



Published by:

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

© Copyright 2010
Rail Safety and Standards Board Limited

GN

GM/GN2686 Guidance on Rail Vehicle Bodysell, Bogie and Suspension Elements Issue One : December 2010 Rail Industry Guidance Note for GM/RT2100 Issue Four (Parts 2, 3 and 4)



Documents

Document Sharing Hub

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

Issue Record

Issue	Date	Comments
One	December 2010	Original document supersedes GM/GN2560.

Superseded documents

The following Railway Group documents are superseded, either in whole or in part as indicated:

Superseded documents	Sections superseded	Date when sections are superseded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/GN2560, issue one, October 2000 Guidance Note: Structural Requirements for Railway Vehicles	All	05 March 2011

Supply

The authoritative version of this document is available at 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. Other Standards and associated documents can also be viewed at www.rgsonline.co.uk.

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

Contents

Section	Description	Page
Part 1	Introduction	4
1.1	Purpose and structure of this document	4
1.2	Copyright	4
1.3	Approval and authorisation of this document	4
Part 2	Guidance on Structural Elements	5
2.1	Primary and secondary structural elements	5
Part 3	Guidance on General Structural Requirements	6
3.1	Common requirements	6
Part 4	Guidance on Structural Requirements for Rail Vehicle Bodies	14
4.1	Structural requirements for all vehicle types	14
4.2	Equipment attached to vehicle bodies	16
4.3	Requirements for vehicles carrying passengers, personnel or traincrew	19
4.4	Requirements for freight vehicles	23
Part 5	Guidance on Structural Requirements for Bogies and Suspension Elements	25
5.1	Structural requirements for bogies and running gear	25
Part 6	Guidance on GM/RT2100 Appendix A	32
6.1	Appendix A: Derivation of load cases from test or service data	32
Definitions		34
References		35

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

Part 1 Introduction

1.1 Purpose and structure of this document

This document gives guidance on interpreting the requirements of Railway Group Standard GM/RT2100 Parts 2, 3 and 4. It does not constitute a recommended method of meeting any set of mandatory requirements.

Relevant requirements in GM/RT2100 are reproduced in the sections that follow. Guidance is provided as a series of sequentially numbered clauses prefixed 'GN'.

Specific responsibilities and compliance requirements are laid down in the Railway Group Standard itself.

1.2 Copyright

Copyright in the Railway Group documents is owned by Rail Safety and Standards Board Limited. All rights are hereby reserved. No Railway Group document (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 documents, 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 documents may be reproduced.

1.3 Approval and authorisation of this document

The content of this document was approved by:

Rolling Stock Standards Committee on 03 September 2010.

This document was authorised by RSSB on 06 October 2010.

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

Part 2 Guidance on Structural Elements

2.1 Primary and secondary structural elements

- GN01 The division between primary and secondary structural elements made in GM/RT2100 is to some extent arbitrary and it is acknowledged that for some vehicle designs the boundaries between the different sub-systems may be difficult to define precisely. In addition different sub-systems often interact, for example bodyshell deflections can affect the performance of door systems and equally mechanical door system loads will be reacted by the local bodyshell structure. As a result the overall structural integrity requirements should always be considered for the vehicle as a complete system.
- GN02 Primary structures should be considered to be those elements of a vehicle whose main purpose is to withstand or distribute the loadings seen in normal operation and in exceptional circumstances such as collisions or derailments.
- GN03 Primary structural elements should include:
- a) Bodyshell (see Part 3 of GM/RT2100).
 - b) Bogies (see Part 4 of GM/RT2100).
 - c) Structural elements required for crashworthiness (see Part 3 of GM/RT2100).
 - d) Couplers and drawgear (see Part 8 of GM/RT2100).
 - e) Equipment rafts and cases (see Part 3 of GM/RT2100).
 - f) Jacking and lifting features (see Part 9 of GM/RT2100).
- GN04 For the purpose of this document, secondary structural elements should be considered to be those elements of a vehicle which interface directly with passengers or traincrew.
- GN05 Secondary structural elements should include:
- a) Windscreens (see Part 5 of GM/RT2100).
 - b) Windows (see Part 5 of GM/RT2100).
 - c) Doors (see Part 5 of GM/RT2100).
 - d) Gangways (see Part 5 of GM/RT2100).
 - e) Interiors, for example seats, tables, panelling, partitions etc. (see Part 6 of GM/RT2100).

