AS 7519:2022

Bogie structural requirements

Rolling Stock Standard

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This Australian Standard® AS 7519 Bogie structural requirements was prepared by a Rail Industry Safety and Standards Board (RISSB) Development Group consisting of representatives from the following organisations:

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The Standard was approved by the Development Group and the Rolling Stock Standing Committee in Select SC approval date. On Select Board approval date the RISSB Board approved the Standard for release.

This standard was issued for public consultation and was independently validated before being approved.

Development of the Standard was undertaken in accordance with RISSB's accredited process. As part of the approval process, the Standing Committee verified that proper process was followed in developing the Standard

RISSB wishes to acknowledge the positive contribution of subject matter experts in the development of this Standard. Their efforts ranged from membership of the Development Group through to individuals providing comment on a draft of the Standard during the open review.

I commend this Standard to the Australasian rail industry as it represents industry good practice and has been developed through a rigorous process.

Deb Spring
Exec. Chair / CEO
Rail Industry Safety and Standards Board

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AS 7519:2022

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This Standard was prepared by the Rail Industry Safety and Standards Board (RISSB) Development Group AS 7519 Bogie structural requirements.

Membership of this Development Group consisted of representatives from the organisations listed on the inside cover of this document

Objective

This document describes requirements for the structural strength of bogie structures and attached equipment.

The main purpose of the requirements is:

(a) to maintain the structural integrity of bogie structures and attached equipment under normal operation; and

(b) to minimize risks to passengers, personnel, train crew and members of the general public in the event of collisions or derailments.

The content of this Standard is intended to assist with the compliance assessment process detailed in AS 7501.

Compliance

There are four types of provisions contained within Australian Standards developed by RISSB:

1. Requirements.
2. Recommendations.
3. Permissions.
4. Constraints.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard. Requirements are identified within the text by the term 'shall'.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term 'should'.

Recommendations recognise that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied or other controls are more appropriate or better.

Permissions – conveys consent by providing an allowable option. Permissions are identified within the text by the term 'may'.

Constraints - provided by an external source such as legislation. Constraints are identified within the text by the term 'must'.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities, or interfacing organisations where the risk may be shared.

RISSB Standards address known hazards within the railway industry. Hazards, and clauses within this Standard that address those hazards, are listed in Appendix A

Contents

Appendix contents

1 Scope and general

1.1 Scope

1.1.1 This document applies to bogies for the following:

(a) Locomotive rolling stock - Section 2.

(b) Freight rolling stock – Section 3.

(c) Passenger rolling stock - Section 4.

(d) Infrastructure maintenance rolling stock – Section 5.

1.1.2 The document covers the design, construction and maintenance of rolling stock.

1.1.3 Operation of rolling stock is not covered.

1.1.4 The Standard is not specifically intended to cover rolling stock used on light rail, cane railway and monorail networks, but items from this Standard may be applied to such systems as deemed appropriate by the relevant railway infrastructure manager (RIM).

1.1.5 Vehicles without bogies are not within the scope of this Standard.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

- AS 7501 Rolling stock compliance certification.
- AS 7507 Rolling stock outlines.
- AS 7509 Dynamic behaviour.
- AAR Manual of Standards and Recommended Practices: – Section S M-202 and M-203.
- EN 13749:2011 Railway applications - Wheelsets and bogies - Method of specifying the structural requirements of bogie frames.

1.3 Terms, definitions, and abbreviations

For the purposes of this document, the terms and definitions given in RISSB Glossary: https://www.rissb.com.au/products/glossary/ and the following apply:

1.3.1
AAR bogie
conventional three-piece freight bogie based on the technical requirements of the AAR manual of standards and recommended practices. Note that the ancillary requirements in the AAR manual, such as those pertaining to AAR approval, are not applicable.

1.3.2
exceptional load cases
these load cases represent those extreme loads that might occur only rarely during the life of the bogie.

1.3.3
fatigue load cases
these load cases represent the loads that occur during normal operation. Also known as service or dynamic load cases.

1.3.4
fatigue test
a test applying repeated fatigue loading to a bogie frame with intermittent checks for crack initiation.

1.3.5
static test
a test for measuring strains and/or deflections in a bogie frame under static loading, using electrical resistance strain gauges or suitable measurement equipment.

1.3.6
trammelling
measurement of the bogie frame e.g. centre line to centre line, check for squareness.

2 Locomotive rolling stock

2.1 Interfaces

2.1.1 Structural body-bogie interface

2.1.1.1 Exceptional load cases

2.1.1.1.1 The bogie shall be attached to the body such that the bogie does not become detached under extreme forces which can occur during the normal life of the bogie.

2.1.1.1.2 Body-bogie interfaces shall:

(a) be designed to withstand the following load cases:

i. longitudinal loads representing the effect on the bogie of a heavy shunt or minor end-on collision;

ii. lateral loads representing a vehicle on its side and supported either on the body or on the bogies; and

iii. vertical loads representing the effects of a minor collision, lifting, and jacking; or

(b) be in accordance with the proof load cases for body to bogie connection requirements provided in EN12663.

C.2.1.1.1.2 Commentary

a) *Refer to the RIMs requirements for retaining bogies.*

b) *An example for load cases for body to bogie attachments is defined in EN 12663:2010+A1:2014. These load cases are intended to ensure that bogies will, as far as is practicable, stay attached to the body in the event of a derailment, collision and during lifting or jacking for recovery.*

c) *Good practice is to ensure that when the ultimate loadings are exceeded, failure of the body to bogie connection will take place in a pre-determined manner and that as a result the primary vehicle structure will not suffer damage that could compromise its integrity and thus expose passenger or traincrew to additional risk of injury.*

2.1.1.2 Fatigue load cases

2.1.1.2.1 Structural elements connecting the bogie to the body shall be designed to withstand fatigue loads that are representative of the expected in-service loads.

C.2.1.1.2.1 Commentary

a) *Examples of international reference standards containing a comprehensive set of fatigue load cases are:*

i. *EN 13749: Annex C and Annex D.*

ii. *JIS E 4207: Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

b) *Considerations for expected in-service loads can include:*

i. *loading / unloading operations;*

ii. *traction and braking;*

iii. *overloading;*

iv. *speed;*

v. *wheel defects such as: wheel flats, shelling, ovality or wheel polygonization (see note 1);*

vi. *track irregularities such as: track weld dips, variations in track alignment and travelling through turnouts (see note 2).*

Note 1 – RISSB Code of Practice – Wheel Defects: provides additional information regarding wheel defects commonly found in service.

Note 2 - Refer to AS 7635 for additional information regarding track geometry defects.

2.1.2 Interface geometry

2.1.2.1 Interface geometry should be arranged to minimize the introduction of longitudinal and lateral forces into the vehicle body from bogie pitch and roll movements.

C2.1.2.1 Commentary

a) *Refer to AS 7509 for requirements on bogie to vehicle clearances when negotiating horizontal and vertical curves.*

b) *Refer to AS 7507 for requirements on bogie to infrastructure clearances.*

c) *Examples of interface geometry which affect the introduction of forces into the body include:*

i. *yaw damper height;*

ii. *lateral damper height; and*

iii. *centre pivot height.*

2.2 Design load cases

2.2.1 Bogie structures

2.2.1.1 Exceptional load cases

2.2.1.1.1 Bogie structures shall be designed to withstand the extreme forces which can occur during the normal life of the bogie.

2.2.1.1.2 Extreme forces that should be considered include:

(a) vertical - vehicle body at its maximum loaded condition;

(b) lateral - maximum lateral track force or vehicle overturning;

(c) longitudinal - minor derailments at low speeds;

(d) track twist - track irregularities;

(e) vertical - forces imposed by the vehicle body during lifting or jacking operations;

(f) curving - lozenging forces at wheel/rail adhesion limit;

(g) braking - emergency application;

(h) motor - short circuit torque;

(i) significant wheel defects – forces imposed by significant wheel damage such as large wheel flats; and

(j) bottoming of the frame on the springs due to track defects.

C2.2.1.1.2 Commentary

a) *It is difficult to develop detailed design load cases suitable for all bogie types, so the requirements describe circumstances under which the integrity of bogie structures should be maintained.*

b) *Safety factors are commonly applied where specific extreme forces are difficult to ascertain.*

c) *Examples of suitable exceptional load cases for locomotive bogie structures are included in:*

   i. *EN 13749:2011 Annex C.4.1 and Annex D;*

   ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

d) *Track twist – track irregularities as per Clause 2.2.1.1.2(d) could use values obtained from the references provided by C2.2.1.1.2(b). Alternatively refer to AS 7509 for Track Twist parameters on Various Routes.*

e) *Motor – short circuit torque as per Clause 2.2.1.1.2(h), is caused when a short circuit in the inverter generates a high torque pulse in the motor. The value is normally specified by the motor manufacturer.*

f) *Guidance assessing the significance of wheel defects as per Clause 2.2.1.1.2(i), can be sought from the RISSB Wheel defect Code of Practice. This Code describes requirements for the inspection of freight, passenger, and infrastructure maintenance rolling stock wheels and determination of the action required. The document provides definitions and illustrations of wheel faults and defects. Each defect category has a severity and corresponding action.*

2.2.1.2 Fatigue load cases

2.2.1.2.1 Bogie structures shall be designed to withstand fatigue loads that are representative of the expected in-service loads and service life.

2.2.1.2.2 Fatigue forces that should be considered include:

(a) vertical - the weight of the supported body;

(b) lateral - running on curves;

(c) longitudinal - traction and braking;

(d) track twist - track irregularities;

(e) attached equipment;

(f) dampers;

(g) changes in payload;

(h) curving - lozenging forces at wheel/rail adhesion limit;

(i) braking - local forces at the brake bracketry and bogie frame under standard braking applications;

(j) motor - fatigue load torque;

(k) motor - vertical inertia;

(l) wheels with allowable tread defects.

C2.2.1.2.2 Commentary

a) *It is difficult to develop detailed design load cases suitable for all bogie types, so the requirements describe circumstances under which the integrity of bogie structures should be maintained.*

b) *Examples of international reference standards containing a comprehensive set of fatigue load cases are:*

   i. *EN 13749 : Annex C.4.2 and Annex D.*

   ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

   These standards use constant amplitude loads which are intended to show that the design has infinite life regardless of mileage.

c) *Track twist – track irregularities as per Clause 2.2.1.2.2(d) could use values obtained from the references provided by C2.2.1.2.2(b). Alternatively refer to AS 7509 Table A2 for Track Twist parameters on Various Routes.*

d) *Motor torque values for each stop and start can be obtained from the torque curves supplied by the motor manufacturer.*

e) *The load case for motor vertical inertia is specified in Clause 2.2.2.6 below for the equipment and its local mounting. This clause relates to this load case being imposed on the remaining bogie structures.*

f) *For guidance relating to wheels with allowable defects as per Clause 2.2.1.2.2(i) ,the RISSB Wheel defect Code of Practice describes requirements for the inspection of freight, passenger, and infrastructure maintenance rolling stock wheels and determination of the action required. The document provides definitions and illustrations of wheel faults and defects. Each defect category has a severity and corresponding action.*

2.2.2 Equipment attached to bogie frames

2.2.2.1 Unless otherwise stated, Section 2.2.2 applies to items of equipment which are light relative to the bogie frame such that they do not influence the dynamic behaviour of the bogie frame.

