BS EN 13749:2011

BSI Standards Publication

Railway applications — Wheelsets and bogies — Method of specifying the structural requirements of bogie frames

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National foreword

This British Standard is the UK implementation of EN 13749:2011. It supersedes BS EN 13749:2005 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RAE/3, Railway Applications - Rolling Stock Material.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 62746 0

ICS 45.040

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2011.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13749

March 2011

ICS 45.040

Supersedes EN 13749:2005

English Version

Railway applications - Wheelsets and bogies - Method of specifying the structural requirements of bogie frames

Applications ferroviaires - Essieux montés et bogies - Méthode pour spécifier les exigences en matière de résistance des structures de châssis de bogie

Bahnanwendungen - Radsätze und Drehgestelle - Festlegungsverfahren für Festigkeitsanforderungen an Drehgestellrahmen

This European Standard was approved by CEN on 26 February 2011.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 13749:2011) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2011, and conflicting national standards shall be withdrawn at the latest by September 2011.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document will supersede EN 13749:2005.

The general scope and requirements of EN 13749 are unaltered by this revision. Changes were necessary to make the standard compatible with more recent Euronorms. Certain areas of the normative text had to be revised to make correct reference to the structural analysis and validation processes now specified in the new bogie and running gear standard EN 15827. Other new normative references are to EN 15085 and EN 15663.

The other main changes that have been made concern the informative annexes and are summarized as follows:

a) to comply with CEN rules, the symbols and units have been removed from the normative text and added as informative Annex A, as they apply only to the other informative annexes;

b) the old informative Annex C has been removed and reference made to EN 15663, which now covers vehicle mass data;

c) the informative Annex E has been re-written to present the structural analysis and acceptance process as specified in EN 15827;

d) a number of errors in the example load case equations in informative Annex C have been corrected;

e) the guidance on component loads in informative Annex D has been revised to better reflect present practice;

f) the limitations of the example load case data in informative Annexes C, D, F and G have been given greater emphasis and it has been stressed that the loads should be used as presented only when it can be shown that they are applicable to the specific design.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to support Essential Requirements of EU Directive 2008/57/EC.

For relationship with EU Directive 2008/57/EC, see informative Annex ZA, which is an integral part this document.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies the method to be followed to achieve a satisfactory design of bogie frames and includes design procedures, assessment methods, verification and manufacturing quality requirements. It is limited to the structural requirements of bogie frames including bolsters and axlebox housings. For the purpose of this European Standard, these terms are taken to include all functional attachments, e.g. damper brackets.

2 Normative references

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

EN 15085-1, *Railway applications — Welding of railway vehicles and components — Part 1: General*

EN 15085-2, *Railway applications — Welding of railway vehicles and components — Part 2: Quality requirements and certification of welding manufacturer*

EN 15085-3, *Railway applications — Welding of railway vehicles and components — Part 3: Design requirements*

EN 15085-4, *Railway applications — Welding of railway vehicles and components — Part 4: Production requirements*

EN 15085-5, *Railway applications — Welding of railway vehicles and components — Part 5: Inspection, testing and documentation*

EN 15663, *Railway applications — Definition of vehicle reference masses*

EN 15827:2011, *Railway applications — Requirements for bogies and running gear*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 15827:2011 and the following apply.

NOTE Annex A identifies the symbols, units, co-ordinate system and bogie categories used in the informative annexes to this European Standard.

3.1
axlebox
assembly comprising the box housing, rolling bearings, sealing and grease

3.2
bogie frame
load-bearing structure generally located between primary and secondary suspension

3.3
bolster
transverse load-bearing structure between vehicle body and bogie frame

3.4
static force
force which is constant with time

NOTE Force due to gravity is an example of static force.

3.5
quasi-static force
force, which changes with time at a rate which does not cause dynamic excitation

NOTE Quasi-static force might remain constant for limited periods.

3.6
dynamic force
transient, impulsive or continuous force, uniform or random, that changes with time at a rate that causes dynamic excitation

3.7
load case
set of loads or combinations of loads that represents a loading condition to which the structure or component is subjected.

3.8
exceptional load case
extreme load case representing the maximum load at which full serviceability is to be maintained and used for assessment against static material properties

3.9
fatigue load case
repetitive load case used for assessment against fatigue strength

3.10
safety factor
factor applied during the strength assessment which makes an allowance for a combination of the uncertainties and the safety criticality

3.11
sideframe
longitudinal structural member of the bogie frame

3.12
primary suspension
suspension system consisting of the resilient elements (and associated connecting and locating parts) generally located between the axlebox and bogie frame

3.13
secondary suspension
suspension system consisting of the resilient elements (and associated connecting and locating parts) generally located between the bogie frame and vehicle body or bolster

3.14
track testing
performing of tests under expected service conditions, on railway infrastructure that represents the actual operating environment, and monitoring and recording the responses

3.15
validation
process of demonstrating by analysis and/or test that the system under consideration meets in all respects the technical specification, including requirements due to regulations, for that system

3.16
verification
process of demonstrating by comparison or testing that an analytical result or estimated value is of an acceptable level of accuracy

4 Technical specification

4.1 Scope

The technical specification shall consist of all the information describing the functional requirements of the bogie frame and the interfaces with associated components and assemblies. It shall also comprise, as a minimum, the general requirements of use, the conditions associated with the vehicle equipped with the bogies, the operating characteristics, the conditions associated with maintenance and any other particular requirements.

The technical specification shall also identify all appropriate mandatory regulations and define the parts of the validation and acceptance procedure (Clause 6) and the quality requirements (Clause 7), which are specifically required, and the way in which evidence to show that the requirements have been met is to be provided.