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

Part 3 Guidance on General Structural Requirements

3.1 Common requirements

- GN06 GM/RT2100 issue four is intended to establish either limiting values in terms of load capacity or methods to be followed to achieve satisfactory performance. In seeking to achieve an optimum design, it is intended that there should always be sufficient scope to introduce new methods of construction or materials provided that the overall objectives of a safe vehicle are achieved.
- GN07 The standard addresses not only normal operation of rail vehicles but also abnormal conditions including collisions and derailments.
- GN08 Where speeds are specified in miles per hour (mile/h), for operational or historical reasons, exact conversions are not required for the purposes of GM/RT2100 issue four and this guidance note. Values converted to kilometres per hour (km/h) should be rounded. A speed of for example 100 mile/h should thus be treated as fully equivalent to 160 km/h.

3.1.1 Vehicle condition and loading

GM/RT2100 issue four

Section 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.

- GN09 It is not expected that a vehicle should be designed for sustained operation under worst case conditions. The proof and ultimate load cases are intended to define absolute limiting cases for loading but these are expected to occur so infrequently that they should not affect fatigue load cases required for cyclic loading in normal operation. For operation under degraded conditions account should be taken of the maintenance regime and systems or methods for detection of fault conditions to determine appropriate numbers of cycles where higher than normal loadings may be encountered.

- GN10 In a number of cases the load values set out are well established and are considered to result in acceptable performance for a wide range of vehicle applications. It is however permissible to either determine load cases for particular applications using established engineering methods from test data and validated calculations, or by demonstrating equivalence between applications, using service experience to justify a particular design feature.

GM/RT2100 issue four

Section 2.1 Common structural requirements

2.1.1 Vehicle condition and loading

- 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.

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

- GN11 For metallic materials the significant temperature is usually the minimum where material grades should be selected to minimise the risk of brittle fracture at low temperature. For non-metallic materials both minimum and maximum temperatures may be equally significant.
- GN12 Under some circumstances temperatures outside the specified range should be considered to take account of factors such as the operation of systems or equipment (for example diesel engines, power electronics in confined spaces) or external effects such as solar gain or wind chill.
- GN13 It should be noted that BS EN 50125-1:1999 sets out a more onerous external temperature range of -25°C to +40°C for GB conditions. As given in the title and scope, this Euronorm is for electrical, electromechanical and electronic equipment on rolling stock and should not normally be applied to vehicle structural materials.

3.1.2 Structural materials

GM/RT2100 issue four

Section 2.1 Common structural requirements

2.1.2 Structural materials

- 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:
- Conformity with an applicable Euronorm (EN).
 - Conformity with a British Standard (BS).
 - 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).
 - Evidence of established and successful use in other comparable railway vehicle structures.
 - 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.

- GN14 In selecting structural materials, the following general design objectives should always be considered:
- The structure should remain fully serviceable when subject to the maximum loads imposed by exceptional circumstances which are typically represented by the proof load cases set out in GM/RT2100 issue four.
 - The structure should not fail as soon as the design load cases are exceeded to ensure that there is always an acceptable factor of safety, represented by the ultimate load factor, to account for uncertainties arising from calculation or testing and to cater for variations due to manufacture, operation and maintenance and to give a reasonable margin for novel or unforeseen circumstances.
 - The structure should have sufficient durability to withstand the operational loading regime throughout the intended vehicle life, typically 30 - 35 years or, for sub-assemblies, the design life of the item if this is less.