2.2.2.2 Non AAR certified Items of equipment and their mountings should withstand as exceptional loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.1.

C2.2.2.2 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

(a) vertical ±20g;

(b) lateral ±3g; and

(c) longitudinal ±5g.

2.2.2.3 Non-AAR certified Items of equipment and their mountings should withstand as fatigue loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.1 for not less than 10^7 cycles:

C2.2.2.3 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

(a) vertical ±10g;

(b) lateral ±1.5g; and

(c) longitudinal ±0.5g.

2.2.2.4 Locally generated accelerations and forces acting within and on equipment should be considered in addition to Clauses 2.2.2.2 and 2.2.2.3 above.

C2.2.2.4 Commentary

Examples of locally generated forces (ref EN13749 Annex D) include braking forces, failure of traction motors or associated drive system, out of balance rotating forces.

2.2.2.5 Items of equipment and their mountings should be designed to avoid resonance with the bogie suspension or frame natural frequencies for both resilient and non-resilient mounting.

C2.2.2.5 Commentary

Resonance of equipment will result in increased inertia forces and an increase in the number of cycles of fatigue loading.

2.2.2.6 Items of equipment which are heavy enough to influence the dynamic behaviour of the bogie frame should be subject to a dynamic analysis or on-track testing to derive suitable load cases.

C2.2.2.6 Commentary

This applies to heavy equipment, typically traction motors where it is not always possible to satisfy the standard inertia load cases in Clauses 2.2.2.2 to 2.2.2.3.

2.2.3 Equipment attached to axleboxes, axles and wheelsets

2.2.3.1 Non-AAR certified Items of equipment and their mountings should withstand as exceptional loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.2.

C2.2.3.1 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

(a) vertical ±77.5g for non-radial arm axlebox, axles and wheelsets;

(b) vertical ±155g for radial arm axlebox;

(c) lateral ±20g; and

(d) longitudinal ±18g

2.2.3.2 Non AAR certified Items of equipment and their mountings should withstand as fatigue loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.2 for not less than 10^7 cycles.

> *C2.2.3.2 Commentary*
>
> *AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.*
>
> *Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:*
>
> *(a) vertical ±35g for non-radial arm axleboxes, axles and wheelsets;*
>
> *(b) vertical ±70g for radial arm axlebox;*
>
> *(c) lateral ±10g; and*
>
> *(d) longitudinal ±12g.*

2.2.3.3 Locally generated accelerations, forces and resonances acting within and on equipment should be considered in addition to Clauses 2.2.3.1 and 2.2.3.2 above.

> *C3.3.3 Commentary*
>
> *Examples of locally generated forces (ref EN 13749 Annex D) include braking forces, out of balance rotating forces, centrifugal forces. Examples of resonances to be considered include coupling with the natural frequencies of the axlebox, axle, and wheelset.*

2.3 Analysis

2.3.1 Exceptional load cases

2.3.1.1 A stress analysis shall be performed on new designs of interfaces, bogie structures, or attached equipment using the exceptional load cases.

2.3.1.2 The stress analysis shall demonstrate that the assessed structures will withstand exceptional loads without deflecting to an extent that would impair functionality under the application of the loads.

2.3.1.3 The stress analysis shall demonstrate that the assessed structures will withstand exceptional loads without suffering permanent deformation.

> *C.2.3.1.3 Commentary*
>
> a) *In determining the stress levels in ductile materials, it is not necessary to take full account of features producing local stress concentrations.*
>
> b) *From EN 13749, the area of local plastic deformation associated with the stress concentrations are to be sufficiently small in order that clauses 2.3.1.2 and 2.3.1.3 are satisfied.*

2.3.1.4 The assessment method shall incorporate any load or safety factors which are included in the reference standard used to define the exceptional load cases.

> *C.2.3.1.4 Commentary*

> a) *Australian rail standards refer to a "safe working stress" but do not define the associated load cases for bogie structures. Therefore, "safe working stress" is not included in the examples.*
>
> b) *An example of load or safety factors associated with reference standards includes EN 13749 Annex E.4.3 defines a safety factor S1 to allow for uncertainties in the calculation.*

2.3.1.5 The assessment method shall incorporate any requirements for combining load cases which are included in the reference Standard used to define the exceptional load cases.

> *C.2.3.1.5 Commentary*
>
> *An example of combining loads is EN 13749 Annex F.4 which requires that all exceptional load combinations likely to occur in service are considered.*

2.3.2 Fatigue load cases

2.3.2.1 A stress analysis shall be performed on new designs of interfaces, bogie structures, or attached equipment using the fatigue load cases.

2.3.2.2 The stress analysis shall demonstrate that the assessed structures will withstand the fatigue loads without failure for a fatigue life exceeding the required design life.

> *C.2.3.2.2 Commentary*
>
> *Failure is defined as a structural defect which renders the vehicle no longer safe for service operation.*

2.3.2.3 The fatigue assessment method shall be one that is endorsed within the reference standard used to define the fatigue load cases.

> *C.2.3.2.3 Commentary*
>
> a) *The discrepancies in fatigue load cases between different reference standards are partially explained by the variations in the fatigue assessment methods used.*
>
> b) *Examples of fatigue assessment methods associated with reference standards include:*
>
> (i) *EN 13749 Annex E.4.4.3.2 defines an endurance limit approach. EN 13749 specifies that the endurance limit approach can be followed by a cumulative damage approach if it is inappropriate to maintain the stress level below the endurance limit.*
>
> (ii) *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*
>
> *Typically, these standards use an endurance limit approach which is intended to show that the design has infinite life regardless of mileage.*
>
> c) *An alternative to the endurance limit approach included in reference standards is to use an appropriate fatigue load spectrum to relate the fatigue life of the vehicle to mileage.*

2.4 Testing

2.4.1 Acceptance programme

2.4.1.1 For a new design of bogie frame, the following three testing stages should be used:

(a) Static tests.

(b) Fatigue tests.

(c) On-track tests.

> *C.2.4.1.1 Commentary*
>
> *A reduced test programme can be used for:*
>
> a) *an existing design of bogie frame intended for a new application;*
>
> b) *a modification to an existing design; or*
>
> c) *an order for a very small number of bogies where the bogie design is conventional, and testing is impractical for economic reasons.*

2.4.1.2 A calculated analysis and at least one testing stage shall be performed with a reduced test programme.

2.4.1.3 Tested bogie frames shall be of a similar type and manufacture as the bogie frames to be used in service such that the test results are not affected by differences between tested bogie frames and those used in service.

2.4.1.4 Test rig equipment should be capable of producing, as far as is reasonably practical, stresses equal to or greater than those that would appear on a bogie frame when placed under its intended vehicle and supported on its suspension.

> *C.2.4.1.4 Commentary*
>
> *It is often difficult to fully understand the magnitude of all inputs expected in service, therefore by applying stresses that exceed those that are expected provides a conservative approach.*

2.4.1.5 Test rig equipment should be capable of applying the exceptional loads described in Section 2.2.

> *C.2.4.1.5 Commentary*
>
> *Refer to ASTM E1237 for guidance on applying bonded resistance strain gauges.*

2.4.2 Static tests

2.4.2.1 Static tests should validate the numerical stress analysis for exceptional load cases.

> *C.2.4.2.1 Commentary*
>
> *Examples of static test programmes are given in:*
>
> a) *EN 13749 Annex F.4.*
>
> b) *UIC 615-4.*

2.4.3 Dynamic tests

2.4.3.1 The dynamic test should confirm that the frame strength is sufficient with regard to the fatigue loads acting upon it.

> *C.2.4.3.1 Commentary*
>
> a) *Examples of dynamic test programmes are given in:*
>
> i. *EN 13749 Annex G.2.*
>
> ii. *UIC 615-4.*
>
> b) *EN 61373 specifies requirements for testing items of equipment for use on railway vehicles such as bogies which are subjected to vibrations and shock.*
>
> c) *AS 7509 provides requirements for dynamic behaviour, the evaluation and testing of; and specific guidance for modelling using validated software tools, which can be applied for non-structural dynamic analysis.*

2.4.4 On-track tests

2.4.4.1 On track testing should cover the range of conditions expected in service up to 110% of the maximum operational speed. ~~posted speed.~~

> *C.2.4.4.1 Commentary*
>
> *The purpose of the on-track test is to:*
>
> a) *measure the operating stresses.*
>
> b) *check the design assumptions; and*
>
> c) *check the fitness for purpose of the bogie structure and attached equipment.*

2.5 In-service loading

2.5.1 Bogies shall be operated within their design capacity.

2.5.2 Secondary restraint should be used for items that can be prone to detachment and causing a derailment.

> *C.2.5.2 Commentary*
>
> a) *Generally, the design process will take the possibility of detachment into account and produce a design that minimises this possibility as far as practicable. At the end of this process, an item might be considered prone to detachment if there is still a significant risk of detachment due to the location, shape, or method of attachment for the item.*
>
> b) *Examples of secondary restraint include:*
>
> i. *Safety straps for damper seizure and control rod failure.*
>
> ii. *Safety cage for carden shaft failure.*

2.5.3 Secondary locking of a proven design should be used for bolted joints at structural connections prone to vibration and high fatigue loading.

> *C.2.5.3 Commentary*
>
> *Examples of secondary locking include:*
>
> a) *Torque-prevailing nuts, including bent-beam nuts and Nylock nuts.*
>
> b) *Locking wire.*
>
> c) *Tab washers (not spring washers).*
>
> d) *Thread-locking adhesives.*

2.6 Maintenance

2.6.1 RTOs and/or rolling stock owners shall establish and comply with criteria that define when and how bogies are to be checked and maintained so that they remain fit for purpose.

> *C.2.6.1 Commentary*
>
> *Typical maintenance activities include:*
>
> a) *Trammelling of bogie frames (where applicable).*
>
> b) *Non-destructive testing for cracks.*
>
> c) *Monitoring of cracks with due regard to their propagation rate and critical crack dimension. The critical crack dimension can be obtained from either a fracture mechanics analysis, or a standard such as BS 7910.*
>
> d) *Repair of bogie frames and associated componentry including welding, straightening and heat treatment.*
>
> e) *Maintenance of pedestal opening and other component interface dimensions (where applicable).*
>
> f) *Inspection and lubrication of steam locomotive running gear.*
>
> g) *Failure mode and effect analysis to determine appropriate tests and schedules for detection and rectification of in-service defects.*
>
> h) *Maintenance of records for usage and remaining life of components.*

2.7 In-service defects

2.7.1 RTOs shall establish and comply with criteria that define when a vehicle has to be removed from service due to bogie defects.

