Requirements for Rail Vehicle Structures

**Railway Group Standard****GM/RT2100****Issue Five****Date June 2012**

- 
- 5.6.1.5 A gangway shall withstand without significant permanent deformation as a proof load a differential pressure between the inside and outside of the gangway of  $\pm 2.5$  kPa. In the case of vehicles with a maximum speed in excess of 125 mile/h, or pressure sealing, an appropriate quasi-static aerodynamic pressure load shall be determined according to the requirements set out in Part 7.