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

- GN15 Vehicle structures have traditionally been fabricated from steel or aluminium alloys using material grades that exhibit good levels of ductility, with typically elongation of up to 30% for mild steels and typically 6% for aluminium extrusions. In consideration of the many requirements for crashworthiness and localised impact resistance, the performance of alternative materials should be carefully considered to ensure that satisfactory behaviour is achieved under extreme loading conditions. It is often necessary to use tighter tolerances on material properties than given by the standard specifications for structural elements designed to absorb energy in order to achieve consistent behaviour. The need or otherwise for applying additional controls can be demonstrated by varying the properties in simulations or by suitable testing.
- GN16 The materials used should generally exhibit good post-yield plasticity and energy absorption properties. As far as reasonably practicable vehicle structures or sub-structures should, when overloading occurs, collapse in a controlled and reasonably predictable manner. For example aluminium castings using typical commercial alloys and casting techniques would not generally be recommended for widespread structural use due to the relatively low levels of ductility normally obtained (typically 5% or less).
- GN17 It is intended that there should be no barrier to the introduction of new or alternative materials. The suitability of materials should, in addition to fulfilling structural requirements, take full account of all other foreseeable material requirements such as: fire performance, safety in manufacture, repair and disposal, behaviour under fatigue loading, the potential for degradation due to ageing or environmental factors such as temperature, humidity, sunlight, salt spray etc. An understanding of fatigue and degradation properties is essential to ensure that where necessary appropriate inspection intervals can be determined.

3.1.3 Structural failure

GM/RT2100 issue four

Section 2.1 Common structural requirements

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.

- GN18 Failure is classed as a structural defect or defects, which render the vehicle no longer safe for normal operation. Failure can be as a result of overload, fatigue loading, corrosion, degradation or any combination of all of these.

- GN19 An acceptable fatigue life can be achieved by the application of national or European structural fatigue codes such as:

- a) BS EN 1993-1-9:2005.
- b) DD ENV 1999-2:2000 (superseded).
- c) BS EN 1999-1-3:2007 (see GN020).
- d) BS 7608:1993.
- e) BS 8118-1:1991 (superseded).

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

- GN20 There is a risk that the direct application of the fatigue curves set out in BS EN 1999-1-3:2007, which permits higher stress levels than the preceding document, could result in unsatisfactory or potentially dangerous structural details. Reference should therefore be made to the UK national annex and PD 6702-1 for detailed guidance. At the time of publication these documents are being further developed and therefore may be revised. As a result the status of these documents should be checked before use.
- GN21 Many of these fatigue codes have been developed for relatively large structures such as bridges. In applying these codes to rail vehicle structural design the generalised nature of these codes should be taken into account and in particular, where 'thin' materials are being analysed, the assumptions made by these codes for material thicknesses, weld quality and residual stress levels may lead to very conservative conclusions.
- GN22 The majority of recent GB rolling stock has typically been designed using BS 7608:1993 or BS 8118-1:1991, applying Miner's law to summate the fatigue damage from different load cases to give an overall prediction of fatigue life. Where it is intended to adopt different methods for fatigue design, the fatigue load cases used and the combination of fatigue damage from different load cases should be carefully considered. The endurance limit methods set out in BS EN 12663-1:2010 and BS EN 12663-2:2010 for fatigue assessment are not generally recommended without evidence of satisfactory performance under GB operating conditions.
- GN23 It should be noted that the service fatigue life for any given structural item will be the combined effect of the appropriate analysis of loadings, stresses and fatigue together with its manufacture, assembly and operation and therefore all these aspects should be dealt with in a mutually consistent manner.
- GN24 Care should be exercised when interpreting the results of detailed finite element calculations where localised high stresses occur as many fatigue curves, developed for classical calculation methods, have already accounted for, either fully or in part, stress concentration effects.
- GN25 It is generally permissible within these codes to develop fatigue curves from experimental data for particular design details and in some cases this will be highly beneficial in terms of structure weight and cost. Where experimental data is used to develop bespoke fatigue curves, the raw data and its post-treatment should be fully documented.