2.7.2 In the absence of other specific criteria a vehicle shall be removed from service if any of the following defects are found:

(a) Bogie frames and associated components which have fatigue cracks in critical zones.

> *C.2.7.2(a) Commentary*
>
> *The critical crack dimension can be obtained from either a fracture mechanics analysis, or a standard such as BS 7910.*
>
> *Where bogie frames and associated components have cracks in non-critical zones, removal from service for further analysis can assist with identifying defects such as fatigue cracks which are continuing to grow.*

(b) Bogie frames and associated components which are bent or distorted causing an imbalance in wheel loads, and/or incorrect tracking of the bogie.

(c) Loose, missing, or broken, rivets or Huck bolts which connect bolsters, transoms, headstocks, W-guards or other major bogie frame components.

(d) Timber bogie components which have split, or are rotted, compromising their integrity.

2.8 Action following derailments and collisions

2.8.1 An RTO shall establish and comply with procedures that describe how bogies and associated structural components are to be inspected and requalified following a derailment or collision.

3 Freight rolling stock

3.1 Interfaces

3.1.1 Structural body-bogie interface: non – AAR bogies

3.1.1.1 Exceptional load cases

3.1.1.1.1 Non-AAR bogies shall be attached to the body such that the bogie does not become detached under extreme forces which can occur during the normal life of the bogie.

3.1.1.1.2 Body-bogie interfaces for non-AAR bogies shall:

(a) be designed to withstand the following load cases:

i. longitudinal loads representing the effect on the bogie of a heavy shunt or minor end-on collision;

ii. lateral loads representing a vehicle on its side and supported either on the body or on the bogies; and

iii. vertical loads representing the effects of a minor collision, lifting, and jacking; or

(b) be in accordance with the proof load cases for body to bogie connection requirements provided in EN12663.

> *C.3.1.1.1.2 Commentary*
>
> a) *Refer to the RIMs requirements for retaining bogies.*
>
> b) *For long trains, a longitudinal train dynamic simulation might be required to derive the longitudinal load case.*

3.1.1.2 Fatigue load cases

3.1.1.2.1 Structural elements connecting a non-AAR bogie to the body shall be designed to withstand fatigue loads that are representative of the expected in-service loads.

> *C.3.1.1.3.1 Commentary*
>
> a) *Examples of international reference standards containing a comprehensive set of fatigue load cases are:*
>
> i. *EN 13749: Annex C and Annex D.*
>
> ii. *JIS E 4207: Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*
>
> b) *Considerations for expected in-service loads can include:*
>
> i. *loading / unloading operations;*
>
> ii. *traction and braking;*
>
> iii. *overloading;*
>
> iv. *speed;*
>
> v. *wheel defects such as: wheel flats, shelling, ovality or wheel polygonization (see note 1);*
>
> vi. *track irregularities such as: track weld dips, variations in track alignment and travelling through turnouts (see note 2).*
>
> *Note 1 – RISSB Code of Practice – Wheel Defects: provides additional information regarding wheel defects commonly found in service.*

Note 2 - Refer to AS 7635 for additional information regarding track geometry defects.

3.1.2 Structural body-bogie interface: AAR bogies

3.1.2.1 The centre pivot and side bearer arrangements on AAR bogies should comply with the technical requirements given in Section D of the AAR Manual Of Standards and Recommended Practices.

3.1.3 Interface geometry

3.1.3.1 Refer to AS 7509 for requirements on bogie to vehicle clearances when negotiating horizontal and vertical curves.

3.1.3.2 Refer to AS 7507 for requirements on bogie to infrastructure clearances.

3.2 Design load cases

3.2.1 Bogie structures: non-AAR bogies

3.2.1.1 Exceptional load cases

3.2.1.1.1 Non-AAR bogie structures shall be designed to withstand the extreme forces which can occur during the normal life of the bogie.

3.2.1.1.2 Extreme forces that should be considered in the design of non-AAR bogie structures include:

(a) vertical - vehicle body at its maximum loaded condition;

(b) vertical - force of loaded wagon maximum accelerations at 10% over maximum speed over vertical irregularities such as dip subsidence or pitch and bounce per AS 7509.

(c) lateral - maximum lateral track force or vehicle overturning;

(d) longitudinal - minor derailments at low speeds;

(e) track twist - track irregularities;

(f) vertical - forces imposed by the vehicle body during lifting or jacking operations;

(g) curving - lozenging forces at wheel/rail adhesion limit;

(h) braking - emergency application;

(i) significant wheel defects – forces imposed by significant wheel damage such as large wheel flats; and

(j) bottoming of the frame on the springs due to track defects.

C3.2.1.1.2 Commentary

a) *It is difficult to develop detailed design load cases suitable for all bogie types, so the requirements describe circumstances under which the integrity of bogie structures should be maintained.*

b) *Safety factors are commonly applied where specific extreme forces are difficult to ascertain.*

c) *Examples of suitable exceptional load cases for freight rolling stock bogie structures are included in:*

  i. *EN 13749 : Annex C.3.3 and Annex D;*

ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

iii. *AAR M-213 Truck Frames, Fabricated Steel*

d) *Track twist – track irregularities as per Clause 3.2.1.1.2(d) could use values obtained from the references provided by C3.2.1.1.2(b). Alternatively refer to AS 7509 for Track Twist parameters on Various Routes.*

e) *Guidance assessing the significance of wheel defects as per Clause 3.2.1.1.2(i), can be sought from the RISSB Wheel defect Code of Practice. This Code describes requirements for the inspection of freight, passenger, and infrastructure maintenance rolling stock wheels and determination of the action required. The document provides definitions and illustrations of wheel faults and defects. Each defect category has a severity and corresponding action.*

3.2.1.2 Fatigue load cases

3.2.1.2.1 Non-AAR bogie structures shall be designed to withstand fatigue loads that are representative of the expected in-service loads and service life.

3.2.1.2.2 Fatigue forces that should be considered in the design of non-AAR bogie structures include:

(a) vertical - the weight of the supported body and lading;

(b) lateral - running on curves;

(c) longitudinal - traction and braking;

(d) track twist: all vehicles – track irregularities;

(e) attached equipment;

(f) dampers;

(g) changes in payload;

(h) curving - lozenging forces at wheel/rail adhesion limit;

(i) braking - local forces at the brake bracketry and bogie frame under standard braking applications.

(j) wheels with allowable tread defects.

C3.2.1.2.2 Commentary

a) *It is difficult to develop detailed design load cases suitable for all bogie types, so the requirements describe circumstances under which the integrity of bogie structures should be maintained.*

b) *Examples of international reference standards containing a comprehensive set of fatigue load cases are:*

i. *EN 13749: Annex C.3.4 and Annex D;*

ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

c) *Track twist – track irregularities as per Clause 3.2.1.2.2(d) could use values obtained from the references provided by C3.2.1.1.2(b). Alternatively refer to AS 7509 for Track Twist parameters on Various Routes.*

d) *Examples of documents containing a representative load spectrum (which can be less onerous than that using the constant amplitude load cases) that can be used to relate the fatigue life of the vehicle to mileage include:*

i. *AAR Specification M-1001, Chapter 7: REPOS Data (section C specifically applies to the design, fabrication, and construction of freight car structures but this REPOS data is sometimes used for bogie design); and*

ii. *Rail CRC report "The East Australian Railway Load Spectrum with REPOS diagrams and Life Estimation Methods".*

e) *For guidance relating to wheels with allowable defects as per Clause 3.2.1.2.2(j) ,the RISSB Wheel defect Code of Practice describes requirements for the inspection of freight, passenger, and infrastructure maintenance rolling stock wheels and determination of the action required. The document provides definitions and illustrations of wheel faults and defects. Each defect category has a severity and corresponding action.*

3.2.2 Bogie structures: AAR cast 3 piece bogies

3.2.2.1 Bolsters and sideframes on AAR cast 3 piece bogies shall be designed to withstand the static loads given in AAR Specifications M-202 and M-203, respectively.

3.2.2.2 Bolsters and sideframes on AAR cast 3 piece bogies shall be designed to withstand the dynamic test loads given in AAR Specifications M-202 and M-203, respectively.

3.2.3 Equipment attached to bogie frames

3.2.3.1 Unless otherwise stated, Section 3.2.3 applies to items of equipment which are light relative to the bogie frame such that they do not influence the dynamic behaviour of the bogie frame.

3.2.3.2 Non AAR certified Items of equipment and their mountings should withstand as exceptional loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.1.

C3.2.3.2 Commentary

For AAR type freight bogies, standard components such as M-948 side bearers or AAR approved brake equipment are generally considered exempt from this testing / analysis.

AS 7509 provides guidance on measuring, filtering, and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

(a) vertical ± 20 g;

(b) lateral ± 3 g; and

(c) longitudinal ± 5 g.

3.2.3.3 Non AAR certified Items of equipment and their mountings should withstand as fatigue loads the inertia forces associated with the accelerations outlined in EN 13749 Table D.1. for not less than 10^7 cycles.

C3.2.3.3 Commentary

AS 7509 provides guidance on measuring, filtering, and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

(a) vertical ± 10 g;

(b) lateral ± 1.5 g; and

(c) longitudinal ± 0.5 g.

3.2.3.4 Locally generated accelerations and forces acting within and on equipment should be considered in addition to Clauses 3.2.2.2 and 3.2.2.3 above.

C3.2.3.4 Commentary

Examples of locally generated forces (ref EN13749 Annex D) include braking forces and out of balance rotating forces.

3.2.3.5 Items of equipment and their mountings should be designed to avoid resonance with the bogie suspension or frame natural frequencies for both resilient and non-resilient mounting.

C3.2.3.5 Commentary

Resonance of equipment will result in increased inertia forces and an increase in the number of cycles of fatigue loading.

3.2.4 Equipment attached to axleboxes, axles and wheelsets

3.2.4.1 Non – AAR certified items of equipment and their mountings should withstand as exceptional loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.2.

C3.2.4.1 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

(a) vertical ± 77.5 g for non-radial arm axlebox, axles and wheelsets;

(b) vertical ± 155 g for radial arm axlebox;

(c) lateral ± 20 g; and

(d) longitudinal ± 18 g;

3.2.4.2 Non – AAR certified items of equipment and their mountings should withstand as fatigue loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.2 for not less than 10^7 cycles.

C3.2.4.2 Commentary

AS 7509 provides guidance on measuring, filtering, and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

(a) vertical ± 35 g for non-radial arm axleboxes, axles and wheelsets;

(b) vertical ± 70 g for radial arm axlebox;

(c) lateral ± 10 g; and

(d) longitudinal ± 12 g.