NOTE If the customer is unable to define the technical specification completely the supplier may propose a technical specification and submit it to the customer (and the approval authority where relevant) for agreement.

4.2 General requirements

The technical specification shall indicate the type of bogie required in terms of its use. It shall also indicate the intended life of the bogie, its average annual distance run and its total distance run and all the information that is applicable to a bogie frame associated with the Essential Requirements of a TSI as indicated in EN 15827. Information that is particularly relevant to bogie frame design is indicated in the following clauses.

4.3 Design load cases

The technical specification for the bogie frame shall consist primarily of the load cases required for the design of the bogie as specified in EN 15827, plus any additional load cases required by that standard or arising from the application. The load cases shall be based on the vehicle mass states given in EN 15663. However, for some applications and fatigue assessment methods it will be necessary to use additional vehicle loading conditions (expressed as functions of the cases in EN 15663) to obtain an accurate description of the vehicle payload spectrum for design purposes.

The development of the design load cases is discussed in Annex B and examples of design load cases associated with bogie running and due to the attachment of equipment are given in Annexes C and D respectively.

NOTE If it is proposed to use the endurance limit approach to fatigue strength assessment the data on the number of events is not required and only the extreme repetitive load conditions need to be defined.

4.4 Vehicle conditions and interfaces

The technical specification shall also include the following information from the requirements of EN 15827 interpreted for applicability to the bogie frame:

- vehicle body interfaces and clearances;
- gauge reference profile and bogie movement envelope;
- suspension geometry and attachments;
- interfaces to traction and braking systems and all other attached equipment;
- electrical and pneumatic system connections;
- environmental requirements;
- maintenance requirements.

4.5 Particular requirements

The technical specification shall indicate any particular requirements related to the bogie frame that are not covered by the above clauses, for example, operating conditions, materials, types of construction and methods of assembly (e.g. treatment of welds, shot peening).

5 Verification of the design data

All necessary means (e.g. analysis, drawings, tests) shall be used to carry out the design.

The information supporting the design of the bogie frame shall be verified by the documents defined in the technical specification and those required by applicable standards and regulations which permit:

— the bogie frames to be designed and manufactured in accordance with the requirements of the technical specification, EN 15827 and this European Standard;

— all the checks considered necessary for the validation and acceptance to be carried out.

6 Validation and acceptance of the design

6.1 General

The aim of the validation plan is to prove that the design of the bogie frame fulfils the conditions defined in the technical specification. In addition, it shall show that the behaviour of the bogie frame, constructed according to the design, will give satisfactory service without the occurrence of defects such as catastrophic rupture, permanent deformation and fatigue cracks. It shall further demonstrate that there is no adverse influence on the associated bogie components or sub-assemblies.

The validation plan shall be compatible with that for the bogie as a whole as specified in EN 15827 and in particular the requirements of the following clauses of this European Standard.

Acceptance of the product will normally be dependent on a satisfactory completion of the validation plan but may contain other conditions outside the scope of this European Standard.

The technical specification shall include guidance on how the bogie design is to be validated (including conformance with any applicable regulations) and shall state all the parameters that are necessary for the application of the different parts of the procedure. These parameters shall be defined in three stages:

— the validation plan (e.g. combination of load cases for analysis and static tests, programmes for fatigue tests, routes for track tests);

— the values of the different load cases;

— the acceptance criteria (treatment of measured or calculated values, limiting stresses, criteria for completion of fatigue tests, etc.).

6.2 defines which parts of the validation plan should be included in any particular case.

NOTE In order that the acceptance procedure is completely defined, the supplier should identify the methods of demonstrating conformance to the requirements if they are not incorporated into the technical specification.

6.2 The validation plan

6.2.1 Content

The validation plan shall comprise a list of the validation steps planned to demonstrate compliance to the requirements defined in the technical specification.

The procedure for the validation of the mechanical strength of a bogie frame against the acceptance criteria shall be established on the basis of:

— analysis;

— laboratory static tests;

— laboratory fatigue tests;

— track tests.

The content of the plan shall be related to the importance of the problem to be dealt with. In principle, the validation plan shall identify and address those design assumptions and solutions that need to be verified.

All structural components shall be analysed to demonstrate that they will carry the loads to which they are subject.

For a new design of bogie frame destined for a new type of application all four validation stages shall be used, though the fatigue tests can be replaced by other methods of demonstrating the required fatigue life. The plan shall establish a strategy which defines the steps to be taken and the degree of testing necessary to verify, and give confidence in, the analytical results.

NOTE This will determine the scope and objectives for the laboratory and track tests.

The load cases for freight wagon bogies are often based on the experience of the railways over a long period of time and these loads are generally applicable to all similar freight bogie designs. It is common practice that a freight bogie which has passed an appropriate fatigue test will not be subject to structural assessment track tests (only to those validating the dynamic behaviour).

The general requirements of the individual validations records are:

— definition of the validation objective;

— documentation of the method applied (including its limitations);

— presentation of the results;

— definition of acceptance criteria;

— statement of compliance.

In principle the same acceptance criteria should be applied to both the design and testing phases. For example, if the endurance limit approach is used for the analytical verification of the design it shall also be applied for the testing phase. However if during testing the design cannot be verified using the basis of the endurance limit approach then a life assessment using an appropriate cumulative damage approach can be undertaken.

Where the design is a development of an earlier product any previous data, or other evidence of satisfactory performance that is still applicable, can be offered as validation of the revised product.