3.1.4 Demonstration of structural integrity

GM/RT2100 issue four

Section 2.1 Common structural requirements

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.

- GN26 Calculations should take into account the uncertainties associated with material properties and methods of calculation, manufacture and assembly. GM/RT2100 and associated standards such as BS EN 12663-1:2010, BS EN 12663-2:2010 or BS EN 15227:2008 assume that:

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

- a) Calculations are carried out to a high degree of accuracy by competent people who are conversant with the methods to be used, whether finite element analysis or classical methods.
- b) Scatter in material properties is catered for by using the minimum or other appropriate values. For crashworthiness where collapsible elements are required maximum values should also be controlled.
- c) Manufacture is well controlled and carried out in a manner consistent with the design assumptions.

3.1.5 Proof load reserve factor

GM/RT2100 issue four

Section 2.1 Common structural requirements

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.

GN27 The use of a proof load reserve factor is intended to ensure that there is no significant permanent deformation under proof load conditions.

GN28 Glass and similar brittle materials when loaded remain either essentially intact or break (i.e. there is either negligible or no plastic deformation) and thus a proof load reserve factor has little or no relevance. For these materials the proof and ultimate load reserve factors are therefore set to the same value.

GM/RT2100 issue four

Section 2.1 Common structural requirements

2.1.5 Proof load reserve factor

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.

GN29 In determining at any particular localised hot-spot what constitutes significant permanent deformation, consideration should be given to:

- a) The potential consequences of failure or rupture at that point.
- b) The extent to which, in immediately adjacent areas, there is sufficient strain energy stored when loaded to effectively pull back any deformation when the load is removed.
- c) The extent to which any apparent stress concentration may be as a result of simplifications inherent in the analysis model or due to the calculation method itself. In this case it is recommended that a more detailed local analysis is made of the detail or a typical generic detail to clarify the stress pattern wherever possible.

Guidance on Rail Vehicle Bodyshell, Bogie and Suspension Elements

GN30 For finite element calculations 'hot-spots' can be a function of the element type, the representation of the structural geometry, the characteristics of the element mesh (element density and shape) or methods used for applying or reacting loads or the boundary conditions. Stress 'hot-spots' which are related to the method of calculation should be eliminated wherever possible in order to focus attention on genuine stress concentration effects.

GN31 For a friction grip bolted joint, or similar connections, the proof reserve factor should be calculated as the proof load capacity of the joint divided by the load applied rather than directly using fastener stresses. When it is considered that bolts are often torqued to a high proportion of the bolt material yield stress, a well proportioned friction grip joint may not give a reserve factor of 1.15 based on the bolt stresses, but in terms of the load capacity of the joint, the reserve factor specified will be easily exceeded.

GM/RT2100 issue four

Section 2.1 Common structural requirements

2.1.5 Proof load reserve factor

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.

GN32 The difference between proof and ultimate load reserve factors takes into account the potentially catastrophic nature of material rupture or collapse, which may involve serious injury or loss of life. The proof load reserve factor, in determining effective limits operationally, can be considered to have primarily economic consequences. In consideration of this, a localised reduced proof load reserve factor may be acceptable provided that, by detailed non-linear calculations, localised testing or a combination of these, it can be shown that the ultimate load reserve factor is respected.

GM/RT2100 issue four

Section 2.1 Common structural requirements

2.1.5 Proof load reserve factor

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.

GN33 Glazing is not usually considered to be a structural element, however, if the mounting arrangements or bonding methods are sufficiently understood and controlled, it could be possible to include the strength and stiffness of the glass panes in an overall structural assessment and thereby achieve a lighter or simpler structure. This would be an acceptable approach in terms of service or fatigue loadings but under proof and ultimate load conditions, it is essential that any breakage of the glass elements would not jeopardise the integrity of the structure.

3.1.6 Ultimate load reserve factor

GM/RT2100 issue four

Section 2.1 Common structural requirements

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