3.2.4.3 Locally generated accelerations, forces and resonances acting within and on equipment should be considered in addition to Clauses 3.2.4.1 and 3.2.4.2 above.

C3.2.4.3 Commentary

Examples of locally generated forces (ref EN 13749 Annex D) include braking forces, out of balance rotating forces, centrifugal forces. Examples of resonances to be considered include coupling with the natural frequencies of the axlebox, axle, and wheelset.

3.3 Analysis

3.3.1 Exceptional load cases

3.3.1.1 A stress analysis shall be performed on new designs of interfaces, bogie structures, or attached equipment using the exceptional load cases.

3.3.1.2 The stress analysis shall demonstrate that the assessed structures will withstand exceptional loads without deflecting to an extent that would impair functionality under the application of the loads.

C3.3.1.2 Commentary

AAR standards include allowable deflection limits for bogie frame components.

3.3.1.3 The stress analysis shall demonstrate that the assessed structures will withstand exceptional loads without suffering permanent deformation.

C.3.3.1.3 Commentary

a) *In determining the stress levels in ductile materials, it is not necessary to take full account of features producing local stress concentrations.*

b) *From EN 13749, the area of local plastic deformation associated with the stress concentrations are to be sufficiently small in order that clauses 3.3.1.2 and 3.3.1.3 are satisfied.*

3.3.1.4 The assessment method shall incorporate any load or safety factors which are included in the reference Standard used to define the exceptional load cases.

C3.3.1.4 Commentary

a) *Australian rail standards refer to a "safe working stress" but do not define the associated load cases for bogie structures. Therefore, "safe working stress" is not included in the examples.*

b) *Examples of load or safety factors associated with reference standards include:*

> i. *EN 13749 Annex E.4.3 defines a safety factor S1 to allow for uncertainties in the calculation.*
> ii. *AAR Specifications M-202 and M-203, contain load factors for cast freight bogie bolsters and side frames*
> iii. *AAR SpecificationM-213 contains load factors for fabricated “H frame” bogie structures.*

3.3.1.5 The assessment method shall incorporate any requirements for combining load cases which are included in the reference Standard used to define the exceptional load cases.

> *C.3.3.1.5 Commentary*
>
> *An example of combining loads is EN 13749 Annex F.3 which requires that all exceptional load combinations likely to occur in service are considered.*

3.3.2 Fatigue load cases

3.3.2.1 A stress analysis shall be performed on new designs of interfaces, bogie structures, or attached equipment using the fatigue load cases.

3.3.2.2 The stress analysis shall demonstrate that the assessed structures will withstand the fatigue loads without failure for a fatigue life exceeding the required design life.

> *C.3.3.2.2 Commentary*
>
> *Failure is defined as a structural defect which renders the vehicle no longer safe for service operation.*

3.3.2.3 The fatigue assessment method shall be one that is endorsed within the reference Standard used to define the fatigue load cases.

> *C.3.3.2.3 Commentary*
>
> a) *The discrepancies in fatigue load cases between different reference standards are partially explained by the variations in the fatigue assessment methods used.*
>
> b) *Examples of fatigue assessment methods associated with reference standards include:*
>
> i. *EN 13749 Annex E.4.4.3.2 defines an endurance limit approach. EN 13749 specifies that the endurance limit approach can be followed by a cumulative damage approach if it is inappropriate to maintain the stress level below the endurance limit.*
>
> ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*
>
> *Typically, these standards use an endurance limit approach which is intended to show that the design has infinite life regardless of mileage.*
>
> c) *Fatigue assessment methods that are used to derive fatigue life from a fatigue load spectrum are included in AAR Specification M-1001: Chapter 7.2. This section includes fatigue analysis methodologies that can be useful also for non- AAR bogie designs*
>
> d) *For AAR type 3 piece bogie castings AAR M-202 and M-203 have establish well defined test methodologies and load cases for static and fatigue tests based on repos type data, expected life and safety factors and have been validated over time. These tests can serve as a standardized basis for these tests with some parameters (loads or cycles) factored up or down on a case by case basis when the expected service differs from AAR conditions.*

3.4 Testing

3.4.1 Acceptance programme

3.4.1.1 For a new design of bogie frame, the following three testing stages should be used:

(a) Static tests.

(b) Fatigue tests.

(c) On-track tests.

> *C.3.4.1.1 Commentary*
>
> a) *A reduced test programme can be used for:*
>
> i. *an existing design of bogie frame intended for a new application;*
>
> ii. *a modification to an existing design; or*
>
> iii. *an order for a very small number of bogies where the bogie design is conventional, and testing is impractical for economic reasons, or where castings are for temporary use e.g. for dynamic performance tests.*
>
> b) *AAR M-202 and M203 provides examples of permitted changes to an existing design that do not require retesting/recertifying the castings.*

3.4.1.2 A calculated analysis and at least one testing stage shall be performed with a reduced test programme.

3.4.1.3 Tested bogie frames shall be of a similar type and manufacture as the bogie frames to be used in service such that the test results are not affected by differences between tested bogie frames and those used in service.

3.4.1.4 Test rig equipment should be capable of producing, as far as is reasonably practical, stresses equal to or greater than those that would appear on a bogie frame when placed under its intended vehicle and supported on its suspension.

> *C.3.4.1.4 Commentary*
> *It is often difficult to fully understand the magnitude of all inputs expected in service, therefore by applying stresses that exceed those that are expected provides a conservative approach.*

3.4.1.5 Test rig equipment should be capable of applying the exceptional loads described in Section 3.2.

> *C.3.4.1.5 Commentary*
> *Refer to ASTM E1237 for guidance on applying bonded resistance strain gauges.*

3.4.2 Static tests

3.4.2.1 Static tests should validate the numerical stress analysis for exceptional load cases.

> *C.3.4.2.1 Commentary*
>
> *Examples of static test programmes are given in:*
>
> a) *EN 13749 Annexe F.3.*
>
> b) *UIC 515-4.*
>
> c) *AAR Specification M-202 Section 4.0 (bolsters, cast and fabricated).*

d) *AAR Specification M-203 Section 4.0 and Section 5.0 (side frames, cast steel).*
e) *AAR Specification M-203A (six wheel bogie frames).*
f) *AAR Specification M-213 Section 4 and Section 5. (bogie frame - fabricated).*

3.4.3 Dynamic tests

3.4.3.1 The dynamic test should confirm that the frame strength is sufficient with regard to the fatigue loads acting upon it".

C.3.4.3.1 Commentary

a) *Examples of dynamic test programmes are given in:*
   i. *EN 13749 Annex G.3 (Applies to a freight bogie with a central pivot and two side bearers).*
   ii. *UIC 515-4.*
   iii. *AAR Specification M-202 Section 5.0 (bolsters, cast and fabricated).*
   iv. *AAR Specification M-203 Section 6.0 (side frames, cast steel).*
   v. *AAR Specification M-203A (six wheel bogie frames).*
   vi. *AAR Specification M-213 Section 6. (bogie frame - fabricated).*
b) *EN 61373 specifies requirements for testing items of equipment for use on railway vehicles such as bogies which are subjected to vibrations and shock.*
c) *AS 7509 provides requirements for dynamic behaviour, the evaluation and testing of; and specific guidance for modelling using validated software tools, which can be applied for non-structural dynamic analysis.*

3.4.4 On-track tests

3.4.4.1 On track testing should cover the range of conditions expected in service up to 110% of the maximum operational speed. ~~posted speed.~~

C.3.4.4.1 Commentary
The purpose of the on-track test is to:

a) *measure the operating stresses.*
b) *check the design assumptions; and*
c) *check the fitness for purpose of the bogie structure and attached equipment.*

3.5 In-service loading

3.5.1 Bogies shall be operated within their design capacity.

3.5.2 Secondary restraint should be used for items that can be prone to detachment and cause a derailment.

C.3.5.2 Commentary

a) *Generally, the design process will take the possibility of detachment into account and produce a design that minimises this possibility as far as practicable. At the end of this process, an item might be considered prone to detachment if there is still a significant risk of detachment due to the location, shape, or method of attachment for the item.*
b) *Examples of secondary restraint include:*
   i. *Safety straps for damper seizure and control rod failure.*
   ii. *Safety cage for carden shaft failure.*

3.5.3 Secondary locking of a proven design should be used for bolted joints at structural connections prone to vibration and high fatigue loading.

> *C.3.5.3 Commentary*
>
> *Examples of secondary locking include:*
>
> a) *Prevailing-torque nuts, including bent-beam nuts and Nylock nuts.*
>
> b) *Locking wire.*
>
> c) *Tab washers (not spring washers).*
>
> d) *Thread-locking adhesives.*

3.6 Maintenance

3.6.1 RTOs and/or rolling stock owners shall establish and comply with criteria that define when and how bogies are to be checked and maintained so that they remain fit for purpose.

> *C.3.6.1 Commentary*
>
> *Typical maintenance activities include:*
>
> a) *Trammelling of bogie frames (where applicable).*
>
> b) *Non-destructive testing for cracks.*
>
> c) *Monitoring of cracks with due regard to their propagation rate and critical crack dimension. The critical crack dimension can be obtained from either a fracture mechanics analysis, or a standard such as BS 7910.*
>
> d) *Repair of bogie frames (where permitted) and associated componentry including welding, straightening and heat treatment.*
>
> e) *Non-structural maintenance of worn pedestal opening and other component interface dimensions (where applicable).*
>
> f) *Failure mode and effect analysis to determine appropriate tests and schedules for detection and rectification of in-service defects.*
>
> g) *Maintenance of records for usage and remaining life of components.*
>
> h) *Inspection and replacement of worn suspension components such as wear plates, friction shoes, load and control springs that have reached their condemning limits or are worn to the point that dynamic performance is no longer acceptable.*

3.7 In-service defects

3.7.1 RTOs shall establish and comply with criteria that define when a vehicle has to be removed from service due to bogie defects.

3.7.2 In the absence of other specific criteria a vehicle shall be removed from service if any of the following defects are found:

(a) Bogie frames and associated components which have fatigue cracks in critical zones.

> *C.3.7.2(a) Commentary*
>
> *The critical crack dimension can be obtained from either a fracture mechanics analysis, or a standard such as BS 7910.*
>
> *Where bogie frames and associated components have cracks in non-critical zones, removal from service for further analysis can assist with identifying defects such as fatigue cracks which are continuing to grow.*

(b) Bogie frames and associated components which are bent or distorted causing an imbalance in wheel loads, and/or incorrect tracking of the bogie.

(c) Loose, missing, or broken, rivets or Huck bolts which connect bolsters, transoms, headstocks, W-guards or other major bogie frame components.

(d) Timber bogie components which have split, or are rotted, compromising their integrity.

3.8 Action following derailments and collisions

3.8.1 An RTO shall establish and comply with procedures that describe how bogies and associated structural components are to be inspected and requalified following a derailment or collision.