In the case of an existing design of bogie frame intended for a new application, or a modification to an existing design, a reduced programme can be used, depending on the significance of the differences. If the differences are small, analysis, supported if necessary by measurements made during a limited test programme, will be sufficient to validate the design.

Static tests and fatigue tests shall be carried out in accordance with the technical specification and applicable regulations and to a level that is considered necessary to validate the design satisfactorily.

For the validation to be acceptable the series production bogie frames and the test frames shall be manufactured according to an equivalent set of specifications, including drawings, procedures and quality plan. Any differences that could influence the outcome of the tests shall be shown to be acceptable.

The test rig equipment shall be capable of producing, as far as is reasonably practicable, the same stresses as those which would appear on the bogie frame when placed under its intended vehicle and supported on its suspension

In the case of an order for a very small number of bogies it might be impractical to justify all stages of the normal validation procedure. In such cases, analysis shall always be carried out and this shall be supported by taking the alternative measures specified in EN 15827.

Where the load cases for a freight wagon bogie are based on the experience of the railways over a long period of time and these loads are generally applicable to all similar freight bogie designs, it is acceptable that a freight bogie which has passed an appropriate fatigue test need not be subject to structural track testing.

6.2.2 Structural analysis

In addition to the general requirements of the validation records in 6.2.1 structural analysis reports shall include the following information:

- boundary conditions, including design load cases and combinations (as specified in EN 15827 and discussed in Annex B);
- documentation of the simulation model used (including limitations and simplifications);
- locations and types of stresses being assessed (e.g. principal, von Mises);
- permissible design limits (e.g. allowable stresses) and their basis/origin;
- any particular acceptance criteria (e.g. stiffness, deflections, such as the interface between the axlebox housing and bearing);
- documentation of utilisation at critical details (see 4.2 of Annex E).

Load case data specific to the application, and which takes account of the bogie suspension characteristics, vehicle body parameters, track and operating characteristics, should always be used where such data is available (e.g. established empirical data or data from simulations, tests or a previous similar application). Annexes C and D provide examples of design load case data which has been used for specific applications but this data cannot be considered to apply universally. It should be noted that the load case data in Annexes C and D does not take account of differences in the bogie suspension or the vehicle body characteristics or of load changes resulting from active suspension (e.g. tilt) systems, etc.

The structural analysis shall be carried out using the validation process and acceptance criteria as required by EN 15827.

Annex E gives further guidance on factors to be considered in defining an analysis programme and includes the structural acceptance criteria as specified in EN 15827.

6.2.3 Static tests

The purpose of static tests is described in F.1.

In addition to the general requirements for validation records in 6.2.1, laboratory static test reports shall include the following:

- documentation of the test program performed including magnitudes and combinations, direction and position of the loads (nominal values and actual values that have been applied);

- documentation of the test setup including jigs and actuators and any inherent simplifications and limitations;
- documentation of the measuring equipment, including type and location of sensors (strain gauges, load cells, displacement transducers, etc.) and associated calibration certification;
- methods of evaluation and interpretation of measured strains/stresses and permissible values;
- utilisation results for the individual measurement locations.

The loads applied in the tests shall be based on the design load cases.

Annex F indicates general considerations and gives examples of programmes for static tests. Again, this data cannot be considered to apply universally as the load cases do not take into account differences in the bogie suspension or the vehicle body characteristics. Therefore, these examples shall be followed only when they can be shown to be applicable.

6.2.4 Fatigue tests

The purpose of fatigue tests is described in G.1.

In addition to the general requirements for validation records in 6.2.1, laboratory fatigue test reports shall include the following:

- documentation of the test program performed including magnitudes and combinations, direction and position of the loads, number of load cycles (nominal values and actual values that have been applied);
- documentation of test setup including jigs and actuators and any inherent simplifications and limitations;
- documentation of the measuring equipment including type and location of sensors (strain gauges, load cells, etc.) and associated calibration certification;
- acceptance criteria (including schedules and methods of the non-destructive testing);
- test records of non-destructive tests;
- interpretation of results against the acceptance criteria.

The fatigue test plan shall be determined for the specific application.

Annex G indicates general considerations and gives examples of programmes for fatigue tests but, as for the static tests, these programmes do not take into account differences in the bogie suspension or the vehicle body characteristics and shall be adopted only if they can be shown to be appropriate to the application.

6.2.5 Track tests

In addition to the general requirements for the validation records in 6.2.1, track test reports shall include:

- documentation of the test vehicle including the loading conditions;
- documentation of the test program including test routes, length, type of track, operating conditions;
- documentation of the measuring equipment used, including types and locations of sensors (strain gauges, load cells, displacement transducers, accelerometers, etc.) and associated calibration certification;
- methods of evaluation and interpretation of measured strains/stresses and permissible values;
- interpretation of results for the individual measurement locations.

To produce valid results the track tests shall be carried out with the test vehicle, payloads, track quality and speed profile all representative of the intended operating conditions. If the environment can affect the test results the tests shall be carried out under suitable conditions.

NOTE 1 The validation objectives that can be obtained by track tests are:

- verification of design assumptions concerning operating conditions and the operating envelope (without the limitations and simplifications that are inherent in simulations);
- verification/determination of real strain time histories (spectra/collectives) at the measurement locations under real operating conditions (without the limitations and simplifications of structural simulation models and load assumptions);
- design life estimation on the basis of real measured strain time histories (spectra/collectives) and a theoretical fatigue hypothesis.