4 Passenger rolling stock

4.1 Interfaces

4.1.1 Structural body-bogie interface

4.1.1.1 Exceptional load cases

4.1.1.1.1 The bogie shall be attached to the body such that the bogie does not become detached under extreme forces which can occur during the normal life of the bogie.

4.1.1.1.2 Body-bogie interfaces shall:

(a) be designed to withstand the following load cases:

i. longitudinal loads representing the effect on the bogie of a heavy shunt or minor end-on collision;

ii. lateral loads representing a vehicle on its side and supported either on the body or on the bogies; and

iii. vertical loads representing the effects of a minor collision, lifting, and jacking; or

(b) be in accordance with the proof load cases for body to bogie connection requirements provided in EN12663.

C.4.1.1.1.2 Commentary

a) *Refer to the RIMs requirements for retaining bogies.*

b) *An example for load cases for body to bogie attachments is defined in EN 12663:2010+A1:2014. These load cases are intended to ensure that bogies will, as far as is practicable, stay attached to the body in the event of a derailment, collision and during lifting or jacking for recovery.*

c) *Good practice is to ensure that when the ultimate loadings are exceeded, failure of the body to bogie connection will take place in a pre-determined manner and that as a result the primary vehicle structure will not suffer damage that could compromise its integrity and thus expose passenger or traincrew to additional risk of injury.*

4.1.1.2 Fatigue load cases

4.1.1.2.1 Structural elements connecting the bogie to the body shall be designed to withstand fatigue loads that are representative of the expected in-service loads.

C.4.1.1.2.1 Commentary

a) *Examples of international reference standards containing a comprehensive set of fatigue load cases are:*

i. *EN 13749: Annex C and Annex D.*

ii. *JIS E 4207: Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

b) *Considerations for expected in-service loads can include:*

i. *loading / unloading operations;*

ii. *traction and braking;*

iii. *overloading;*

iv. *speed;*

> v. *wheel defects such as: wheel flats, shelling, ovality or wheel polygonization (see note 1);*
>
> vi. *track irregularities such as: track weld dips, variations in track alignment and travelling through turnouts (see note 2).*
>
> *Note 1 – RISSB Code of Practice – Wheel Defects: provides additional information regarding wheel defects commonly found in service.*
>
> *Note 2 - Refer to AS 7635 for additional information regarding track geometry defects.*

4.1.2 Interface geometry

4.1.2.1 Refer to AS 7509 for requirements on bogie to vehicle clearances when negotiating horizontal and vertical curves.

4.1.2.2 Refer to AS 7507 for requirements on bogie to infrastructure clearances.

4.1.2.3 Interface geometry should be arranged to minimize the introduction of longitudinal and lateral forces into the vehicle body from bogie pitch and roll movements.

> *C4.1.2.1 Commentary*
>
> *Examples of interface geometry which affect the introduction of forces into the body include:*
>
> a) *yaw damper height;*
>
> b) *lateral damper height; and*
>
> c) *centre pivot height.*

4.2 Design load cases

4.2.1 Bogie structures

4.2.1.1 Exceptional load cases

4.2.1.1.1 Bogie structures shall be designed to withstand the extreme forces which can occur during the normal life of the bogie.

4.2.1.1.2 Extreme forces that should be considered include:

(a) vertical - vehicle body at its maximum loaded condition;

(b) lateral - maximum lateral track force or vehicle overturning;

(c) longitudinal - minor derailments at low speeds;

(d) track twist - track irregularities;

(e) vertical - forces imposed by the vehicle body during lifting or jacking operations;

(f) curving - lozenging forces at wheel/rail adhesion limit;

(g) braking - emergency application;

(h) motor - short circuit torque;

(i) significant wheel defects – forces imposed by significant wheel damage such as large wheel flats; and

(j) bottoming of the frame on the springs due to track defects.

C4.2.1.1.2 Commentary

a) *It is difficult to develop detailed design load cases suitable for all bogie types, so the requirements describe circumstances under which the integrity of bogie structures should be maintained.*

b) *Safety factors are commonly applied where specific extreme forces are difficult to ascertain.*

c) *Examples of suitable exceptional load cases for locomotive bogie structures are included in:*

– *EN 13749 : Annex C.2.1 and Annex D;*

– *JIS E 4207*:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.

d) *Track twist – track irregularities as per Clause 4.2.1.1.2(d) could use values obtained from the references provided by C4.2.1.1.2(b). Alternatively refer to AS 7509 for Track Twist parameters on Various Routes.*

e) *Motor – short circuit torque as per Clause 4.2.1.1.2(h), is caused when a short circuit in the inverter generates a high torque pulse in the motor. The value is normally specified by the motor manufacturer.*

f) *Guidance assessing the significance of wheel defects as per Clause 4.2.1.1.2(i), can be sought from the RISSB Wheel defect Code of Practice. This Code describes requirements for the inspection of freight, passenger, and infrastructure maintenance rolling stock wheels and determination of the action required. The document provides definitions and illustrations of wheel faults and defects. Each defect category has a severity and corresponding action.*

4.2.1.2 Fatigue load cases

4.2.1.2.1 Bogie structures shall be designed to withstand fatigue loads that are representative of the expected in-service loads and service life.

4.2.1.2.2 Fatigue forces that should be considered include:

(a) vertical - the weight of the supported body;

(b) lateral - running on curves;

(c) longitudinal – traction and braking;

(d) track twist - track irregularities;

(e) attached equipment;

(f) dampers;

(g) changes in payload;

(h) curving - lozenging forces at wheel/rail for typical adhesion value;

(i) braking - local forces at the brake bracketry and bogie frame under standard braking applications;

(j) motor - fatigue load torque;

(k) motor - vertical inertia;

(l) wheels with allowable tread defects.

C4.2.1.2.2 Commentary

g) *It is difficult to develop detailed design load cases suitable for all bogie types, so the requirements describe circumstances under which the integrity of bogie structures should be maintained.*

h) *Examples of international reference standards containing a comprehensive set of fatigue load cases are:*

   i. *EN 13749 : Annex C.2.2 and Annex D;*

   ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

   These standards use constant amplitude loads which are intended to show that the design has

   infinite life regardless of mileage.

i) *Track twist – track irregularities as per Clause 4.2.1.2.2(d) could use values obtained from the references provided by C4.2.1.2.2(b). Alternatively refer to AS 7509 for Track Twist parameters on Various Routes.*

j) *Motor torque values for each stop and start can be obtained from the torque curves supplied by the motor manufacturer.*

k) *The load case for motor vertical inertia is specified in Clause 4.2.2.6 below for the equipment and its local mounting. This clause relates to this load case being imposed on the remaining bogie structures.*

l) *For guidance relating to wheels with allowable defects as per Clause 4.2.1.2.2(l) ,the RISSB Wheel defect Code of Practice describes requirements for the inspection of freight, passenger, and infrastructure maintenance rolling stock wheels and determination of the action required. The document provides definitions and illustrations of wheel faults and defects. Each defect category has a severity and corresponding action.*

4.2.2 Equipment attached to bogie frames

4.2.2.1 Unless otherwise stated, Section 4.2.2 applies to items of equipment which are light relative to the bogie frame such that they do not influence the dynamic behaviour of the bogie frame.

4.2.2.2 Non-AAR certified items of equipment and their mountings should withstand as exceptional loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.1.

C4.2.2.2 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

a) *vertical ± 20 g;*

b) *lateral ± 3 g; and*

c) *longitudinal ± 5 g.*

4.2.2.3 Non-AAR certified items of equipment and their mountings should withstand as fatigue loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.1 for not less than 10^7 cycles.

C4.2.2.3 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

a) *vertical ± 10 g;*

b) *lateral ± 1.5 g; and*

c) *longitudinal ± 0.5 g.*

4.2.2.4 Locally generated accelerations and forces acting within and on equipment should be considered in addition to Clauses 4.2.2.2 and 4.2.2.3 above.

C4.2.2.4 Commentary

Examples of locally generated forces (ref EN13749 Annex D) include braking forces, failure of traction motors or associated drive system, out of balance rotating forces.

4.2.2.5 Items of equipment and their mountings should be designed to avoid resonance with the bogie suspension or frame natural frequencies for both resilient and non-resilient mounting.

C4.2.2.5 Commentary

Resonance of equipment will result in increased inertia forces and an increase in the number of cycles of fatigue loading.

4.2.2.6 Items of equipment which are heavy enough to influence the dynamic behaviour of the bogie frame should be subject to a dynamic analysis or on-track testing to derive suitable load cases.

C4.2.2.6 Commentary

This applies to heavy equipment, typically traction motors where it is not always possible to satisfy the standard inertia load cases in Clauses 4.2.2.2 to 4.2.2.3.

4.2.3 Equipment attached to axleboxes, axles and wheelsets

4.2.3.1 Non- AAR certified items of equipment and their mountings should withstand as exceptional loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.2.

C4.2.3.1 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

a) *vertical ±77.5g for non-radial arm axlebox, axles and wheelsets;*

b) *vertical ±155g for radial arm axlebox;*

c) *lateral ±20g; and*

d) *longitudinal ±18g.*

4.2.3.2 Non- AAR certified items of equipment and their mountings should withstand as fatigue loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.2 for not less than 10^7 cycles:

> *C4.2.3.2 Commentary*
>
> *AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.*
>
> *Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:*
>
> a) *vertical ±35g for non-radial arm axleboxes, axles and wheelsets;*
>
> b) *vertical ±70g for radial arm axlebox;*
>
> c) *lateral ±10g; and*
>
> d) *longitudinal ±12g.*

4.2.3.3 Locally generated accelerations, forces and resonances acting within and on equipment should be considered in addition to Clauses 4.2.3.1 and 4.2.3.2 above.

> *C4.2.3.3 Commentary*
>
> *Examples of locally generated forces (ref EN 13749 Annex D) include braking forces, out of balance rotating forces, centrifugal forces. Examples of resonances to be considered include coupling with the natural frequencies of the axlebox, axle, and wheelset.*

4.3 Analysis

4.3.1 Exceptional load cases

4.3.1.1 A stress analysis shall be performed on new designs of interfaces, bogie structures, or attached equipment using the exceptional load cases.

4.3.1.2 The stress analysis shall demonstrate that the assessed structures will withstand exceptional loads without deflecting to an extent that would impair functionality under the application of the loads.

4.3.1.3 The stress analysis shall demonstrate that the assessed structures will withstand exceptional loads without suffering permanent deformation.

> *C.4.3.1.3 Commentary*
>
> a) *In determining the stress levels in ductile materials, it is not necessary to take full account of features producing local stress concentrations.*
>
> b) *From EN 13749, the area of local plastic deformation associated with the stress concentrations are to be sufficiently small in order that clauses 4.3.1.2 and 4.3.1.3 are satisfied.*

4.3.1.4 The assessment method shall incorporate any load or safety factors which are included in the reference standard used to define the exceptional load cases.

> *C.4.3.1.4 Commentary*
>
> a) *Australian rail standards refer to a "safe working stress" but do not define the associated load cases for bogie structures. Therefore, "safe working stress" is not included in the examples.*

b) *Examples of load or safety factors associated with reference standards include:*
   i. *EN 13749 Annex E.4.3 defines a safety factor S1 to allow for uncertainties in the calculation.*
   ii. *RSSB GM/RT2100 Clause 5 defines a proof load factor (1.15) and an ultimate load factor (1.5) to allow for uncertainties associated with methods of calculation and for the consequences of failure.*

4.3.1.5 The assessment method shall incorporate any requirements for combining load cases which are included in the reference Standard used to define the exceptional load cases.

C.4.3.1.5 Commentary

An example of combining loads is EN 13749 Annex F.2.1.2 which requires that all exceptional load combinations likely to occur in service are considered.

4.3.2 Fatigue load cases

4.3.2.1 A stress analysis shall be performed on new designs of interfaces, bogie structures, or attached equipment using the fatigue load cases.

4.3.2.2 The stress analysis shall demonstrate that the assessed structures will withstand the fatigue loads without failure for a fatigue life exceeding the required design life.

C.4.3.2.2 Commentary

Failure is defined as a structural defect which renders the vehicle no longer safe for service operation.

4.3.2.3 The fatigue assessment method shall be one that is endorsed within the reference standard used to define the fatigue load cases.

C.4.2.3.3 Commentary

a) *The discrepancies in fatigue load cases between different reference standards are partially explained by the variations in the fatigue assessment methods used.*
b) *Examples of fatigue assessment methods associated with reference standards include:*
   (i) *EN 13749 Annex E4.4.3.2 defines an endurance limit approach. EN 13749 specifies that the endurance limit approach can be followed by a cumulative damage approach if it is inappropriate to maintain the stress level below the endurance limit.*
   (ii) *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

An alternative to the endurance limit approach included in reference standards is to use an appropriate fatigue load spectrum to relate the fatigue life of the vehicle to mileage.

4.4 Testing

4.4.1 Acceptance programme

4.4.1.1 For a new design of bogie frame, the following three testing stages should be used:

(a) Static tests.

(b) Fatigue tests.

(c) On-track tests.

C.4.4.1.1 Commentary

A reduced test programme can be used for:

a) *an existing design of bogie frame intended for a new application;*

b) *a modification to an existing design; or*

c) *an order for a very small number of bogies where the bogie design is conventional, and testing is impractical for economic reasons.*

4.4.1.2 A calculated analysis and at least one testing stage shall be performed with a reduced test programme.

4.4.1.3 Tested bogie frames shall be of a similar type and manufacture as the bogie frames to be used in service such that the test results are not affected by differences between tested bogie frames and those used in service.

4.4.1.4 Test rig equipment should be capable of producing, as far as is reasonably practical, stresses equal to or greater than those that would appear on a bogie frame when placed under its intended vehicle and supported on its suspension.

C.4.4.1.4 Commentary

It is often difficult to fully understand the magnitude of all inputs expected in service, therefore by applying stresses that exceed those that are expected provides a conservative approach.

4.4.1.5 Test rig equipment should be capable of applying the exceptional loads described in Section 4.2.

C.4.4.1.5 Commentary

Refer to ASTM E1237 for guidance on applying bonded resistance strain gauges.

4.4.2 Static tests

4.4.2.1 Static tests should validate the numerical stress analysis for exceptional load cases.

C.4.4.2.1 Commentary

Examples of static test programmes are given in:

a) *EN 13749 Annex F.2.*

b) *UIC 515-4 and UIC 615-4.*

4.4.3 Dynamic tests

4.4.3.1 The dynamic test should confirm that the frame strength is sufficient with regard to the fatigue loads acting upon it.

C.4.4.3.1 Commentary

a) *Examples of dynamic test programmes are given in:*

i. *EN 13749 Annex G.2.*

ii. *UIC 515-4 and UIC 615-4.*

b) *EN 61373 specifies requirements for testing items of equipment for use on railway vehicles such as bogies which are subjected to vibrations and shock.*

c) *AS 7509 provides requirements for dynamic behaviour, the evaluation and testing of; and specific guidance for modelling using validated software tools, which can be applied for non-structural dynamic analysis.*

4.4.4 On-track tests

4.4.4.1 On track testing should cover the range of conditions expected in service up to 110% of the maximum operational speed ~~posted speed~~.

C.4.4.4.1 Commentary

The purpose of the on-track test is to:

a) *measure the operating stresses.*

b) *check the design assumptions; and*

c) *check the fitness for purpose of the bogie structure and attached equipment.*

4.5 In-service loading

4.5.1 Bogies shall be operated within their design capacity.

4.5.2 Secondary restraint should be used for items that can be prone to detachment and causing a derailment.

C.4.5.2 Commentary

a) *Generally, the design process will take the possibility of detachment into account and produce a design that minimises this possibility as far as practicable. At the end of this process, an item might be considered prone to detachment if there is still a significant risk of detachment due to the location, shape, or method of attachment for the item.*

b) *Examples of secondary restraint include:*

  i. *Safety straps for damper seizure and control rod failure.*

  ii. *Safety cage for carden shaft failure.*

4.5.3 Secondary locking of a proven design should be used for bolted joints at structural connections prone to vibration and high fatigue loading.

C.4.5.3 Commentary

Examples of secondary locking include:

a) *Torque-prevailing nuts, including bent-beam nuts and Nylock nuts.*

b) *Locking wire.*

c) *Tab washers (not spring washers).*

d) *Thread-locking adhesives.*

4.6 Maintenance

4.6.1 RTOs and/or rolling stock owners shall establish and comply with criteria that define when and how bogies are to be checked and maintained so that they remain fit for purpose.

C.4.6.1 Commentary

Typical maintenance activities include:

a) *Trammelling of bogie frames (where applicable).*

b) *Non-destructive testing for cracks.*

c) *Monitoring of cracks with due regard to their propagation rate and critical crack dimension. The critical crack dimension can be obtained from either a fracture mechanics analysis, or a standard such as BS 7910.*

d) *Repair of bogie frames and associated componentry including welding, straightening and heat treatment.*

e) *Maintenance of pedestal opening and other component interface dimensions (where applicable).*

f) *Failure mode and effect analysis to determine appropriate tests and schedules for detection and rectification of in-service defects.*

g) *Maintenance of records for usage and remaining life of components.*

4.7 In-service defects

4.7.1 RTOs shall establish and comply with criteria that define when a vehicle has to be removed from service due to bogie defects.

4.7.2 In the absence of other specific criteria a vehicle shall be removed from service if any of the following defects are found:

(a) Bogie frames and associated components which have fatigue cracks in critical zones.

C.4.7.2(b) Commentary

The critical crack dimension can be obtained from either a fracture mechanics analysis, or a standard such as BS 7910.

Where bogie frames and associated components have cracks in non-critical zones, removal from service for further analysis can assist with identifying defects such as fatigue cracks which are continuing to grow.

(b) Bogie frames and associated components which are bent or distorted causing an imbalance in wheel loads, and/or incorrect tracking of the bogie.

(c) Loose, missing, or broken, rivets or Huck bolts which connect bolsters, transoms, headstocks, W-guards or other major bogie frame components.

(d) Timber bogie components which have split, or are rotted, compromising their integrity.

4.8 Action following derailments and collisions

4.8.1 An RTO shall establish and comply with procedures that describe how bogies and associated structural components are to be inspected and requalified following a derailment or collision.

5 Infrastructure rolling stock

5.1 Interfaces

5.1.1 Structural interface with body for a vehicle with non- AAR bogies

5.1.1.1 Exceptional load cases

5.1.1.1.1 Non-AAR bogies shall be attached to the body such that the bogie does not become detached under extreme forces which can occur during the normal life of the bogie.

5.1.1.1.2 Body-bogie interfaces for non-AAR bogies shall:

(a) be designed to withstand the following load cases:

i. longitudinal loads representing the effect on the bogie of a heavy shunt or minor end-on collision;

ii. lateral loads representing a vehicle on its side and supported either on the body or on the bogies;

iii. vertical loads representing the effects of a minor collision, lifting, and jacking; and

iv. exceptional loads when working; or

(b) be in accordance with the proof load cases for body to bogie connection requirements provided in EN12663.

C.5.1.1.1.2 Commentary

a) *Refer to the RIMs requirements for retaining bogies.*

b) *Good practice is to ensure that when the ultimate loadings are exceeded, failure of the body to bogie connection will take place in a pre-determined manner and that as a result the primary vehicle structure will not suffer damage that could compromise its integrity and thus expose passenger or traincrew to additional risk of injury.*

5.1.1.2 Fatigue load cases

5.1.1.2.1 Structural elements connecting a non-AAR bogie to the body shall be designed to withstand fatigue loads that are representative of the expected in-service loads.

C.5.1.1.2.1 Commentary

a) *Examples of international reference standards containing a comprehensive set of fatigue load cases are:*

i. *EN 13749: Annex C and Annex D.*

ii. *JIS E 4207: Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

b) *Considerations for expected in-service loads can include:*

i. *loading / unloading operations (dumping);*

ii. *traction and braking;*

iii. *overloading;*

iv. *speed;*

v. *wheel defects such as: wheel flats, shelling, ovality or wheel polygonization (see note 1);*

vi. *track irregularities such as: track weld dips, variations in track alignment and travelling through turnouts (see note 2).*

Note 1 – RISSB Code of Practice – Wheel Defects: provides additional information regarding wheel defects commonly found in service.

Note 2 - Refer to AS 7635 for additional information regarding track geometry defects.

5.1.2 Structural interface with body for a vehicle with AAR bogies

5.1.2.1 The centre pivot and side bearer arrangements on AAR bogies should comply with the technical requirements given in Section D of the AAR Manual Of Standards And Recommended Practices.

5.1.3 Interface geometry

5.1.3.1 Refer to AS 7509 for requirements on bogie to vehicle clearances when negotiating horizontal and vertical curves.

5.1.3.2 Refer to AS 7507 for requirements on bogie to infrastructure clearances.

5.2 Design load cases

5.2.1 Bogie structures: Non-AAR bogies

5.2.1.1 Exceptional load cases

5.2.1.1.1 Non-AAR bogie structures shall be designed to withstand the extreme forces which can occur during the normal life of the bogie.

5.2.1.1.2 Extreme forces that should be considered in the design of non-AAR bogie structures should include:

(a) vertical - vehicle body at its maximum loaded condition;

(b) lateral - maximum lateral track force or vehicle overturning;

(c) longitudinal - minor derailments at low speeds;

(d) track twist - track irregularities;

(e) vertical - forces imposed by the vehicle body during lifting or jacking operations;

(f) curving - lozenging forces at wheel/rail adhesion limit;

(g) braking - emergency application;

(h) significant wheel defects – forces imposed by significant wheel damage such as large wheel flats; and

(i) bottoming of the frame on the springs due to track defects.