NOTE 2 The limitations of track tests are:

- the test program can only represent a small part of the total operating design life of the bogie;
- simplification is unavoidable in the extrapolation of the test results to the total design life of bogie and the assessment of the results has to take into account the degree to which the test program was able to represent the total real life conditions;
- the design life prediction is based on a theoretical fatigue hypothesis and therefore has a level of confidence limited by the hypothesis itself (including any uncertainties in the classification of the assessed detail).

7 Quality requirements

For the validation to be applicable, all manufactured bogie frames shall be of a quality consistent with the requirements of the technical specification and the assumptions and data used as the basis of the design.

The bogie frame design and manufacture shall be covered by a quality plan as required by EN 15827.

Welded fabrication shall be carried out in accordance with the requirements of EN 15085-1 to EN 15085-5 or to a process that gives an equivalent level of control.

Annex A
(informative)

Symbols and units used in the informative annexes

NOTE Certain symbols used in this European Standard may have a different meaning to those adopted in related standards (e.g. EN 13103, EN 13104 and EN 13979-1).

A.1 Forces

Table A.1 — Forces

Force (N)	Position	Symbol		
		Static	Quasi-Static	Dynamic
Vertical	Load applied to bogie	F_z		
	Force on sideframe 1 or sidebearer 1	F_{z1}	F_{z1qs}	F_{z1d}
	Force on sideframe 2 or sidebearer 2	F_{z2}	F_{z2qs}	F_{z2d}
	Force on centre pivot	F_{zp}	F_{zpqs}	F_{zpd}
	Force at (vehicle body) c of g	F_{zc}		
Transverse	Load applied to bogie	F_y		
	Force on axle 1	F_{y1}	F_{y1qs}	F_{y1d}
	Force on axle 2	F_{y2}	F_{y2qs}	F_{y2d}
	Force at (vehicle body) c of g	F_{yc}		
	Force due to wind	F_{w1}		
Longitudinal	Force at each wheel	F_{x1}		
	Force at (vehicle body) c of g	F_{xc}		
	Force at (vehicle bogie) c of g	F_x		

A.2 Accelerations

Table A.2 — Accelerations

Acceleration (m/s^2)	Symbol	
	Vehicle body	Bogie (primary spring)
Vertical	a_{zc}	a_{zb}
Transverse (dynamic)	a_{yc}	a_{yb}
Centrifugal (quasi-static)	a_{ycc}	a_{ycb}
Longitudinal	a_{xc}	a_{xb}

A.3 Masses

Table A.3 — Masses

Mass (kg)	Symbol
Vehicle in running order	M_V
Vehicle body	m_1
Bogie mass without any secondary spring masses (if present)	m^+
Bogie primary spring mass	m_2
Exceptional payload	P_1
Normal service payload	P_2

The values assigned to the above symbols should be based on the descriptions of the quantities in EN 15663.

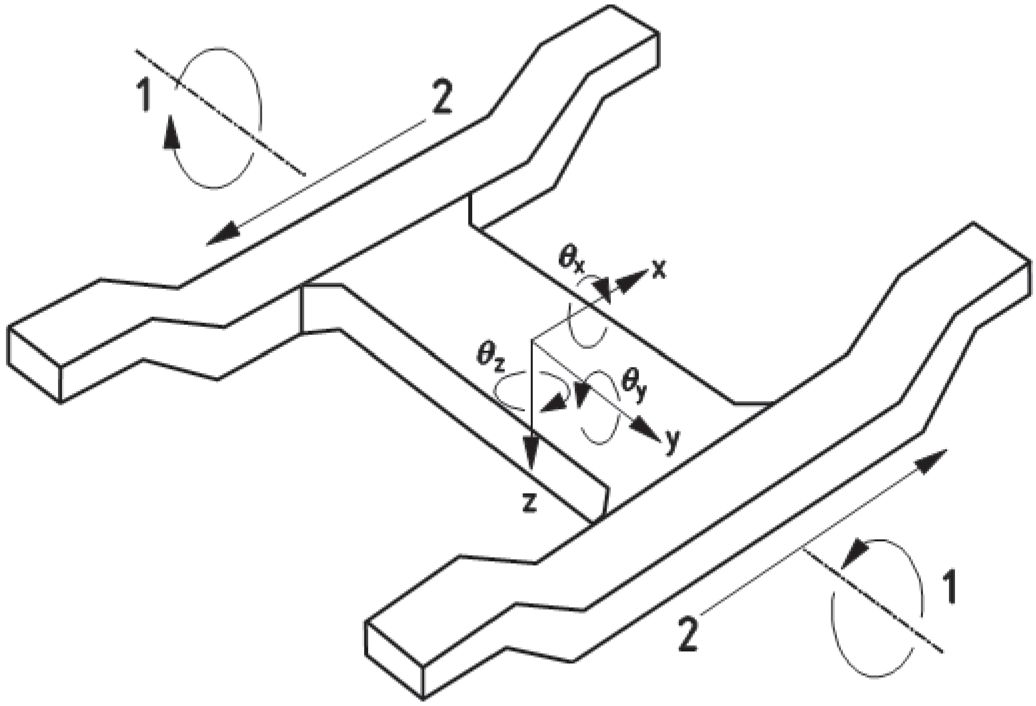
A.4 Other symbols and units

Table A.4 — Other symbols and units

Other	Symbol	Unit
Acceleration due to gravity	g	9,806 65 m/s^2
Wind pressure	q	N/m^2
Stress	σ	N/mm^2
Determined stress	σ_c	N/mm^2
Material proof or yield stress	R_{eH}	N/mm^2
Material 0,2 % proof stress	$R_{p0,2}$	N/mm^2
Material ultimate stress	R_m	N/mm^2
Uncertainty factor or Factor of safety	S_1	
Car body surface area	A_w	m^2
Roll coefficient	α	
Bounce coefficient	β	
Adhesion or friction coefficient	μ	

A.5 Co-ordinate system

Figure A.1 shows the co-ordinate system adopted in this European Standard.