C5.2.1.1.2 Commentary

a) *It is difficult to develop detailed design load cases suitable for all bogie types, so the requirements describe circumstances under which the integrity of bogie structures should be maintained.*

b) *Safety factors are commonly applied where specific extreme forces are difficult to ascertain.*

c) *Examples of suitable exceptional load cases for bogie structures are included in:*

i. *EN 13749: Annex C.3.3 and Annex D (note: applies to a freight bogie with a central pivot and two side bearers);*

ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

d) *Track twist – track irregularities as per Clause 5.2.1.1.2(d) could use values obtained from the references provided by C5.2.1.1.2(b). Alternatively refer to AS 7509 for Track Twist parameters on Various Routes.*

e) *Guidance assessing the significance of wheel defects as per Clause 5.2.1.1.2(i), can be sought from the RISSB Wheel defect Code of Practice. This Code describes requirements for the inspection of freight, passenger, and infrastructure maintenance rolling stock wheels and determination of the action required. The document provides definitions and illustrations of wheel faults and defects. Each defect category has a severity and corresponding action.*

5.2.1.2 Fatigue load cases

5.2.1.2.1 Non-AAR bogie structures shall be designed to withstand fatigue loads that are representative of the expected in-service loads and service life.

5.2.1.2.2 Fatigue forces that should be considered in the design of non-AAR bogie structures include:

(a) vertical - the weight of the supported body;

(b) lateral - running on curves;

(c) longitudinal - traction and braking;

(d) track twist - track irregularities;

(e) attached equipment;

(f) dampers;

(g) changes in payload;

(h) curving - lozenging forces at wheel/rail adhesion limit;

(i) braking - local forces at the brake bracketry and bogie frame under standard braking applications;

(j) wheels with allowable tread defects.

C5.2.1.2.2 Commentary

a) *It is difficult to develop detailed design load cases suitable for all bogie types, so the requirements describe circumstances under which the integrity of bogie structures should be maintained.*

b) *Examples of international reference standards containing a comprehensive set of fatigue load cases are:*

i. *EN 13749 : Annex C.3.4 and Annex D (note: applies to a freight bogie with a central pivot and two side bearers);*

ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

These standards use constant amplitude loads which are intended to show that the design has infinite life regardless of mileage.

c) *Track twist – track irregularities as per Clause 5.2.1.2.2(d) could use values obtained from the references provided by C5.2.1.2.2(b). Alternatively refer to AS 7509 for Track Twist parameters on Various Routes.*

d) *Examples of documents containing a representative load spectrum (which can be less onerous than that using the constant amplitude load cases) that can be used to relate the fatigue life of the vehicle to mileage include:*

   i. *AAR Specification M-1001, Chapter 7: REPOS Data (section C specifically applies to the design, fabrication, and construction of freight car structures but this REPOS data is sometimes used for bogie design); and*

   ii. *Rail CRC report "The East Australian Railway Load Spectrum with REPOS diagrams and Life Estimation Methods".*

e) *For guidance relating to wheels with allowable defects as per Clause 5.2.1.2.2(j) ,the RISSB Wheel defect Code of Practice describes requirements for the inspection of freight, passenger, and infrastructure maintenance rolling stock wheels and determination of the action required. The document provides definitions and illustrations of wheel faults and defects. Each defect category has a severity and corresponding action.*

5.2.2 Bogie structures: AAR bogies

5.2.2.1 Bolsters and sideframes on AAR bogies shall be designed to withstand the static loads given in AAR Specifications M-202 and M-203, respectively.

5.2.2.2 Bolsters and sideframes on AAR bogies shall be designed to withstand the dynamic test loads given in AAR Specifications M-202 and M-203 respectively.

5.2.3 Equipment attached to bogie frames

5.2.3.1 Unless otherwise stated, Section 5.2.3 applies to items of equipment which are light relative to the bogie frame such that they do not influence the dynamic behaviour of the bogie frame.

5.2.3.2 Non-AAR certified items of equipment and their mountings should withstand as exceptional loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.1.

C5.2.3.2 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

a) *vertical ±20g;*

b) *lateral ±3g; and*

c) *longitudinal ±5g.*

5.2.3.3 Non-AAR certified items of equipment and their mountings should withstand as fatigue loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.1 for not less than 10^7 cycles.

C5.2.3.3 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

a) *vertical ± 10 g;*

b) *lateral ± 1.5 g; and*

c) *longitudinal ± 0.5 g.*

5.2.3.4 Locally generated accelerations and forces acting within and on equipment should be considered in addition to Clauses 5.2.3.2 and 5.2.3.3 above.

C5.2.3.4 Commentary

Examples of locally generated forces (ref EN13749 Annex D) include braking forces, failure of traction motors or associated drive system, out of balance rotating forces.

5.2.3.5 Items of equipment and their mountings should be designed to avoid resonance with the bogie suspension or frame natural frequencies for both resilient and non-resilient mounting.

C5.2.3.5 Commentary

Resonance of equipment will result in increased inertia forces and an increase in the number of cycles of fatigue loading.

5.2.3.6 Items of equipment which are heavy enough to influence the dynamic behaviour of the bogie frame should be subject to a dynamic analysis or on-track testing to derive suitable load cases.

C5.2.3.6 Commentary

This applies to heavy equipment, typically traction motors where it is not always possible to satisfy the standard inertia load cases in Clauses 5.3.3.2 to 5.2.3.3.

5.2.4 Equipment attached to axleboxes, axles and wheelsets

5.2.4.1 Non-AAR certified items of equipment and their mountings should withstand as exceptional loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.2.

C5.2.4.1 Commentary

AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.

Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:

a) *vertical ± 77.5 g for non-radial arm axlebox, axles and wheelsets;*

b) *vertical ± 155 g for radial arm axlebox;*

c) *lateral ± 20 g; and*

d) *longitudinal ± 18 g.*

5.2.4.2 Non-AAR certified items of equipment and their mountings should withstand as fatigue loads the inertia forces associated with the accelerations outlined in EN 13749:2011 Table D.2 for not less than 10^7 cycles:

> *C5.2.4.2 Commentary*
>
> *AS 7509 provides guidance on measuring, filtering and calculating RMS values of acceleration for rolling stock dynamic behaviour.*
>
> *Previous editions of this Standard have specified accelerations source from reference material no longer publicly available. The following accelerations are provided historical reference:*
>
> a) *vertical ± 35 g for non-radial arm axleboxes, axles and wheelsets;*
>
> b) *vertical ± 70 g for radial arm axlebox;*
>
> c) *lateral ± 10 g; and*
>
> d) *longitudinal ± 1 2g.*

5.2.4.3 Locally generated accelerations, forces and resonances acting within and on equipment should be considered in addition to Clauses 5.2.4.1 and 5.2.4.2 above.

> *C5.2.4.3 Commentary*
>
> *Examples of locally generated forces (ref EN 13749 Annex D) include braking forces, out of balance rotating forces, centrifugal forces. Examples of resonances to be considered include*
> *coupling with the natural frequencies of the axlebox, axle, and wheelset.*

5.2.5 Vehicles without bogies

5.2.5.1 Design load cases for vehicles that do not include suspension should incorporate the following recommendations:

(a) components of the entire vehicle should be considered as equipment attached to axleboxes, axles and wheelsets as described in Section 5.2.4;

(b) reductions of the inertia values described in Section 5.2.4 should be proven by design calculation or testing.

5.2.5.2 For vehicles that do include suspension, design load cases resulting from the following should be considered:

(a) exceptional loads from derailments;

(b) exceptional and fatigue loads from travel; and

(c) exceptional and fatigue loads from work.

5.3 Analysis

5.3.1 Exceptional load cases

5.3.1.1 A stress analysis shall be performed on new designs of interfaces, bogie structures, or attached equipment using the exceptional load cases.

5.3.1.2 The stress analysis shall demonstrate that the assessed structures will withstand exceptional loads without deflecting to an extent that would impair functionality under the application of the loads.

5.3.1.3 The stress analysis shall demonstrate that the assessed structures will withstand exceptional loads without suffering permanent deformation.

> *C.5.3.1.3 Commentary*
>
> a) *In determining the stress levels in ductile materials, it is not necessary to take full account of features producing local stress concentrations.*
>
> b) *From EN 13749, the area of local plastic deformation associated with the stress concentrations are to be sufficiently small in order that clauses 5.3.1.2 and 5.3.1.3 are satisfied.*

5.3.1.4 The assessment method shall incorporate any load or safety factors which are included in the reference standard used to define the exceptional load cases.

> *C.5.3.1.4 Commentary*
>
> a) *Australian rail standards refer to a "safe working stress" but do not define the associated load cases for bogie structures. Therefore, "safe working stress" is not included in the examples.*
>
> b) *Examples of load or safety factors associated with reference standards include:*
>
> (i) *EN 13749 Annex E.4.3 defines a safety factor S1 to allow for uncertainties in the calculation.*
>
> (ii) *AAR Specifications M-202, M-203, and M-213 contain load factors for freight bogie and infrastructure bogie structures.*

5.3.1.5 The assessment method shall incorporate any requirements for combining load cases which are included in the reference Standard used to define the exceptional load cases.

> *C.5.3.1.5 Commentary*
>
> *An example of combining loads is EN 13749 Annex F.3 which requires that all exceptional load combinations likely to occur in service are considered.*

5.3.2 Fatigue load cases

5.3.2.1 A stress analysis shall be performed on new designs of interfaces, bogie structures, or attached equipment using the fatigue load cases.

5.3.2.2 The stress analysis shall demonstrate that the assessed structures will withstand the fatigue loads without failure for a fatigue life exceeding the required design life.

> *C.5.3.2.2 Commentary*
>
> *Failure is defined as a structural defect which renders the vehicle no longer safe for service operation.*

5.3.2.3 The fatigue assessment method shall be one that is endorsed within the reference standard used to define the fatigue load cases.

C.5.3.2.3 Commentary

a) *The discrepancies in fatigue load cases between different reference standards are partially explained by the variations in the fatigue assessment methods used.*

b) *Examples of fatigue assessment methods associated with reference standards include:*

   i. *EN 13749 Annex E.4.4.3.2 defines an endurance limit approach, which can be followed by a cumulative damage approach if it is inappropriate to maintain the stress level below the endurance limit.*

   ii. *JIS E 4207:2019 Section 5 defines loading conditions as both static and dynamic, Section 6 describes the Strength design condition including methods for the calculation of stresses and determining allowable stress.*

   Typically, these standards use an endurance limit approach which is intended to show that the design has infinite life regardless of mileage

c) *Fatigue assessment methods that are used to derive fatigue life from a fatigue load spectrum are included in AAR Specification M-1001: Chapter 7.2. This section includes fatigue analysis methodologies that can be useful also for non- AAR bogie designs*

d) *For AAR type 3 piece bogie castings AAR M-202 and M-203 have establish well defined test methodologies and load cases for static and fatigue tests based on repos type data, expected life and safety factors and have been validated over time. These tests can serve as a standardized basis for these tests with some parameters (loads or cycles) factored up or down on a case by case basis when the expected service differs from AAR conditions.*

5.4 Testing

5.4.1 Acceptance program

5.4.1.1 For a new design of bogie frame, the following three testing stages should be used:

(a) Static tests.