Key

1 twist

2 lozenge (shear)

Figure A.1 — Co-ordinate system

Table A.5 defines movements and deformations and their directions.

Table A.5 — Movements and deformations in railway bogie assemblies

Direction	Symbol	Description
Longitudinal	x	Linear in the direction of travel
Transverse	y	Linear parallel to the plane of the track, perpendicular to the direction of travel
Vertical	z	Linear perpendicular to the plane of the track
Roll	θ_x	Rotation about the longitudinal axis
Pitch	θ_y	Rotation about the transverse axis
Yaw	θ_z	Rotation about the vertical axis
Twist	—	Out-of-plane (x-y) movement resulting in relative rotation of the sideframes
Lozenging	—	Shear due to relative longitudinal movement of sideframes

A.6 Bogie classification

This European Standard covers a wide variety of different bogie types. For reference purposes it is convenient to categorise them in the following informative annexes. Although identified generally in terms of vehicle types, the selection of the category for a bogie should also take into account the structural requirements of the bogie frame.

The structural requirements for bogies in a particular category are not unique and should always be defined according to the operating requirements. There will be differences in choice between applications. This is to be expected and should not be considered as conflicting with this European Standard. Some bogies may not fit into any of the defined categories.

category B-I bogies for main line and inter-city passenger carrying rolling stock including high speed and very high speed vehicles, powered and un-powered;

category B-II bogies for inner and outer suburban passenger carrying vehicles, powered and un-powered;

category B-III bogies for metro and rapid transit rolling stock, powered and un-powered;

category B-IV bogies for light rail vehicles and trams;

category B-V bogies for freight rolling stock with single-stage suspensions;

category B-VI bogies for freight rolling stock with two-stage suspensions;

category B-VII bogies for locomotives.

NOTE The classifications are similar to (but are not intended to be consistent with) those adopted for vehicle bodies in EN 12663 [1, 2].

Annex B
(informative)

Load cases

The load cases used for the bogie frame analysis, static tests and fatigue tests are defined on the basis of the loading condition of the vehicle equipped with the bogies and the resulting bogie load cases as specified in EN 15827 (see Clause 4). EN 15663 provides standard reference masses from which design loading conditions may be derived for different types of vehicle if the technical specification is inadequate. As indicated in 4.3, for some applications and fatigue assessment methods it will be necessary to use additional vehicle loading conditions (expressed as functions of the cases in EN 15663) in order to obtain an accurate description of the vehicle payload spectrum for design purposes.

The load cases can comprise displacements as well as forces, e.g. track twist.

The load cases fall into two groups namely, external and internal.

External load cases can result from:

— running on the track (e.g. vertical forces due to the load carried by the vehicle, transverse forces on curves or when going across points and crossings, twisting of the bogie frame as a result of the vehicle going over twisted track);

— starts/stops and associated vehicle accelerations;

— loading/unloading cycles of the vehicle;

— lifting and jacking.

Internal load cases are due to the presence and operation of bogie mounted components (e.g. brakes, dampers, anti-roll bars, motors, inertia forces caused by masses attached to the bogie frame).

The definition of each load case can comprise three components:

— static;

— quasi static;

— dynamic.

The different load cases can have several levels. The commonly adopted approach for the design and assessment of structures is to divide the load cases into two main types.

The first type comprises static load cases, which represent those extreme (exceptional) loads that might occur only rarely during the life of the bogie. A bogie structure is required to withstand such loads without deflecting to an extent that would impair functionality under the application of the loads or without suffering permanent deformation after removal of the loads.

The second type comprises fatigue load cases, which represent those loads that occur repeatedly during normal operation; such cases are used to demonstrate the ability of the bogie to survive its intended operational requirement without fatigue failure. Where appropriate, account should be taken of quasi-static loads, which occur at low frequencies.

This distinction between the load cases is necessary to be consistent with the material behaviour and the associated acceptance criteria required by EN 15827 and as presented in Annex E.

Annex C gives examples of external load cases for different categories of bogies, due to both normal service and exceptional circumstances. Similarly, Annex D gives examples of internal load cases. The load case examples given in these annexes do not take account of differences in the vehicle characteristics, the bogie suspension or the bogie application. These load case examples should therefore be used only when they can be shown to be applicable and/or by agreement between the supplier and customer.

Annex C
(informative)

Loads due to bogie running

C.1 General

In service, bogies are subject to, and should withstand, loads caused by the following:

- the weight of the supported vehicle, including any payload;
- changes in the payload;
- track irregularities;
- running on curves;
- acceleration and braking;
- abrupt application of payload (freight wagons);
- minor derailments (e.g. low speed drop on to ballast, if required by the specification);
- buffing impacts;
- extreme environmental conditions (e.g. see EN 50125-1);
- fault conditions (e.g. motor short circuit torque);
- maintenance/recovery situations (e.g. lifting and jacking).

In reality the loads are combined in a complex manner and so it is difficult to represent them exactly in analysis. Consequently it is generally the practice, for ease of analysis, to represent the true loads by a series of load cases which include the above effects in a simplified form, either individually or in combination. It is essential that the simplification ensures that the effects of the true loads are not underestimated.

The resulting load cases are then identified as exceptional or normal service (fatigue) loads as indicated in Annex B.

The load cases required for the design and assessment of the bogie frame will be dependent on the application being considered.

The examples given in C.2, C.3 and C.4 follow the approach described above and have been used for those bogies which were intended for operation under UIC regulations [9], [10] and [11]. These examples do not take into account differences in suspension characteristics or vehicle body characteristics therefore adjustments to the values given in the examples may need to be applied to take account of the differences in these characteristics for different bogie designs. They may not represent the exceptional (extreme) or service (fatigue) operating conditions as defined in EN 15827 and Annex B.

Bogies subject to operating conditions not previously covered by UIC regulations will normally require alternative load cases for their design and assessment; they are not considered in this annex and should be defined, if necessary, in the technical specification.

Similarly, the examples given in C.5 are often adopted for the design of tram bogies [14], but customers/suppliers may consider alternative requirements more appropriate for their applications.

The source data does not indicate how the specified loads should be reacted. Therefore, the designer needs to consider load balances appropriate to the application. In particular the reactions to the lateral loads specified as acting at the wheelsets should include the bogie inertia forces to determine realistic secondary suspension forces.

In the following sub-clauses, the equations apply to bogies with two axles (with adjustments indicated for three axle bogies). It should be noted that the equations assume two bogies with an equal loading on each bogie. If this is not the case then the equations will need to be adjusted accordingly. A consistent set of SI units is assumed and the forces are in Newtons.

C.2 Examples of loads for bogies of passenger rolling stock - categories B-I and B-II

C.2.1 Exceptional loads

Vertical forces (applied to each sideframe, based on the assumption of vehicles whose mass is evenly distributed between the two bogies and the body supported directly on each sideframe):

$$F_{z1\max} = F_{z2\max} = \frac{F_{z\max}}{2} = \frac{1{,}4g(M_v + P_1 - 2m^+)}{4} \qquad \text{(C.1)}$$

where

M_V is the vehicle mass in running order;

P_1 is the exceptional design payload (according to EN 15663);

m^+ is the bogie mass;

$F_{z\max}$ is the total vertical force on bogie.

Transverse forces (applied to each axle):

$$F_{y1\max} = F_{y2\max} = \frac{F_{y\max}}{2} = 10^4 + \frac{(M_v + P_1)g}{12} \qquad \text{(i.e. Prud'homme limit)} \qquad \text{(C.2)}$$

Longitudinal lozenging forces (applied to each wheel and in the opposite sense on the opposite sides of the bogie frame):

$$F_{x1\max} = 0{,}1 \times (F_{z\max} + m^+ g) \qquad \text{(C.3)}$$

Longitudinal shunt loads

An analysis or static test should be carried out, in which a longitudinal force equal to the bogie inertia force under an acceleration of $3g$ for motor bogies and $5g$ for trailer bogies is applied to the bogie attachment as an exceptional (proof) load.

In multiple units and fixed passenger train formations it is sufficient to use $3g$ for all bogies.

Twist loading (two cases may be considered):

Case 1 - With the vehicle in the exceptional load state (vertical and transverse), the bogie frame should withstand the loads resulting from a track twist of 1 %.

Case 2 - With the vehicle empty (under vertical load only), consider a complete unloading of one wheel with the vertical displacement of the wheel being limited to rail height.

Case 2 replicates the effects of a slow speed derailment on, say, depot track. The technical specification may permit some permanent deformation of the bogie frame in this case. This case does not need to be considered for locomotives unless required in the specification.

C.2.2 Normal service loads

Vertical forces (applied to each sideframe):

$$F_{z1} = F_{z2} = \frac{F_z}{2} = \frac{(M_v + 1{,}2P_2 - 2m^+)g}{4} \quad \text{(C.4)}$$

where P_2 is the normal design payload (according to EN 15663).

Transverse forces (applied to each axle):

$$F_{y1} = F_{y2} = \frac{F_y}{2} = \frac{F_z + m^+g}{8} \quad \text{(C.5)}$$

Longitudinal lozenging forces (applied to each wheel and in the opposite sense on the opposite sides of the bogie frame):

$$F_{x1} = 0{,}05 \times (F_z + m^+g) \quad \text{(C.6)}$$

Twist loading

The loads resulting from a track twist of 0,5 %.

C.3 Examples of loads for freight bogies with a central pivot and two sidebearers - category B-V

C.3.1 Bogie types

The load cases below are specified for 2-axle bogies. For a 3-axle bogies the same global loads generally apply. Traditionally the vertical loads have been distributed equally on all three axles and the transverse and longitudinal loads distributed with 37,5 % on the outer axles and 25 % on the central axle. Where it is necessary to change the global loads for a 3-axle bogie this is indicated in the text. However, it should be noted that for modern bogie designs these loads and distributions may not be appropriate.

C.3.2 Relationship of vertical forces

F_z is the total vertical load supported by the bogie;

F_{zp} is the vertical force applied to the pivot;

F_{z1} , F_{z2} is the vertical forces applied to each sidebearer.

where F_{z1} and F_{z2} are obtained by the multiplication of F_z by a coefficient α, representing the effect of roll. When a force $F_z \alpha$ is applied to one sidebearer, the applied force to the pivot is reduced to $F_z (1\text{-}\alpha)$.