(b) Fatigue tests.

(c) On-track tests.

C.5.4.1.1 Commentary

A reduced test programme can be used for:

a) *an existing design of bogie frame intended for a new application;*

b) *a modification to an existing design; or*

c) *an order for a very small number of bogies where the bogie design is conventional, and testing is impractical for economic reasons.*

5.4.1.2 A calculated analysis and at least one testing stage shall be performed with a reduced test programme.

5.4.1.3 Tested bogie frames shall be of a similar type and manufacture as the bogie frames to be used in service such that the test results are not affected by differences between tested bogie frames and those used in service.

5.4.1.4 Test rig equipment should be capable of producing, as far as is reasonably practical, stresses equal to or greater than those that would appear on a bogie frame when placed under its intended vehicle and supported on its suspension (excluding infrastructure maintenance rolling stock that does not include suspension).

C.5.4.1.4 Commentary
It is often difficult to fully understand the magnitude of all inputs expected in service, therefore by applying stresses that exceed those that are expected provides a conservative approach.

5.4.1.5 Test rig equipment should be capable of applying the exceptional loads described in Section 5.2.

C.5.4.1.5 Commentary
Refer to ASTM E1237 for guidance on applying bonded resistance strain gauges.

5.4.2 Static tests

5.4.2.1 Static tests should validate the numerical stress analysis for exceptional load cases.

C.5.4.2.1 Commentary
Examples of static test programmes are given in:
a) *EN 13749 Annex F.3*
b) *UIC 515-4 and UIC 615-4.*
c) *AAR Specification M-202 Section 4.0 (bolsters, cast and fabricated).*
d) *AAR Specification M-203 Section 4.0 (side frames, cast steel).*
e) *AAR Specification M-203A (six wheel bogie frames).*
f) *AAR Specification M-213 Section 4. (bogie frame - fabricated).*

5.4.3 Dynamic tests

5.4.3.1 The dynamic test should confirm that the frame strength is sufficient with regard to the fatigue loads acting upon it.

C.5.4.3.1 Commentary
a) *Examples of dynamic test programmes are given in:*
   i. *EN 13749 Annex G.3 (Applies to a freight bogie with a central pivot and two side bearers).*
   ii. *UIC 515-4 and UIC 615-4.*
   iii. *AAR Specification M-202 Section 5.0 (bolsters, cast and fabricated).*
   iv. *AAR Specification M-203 Section 6.0 (side frames, cast steel).*
   v. *AAR Specification M-203A (six wheel bogie frames).*
   vi. *AAR Specification M-213 Section 6. (bogie frame - fabricated).*

> b) *EN 61373 specifies requirements for testing items of equipment for use on railway vehicles such as bogies which are subjected to vibrations and shock.*
>
> c) *AS 7509 provides requirements for dynamic behaviour, the evaluation and testing of; and specific guidance for modelling using validated software tools, which can be applied for non-structural dynamic analysis.*

5.4.4 On-track tests

5.4.4.1 On track testing should cover the range of conditions expected in service up to 110% of the posted speed.

> *C.5.4.4.1 Commentary*
> *The purpose of the on-track test is to:*
>
> a) *measure the operating stresses.*
>
> b) *check the design assumptions; and*
>
> c) *check the fitness for purpose of the bogie structure and attached equipment.*

5.5 In-service loading

5.5.1 Bogies shall be operated within their design capacity.

5.5.2 Secondary restraint should be used for items that may be prone to detachment and cause a derailment.

> *C.5.5.2 Commentary*
>
> a) *Generally, the design process will take the possibility of detachment into account and produce a design that minimises this possibility as far as practicable. At the end of this process, an item might be considered prone to detachment if there is still a significant risk of detachment due to the location, shape, or method of attachment for the item.*
>
> b) *Examples of secondary restraint include:*
>
> i. *Safety straps for damper seizure and control rod failure.*
>
> ii. *Safety cage for carden shaft failure.*

5.5.3 Secondary locking of a proven design should be used for bolted joints at structural connections prone to vibration and high fatigue loading.

> *C.5.5.3 Commentary*
>
> *Examples of secondary locking include:*
>
> a) *Prevailing-torque nuts, including bent-beam nuts and Nylock nuts.*
>
> b) *Locking wire.*
>
> c) *Tab washers (not spring washers).*
>
> d) *Thread-locking adhesives.*

5.6 Maintenance

5.6.1 RTOs and/or rolling stock owners shall establish and comply with criteria that define when and how bogies are to be checked and maintained so that they remain fit for purpose.

> *C.5.6.1 Commentary*
>
> a) *Typical maintenance activities include:*
>
> i. *Trammelling of bogie frames (where applicable).*

ii. *Non-destructive testing for cracks.*

iii. *Monitoring of cracks with due regard to their propagation rate and critical crack dimension.*

iv. *Repair of bogie frames and associated componentry including welding, straightening and heat treatment.*

v. *Maintenance of pedestal opening and other component interface dimensions (where applicable).*

vi. *Failure mode and effect analysis to determine appropriate tests and schedules for detection and rectification of in-service defects.*

vii. *Maintenance of records for usage and remaining life of components.*

b) *For Road Rail Vehicles, maintenance requirements for bogie structures are included in the Master Checklist of Roll 41-1 (Guideline - Road Rail Vehicle Operation).*

5.7 In-service defects

5.7.1 RTOs shall establish and comply with criteria that define when a vehicle has to be removed from service due to bogie defects.

5.7.2 In the absence of other specific criteria a vehicle shall be removed from service if any of the following defects are found:

(a) Bogie frames and associated components which have fatigue cracks in critical zones.

C.5.7.2(a) Commentary

The critical crack dimension can be obtained from either a fracture mechanics analysis, or a standard such as BS 7910.

Where bogie frames and associated components have cracks in non-critical zones, removal from service for further analysis can assist with identifying defects such as fatigue cracks which are continuing to grow.

(b) Bogie frames and associated components which are bent or distorted causing an imbalance in wheel loads, and/or incorrect tracking of the bogie.

(c) Loose, missing, or broken, rivets or Huck bolts which connect bolsters, transoms, headstocks, W-guards, or other major bogie frame components.

(d) Timber bogie components which have split, or are rotted, compromising their integrity.

5.8 Action following a derailment or collision

5.8.1 An RTO shall establish and comply with procedures that describe how bogies and associated structural components are to be inspected and requalified following a derailment or collision.

C.5.8.1 Commentary
For road rail vehicles, maintenance requirements following derailment/collision are included in the Master Checklist of Roll 41-1 (Guideline - Road Rail Vehicle Operation).

5.9 Rail wheel guidance equipment on road-rail vehicles

5.9.1 Design

5.9.1.1 The load on the rail wheels of road-rail vehicles shall be maintained continually when in the on-track position by use of one of the following:

(a) mechanical locking or overcentre design; or

(b) active suspension system.

5.9.1.2 A failure of the systems described in Clauses 5.9.1 (a) and (b) should not make the vehicle unstable while operating at the limits of its rated load or reach.

5.9.1.3 The structural integrity of road-rail vehicle running gear and its attachment to the vehicle shall be demonstrated by calculation or testing as required in Sections 5.1 to 5.4 above.

> *C.5.9.1.3 Commentary*
> *On powered rail wheel guidance systems, a backup system for raising and lowering rail wheel assemblies is generally provided.*

5.9.1.4 The rail wheel guidance equipment on road-rail vehicles shall not allow the vehicle to become unbraked (e.g., all braked wheels and tracks being lifted completely off the rails) when deploying the rail wheels.

5.9.2 Mechanical locking

5.9.2.1 For non-automatic systems, mechanical locking for the rail wheel assemblies on Road-Rail Vehicles should be:

(a) accessible without difficulty; and

(b) operated from outside the vehicle.

5.9.2.2 Rail wheel assemblies on road-rail vehicles shall be mechanically locked in the raised position when in road travel mode.

5.9.3 Active suspension system (rail wheel guidance systems)

5.9.3.1 Following a sudden loss in pressure in an active suspension system on a road-rail vehicle, the rail wheel guidance system shall allow the vehicle to be stopped safely.

5.9.3.2 Following a sudden loss in pressure in an active suspension an alarm shall be given to the driver.

Appendix A Australian Railway Risk Model (informative)

Australian Railway Risk Model (ARRM) hazardous event category
Maintenance vehicle collision with infrastructure on running line
Maintenance vehicle collision with other train on running line
Maintenance vehicle collision with other train in yard
Train collision with infrastructure on running line
Train collision with other train on running Line
Train collision with other train in yard
Collision between train and projectile
Collision between maintenance vehicle and projectile
Train derailed or load dropped at loader/unloader in yard

For addition information, including how you can become part of ARRM, please contact RISSB. If you are already participating in ARRM please go directly to https://arrm.org.au/

Appendix B Bibliography

The following referenced documents are used by this Standard for information only:

(a) AS 7635 Track Geometry

(b) ASTM E1237 Standard guide for installing bonded resistance strain gages.

(c) BS 7608 Code of practice for fatigue design and assessment of steel structures.

(d) BS 8118 Structural use of aluminium.

(e) BS 7910 Guide on methods for assessing the acceptability of flaws in metallic structures.

(f) EN 61373: 2010 Railway applications – Rolling stock equipment – Shock and Vibration tests.

(g) JIS E 4207:2019 Rolling stock – Bogie- General rules for design of bogie frame strength.

(h) RISSB Code of Practice – Wheel Defects.

(i) UIC Code 515-4 Passenger rolling stock – Trailer bogies - Running gear – Bogie frame structure strength tests.

(j) UIC Code 615-4 Motive power units – Bogies and running gear – Bogie frame structure strength tests.

(k) UK RSSB document GM/GN2560 Guidance note: Structural requirements for railway vehicles

(l) UK RSSB document GM/GN2560 Guidance note: Structural requirements for railway vehicles

(m) Rail CRC Project 38 report The East Australian railway load spectrum with REPOS diagrams and life estimation methods, 2005

(n) CMC (RISSB) document Roll 41-1 Guideline for the safe operation of road-rail vehicles

(o) AAR Specification M-213.

(p) EN 12663:2010+A1:2014 Railway applications - Structural requirements of railway vehicle bodies - Part 1: Locomotives and passenger rolling stock (and alternative method for freight wagons).

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