C.3.3 Exceptional loads

Vertical forces (two main cases are considered):

Case 1 - The case where the force is applied only to the pivot:

$$F_{zp\,max} = 2F_z \quad \text{(using load factor = 2)} \tag{C.7}$$

Case 2 - The (roll) case where the force is applied to both the pivot and one sidebearer:

$$F_{z1max} \left(\text{or } F_{z2\,max}\right) = 1{,}5 \times F_z \alpha \tag{C.8}$$

$$F_{zp\,max} = 1{,}5 \times F_z (1\text{-}\alpha) \quad \text{(using load factor = 1,5)} \tag{C.9}$$

where α depends on the service and the distance between the centrelines of the sidebearers. For UIC service with a distance between the sidebearers of 1,7m, α is taken as 0,3. If the spacing between sidebearers $(2b_g)$ differs from 1,7m then $\alpha = 0{,}3 \times \left(\frac{1{,}7}{2b_g}\right)$.

Transverse forces (applied to each axle):

$$F_{y1max} = F_{y2\,max} = \frac{F_{y\,max}}{2} = 10^4 + \frac{F_z + m^+ g}{6} \quad \text{(i.e. Prud'homme limit)} \tag{C.10}$$

The total force $F_{y\,max}$ should be increased to $\frac{8}{3}\left(10^4 + \frac{F_z + m^+ g}{6}\right)$ for 3-axle bogies (based on running trials of Type 714 freight bogies). For other types of bogie the load distribution recorded during running trials of a similar type should be used or loads determined from simulations,

Longitudinal lozenging forces (applied to each wheel and in the opposite sense on the opposite sides of the bogie frame):

$$F_{x1max} = 0{,}1 \times (F_z + m^+ g) \tag{C.11}$$

Longitudinal shunt loads

If the vehicle is to be subject to shunting when in service, a shock test should be performed using a 80 t wagon running at a speed of 15 km/h. If this test is not done apply a static longitudinal force at the attachment position equal to the bogie mass multiplied by the maximum vehicle acceleration in such a collision.

Twist loading

See C.2.1.

C.3.4 Normal service loads

Vertical forces (two main cases are considered):

Case 1 - The case where the force is applied only to the pivot:

$$F_{zp} = F_z \tag{C.12}$$

Case 2 - The (roll) case where the force is applied to both the pivot and one sidebearer:

$$F_{z1}\,(\text{or } F_{z2}) = F_z\,\alpha \tag{C.13}$$

$$F_{zp} = F_z\,(1-\alpha) \tag{C.14}$$

where α depends on the service and the distance between the centrelines of the sidebearers. (For UIC service with a distance between the sidebearers of 1,7m, α is taken as 0,2). If the spacing between sidebearers $(2b_g)$ differs from 1,7m then $\alpha = 0{,}2 \times \left(\frac{1{,}7}{2b_g}\right)$

Transverse forces (applied to each axle):

$$F_{y1} = F_{y2} = \frac{F_y}{2} = 0{,}1 \times (F_z + m^+ g) \tag{C.15}$$

The total force F_y should be increased to $0{,}265 \times (F_z + m^+ g)$ for 3-axle bogies, distributed as indicated in C.3.1.

Longitudinal lozenging forces (applied to each wheel and in the opposite sense on the opposite sides of the bogie frame):

$$F_{x1} = 0{,}05 \times (F_z + m^+ g) \tag{C.16}$$

Twist loading

The loads resulting from a track twist of 0,5 %.

C.4 Examples of loads for bogies of locomotives (with two bogies) - category B-VII

C.4.1 Exceptional loads

Vertical forces (applied to each sideframe, based on the assumption of vehicles whose mass is evenly distributed between the two bogies and the body supported directly on each sideframe):

$$F_{z1\max} = F_{z2\max} = \frac{F_{z\max}}{2} = \frac{1{,}4g(M_v - 2m^+)}{4} \tag{C.17}$$

where

M_V is the locomotive mass in running order;

m^+ is the bogie mass;

$F_{z\,max}$ is the total vertical force on bogie.

NOTE If the operating conditions are considered as very poor, the factor 1,4 may exceptionally be increased up to 2,0.

Transverse forces (applied to each end axle):

$$F_{y1max} = F_{y2max} = \frac{F_{y\,max}}{2} = 10^4 + \frac{(M_v + c_1)g}{3n_a n_b} \quad \text{(i.e. Prud'homme limit)} \qquad (C.18)$$

where

c_1 is the mass of the driver (80 kg);

n_a is the number of axles,

n_b is the number of bogies.

For bogies with 3 axles it is assumed that the middle axles do not transmit transverse forces.

Longitudinal force

A bogie longitudinal acceleration of at least 3 g should be considered for all locomotives except shunting locomotives where the acceleration to be considered should be 5 g .

Twist loading This case is the same as C.2.1.

C.4.2 Normal service loads

Vertical forces (applied to each side frame):

$$F_{z1} = F_{z2} = \frac{F_z}{2} = \frac{(M_v - 2m^+)g}{4} \qquad (C.19)$$

Transverse forces (applied to each axle):

$$F_{y1} = F_{y2} = \frac{F_y}{2} = \frac{F_z + m^+ g}{8} \qquad (C.20)$$

Longitudinal forces (applied to each wheel) due to tractive effort (μ = 0,4):

$$F_{x1} = 0{,}1 \times \frac{M_v g}{n_a} \qquad (C.21)$$

where

n_a is the number of axles;

0,1 is derived from $\mu/4$.

Longitudinal lozenging forces (applied to each wheel and in the opposite sense on the opposite sides of the bogie frame) due to dynamics.

$$F_{x1} = 0{,}05 \times \frac{M_v g}{n_a} \tag{C22}$$

Twist loading The bogie should withstand the loads due to a track twist of 0,5 %.

C.5 Examples of loads for bogies of metro, rapid transit, light rail vehicles and trams - categories B-III and B-IV

C.5.1 Application

The load cases apply to multiple, articulated and single car units with bogies. For vehicles with any other configuration the same principles can be applied to determine the alternative appropriate design load cases.

C.5.2 Load cases

The basic load cases, which are given below, are derived from [14]. It is customary to express the loads per bogie according to the respective bogie axle loads. Load combinations are given in Annex F.

For exceptional loads the effective car body mass m_1, including passengers, corresponding to a particular bogie is:

$$m_1 = \frac{(M_v + P_1)c}{100} - m^+ \tag{C.23}$$

For normal service loads the effective car body mass m_1, including passengers, corresponding to a particular bogie is:

$$m_1 = \frac{(M_v + P_2)c}{100} - m^+ \tag{C.24}$$

where

M_V is the mass of car in running order;

P_1, P_2 is the mass of passengers (e.g. expressed as a function of the reference masses in EN 15663);

c are the wheel loads of the relevant bogie expressed as a %;

m^+ is the bogie mass.

When considering forces resulting from wind pressure, the proportion of the lateral car body surface area, A_w , assigned to each bogie is determined according to the axle loads, as above.

Inertia forces are assumed to act at the centre of gravity of either the car body or the bogie frame, as appropriate. Wind forces are assumed to act at the centre of pressure of the car body side.

The load cases below use the additional symbols defined in Annex A.

C.5.3 General expressions for the basic load cases

C.5.3.1 Car body loads

Longitudinal force (applied at the centre of gravity)

$$F_{xc} = m_1 \times a_{xc} \tag{C.25}$$

Transverse force (applied at the centre of gravity)

$$F_{yc} = m_1(a_{yc} + a_{ycc}) \tag{C.26}$$

Vertical force (applied at the centre of gravity)

$$F_{zc} = m_1(g + a_{zc}) \tag{C.27}$$

Transverse force due to wind (applied at centre of pressure of body side)

$$F_{w1} = A_w \times q \tag{C.28}$$

C.5.3.2 Bogie frame loads

Longitudinal force (applied at the centre of gravity)

$$F_{xb} = m_2 \times a_{xb} \tag{C.29}$$

Transverse force (applied at the centre of gravity)

$$F_{yb} = m_2(a_{yb} + a_{ycb}) \tag{C.30}$$

Vertical force (applied at the centre of gravity)

$$F_{zb} = m_2(g + a_{zb}) \tag{C.31}$$

C.5.3.3 Loads in the connection between the bogie and car body (buffing conditions)

$$F_{xb} = m^+ \times 3g \tag{C.32}$$

Annex D
(informative)

Loads due to components attached to the bogie frame

D.1 General

The strength of equipment attachments to the bogie structure should carry the inertia loads generated by the bogie motion and any loads generated by the operation of the equipment. For all bogie types and for all applications, the loads can be defined in the same manner as those set out in Annex B, namely:

— exceptional loads, which should not produce permanent deformation or excessive deflections;

— normal service loads, which should not induce fatigue cracks.

However, it should be pointed out that in addition to load magnitudes, it is necessary in any analysis for fatigue damage to consider the number of applications for these loads. For example, braking loads have generally similar values for different types of bogies, but their number of applications can nevertheless be markedly different for underground or suburban railways, inter-city coaches, freight wagons or high speed trains.

D.2 Component inertia loads

D.2.1 Derivation

The accelerations used to determine the inertia loads should be based on the best available information for the application. This will depend on the mass, location and orientation on the bogie, bogie dynamics, natural frequency of the structure, stiffness of the local attachment, track quality, speed, etc.

It is acceptable to use general rules for the attachment of bogie equipment if it is light enough not to affect the dynamic behaviour. If no more accurate information is available the data given in D.2.2 and D.2.3 below can be used to determine the loads at the attachment interface due to the mass of the mounted equipment.

The design loads due to any component which has a significant mass/inertia (i.e. is sufficient in itself to affect the principal dynamic modes of the bogie) should be individually assessed. This also applies to any equipment that is resiliently mounted. The design requirement may be determined from empirical data proven in a comparative application, test data, or the results of simulations, etc.

The acceleration levels given below are indicative of typical design levels applicable to rolling stock using European TENs routes but designers shall be aware that in certain applications the levels can be substantially less or more than these values. For fatigue design the levels in the tables below may be assumed to represent a constant amplitude load acting for 10^7 cycles that will result in the same damage as the actual dynamic excitation spectra.

If tests are being performed to determine the inertia loads the data should be sampled and filtered at an appropriate level for the relevant frequencies. Strain gauge output generally gives a clearer indication of the effective structural load cycles than data from accelerometers.

The accelerations quoted in the tables relate to the bogie frame and axle box in general and do not include the effect of local structural flexibility, the mounting arrangements, or any associated resonance effects.

The figures quoted may not be appropriate for all bogie designs. The characteristics of the primary suspension and the bump stop arrangements can have a marked effect on bogie frame acceleration levels. Values substantially higher than those quoted can be experienced.

The acceleration levels used in any application should be agreed between the interested parties (e.g. customer, supplier and approval authority, where relevant).

D.2.2 Design accelerations for equipment attached to the bogie frame

This equipment can be antennas, lifeguards/railguards, flange lubrication equipment, sand boxes, etc.

Table D.1 — Typical accelerations of frame-mounted equipment

Direction	Exceptional Acceleration	Fatigue Acceleration
Vertical+	± 20 *g*	± 6 *g*
Lateral+	± 10 *g*	± 5 *g*
Longitudinal	± 3 *g* or ± 5 *g* *	± 2,5 *g*
+ The values in the table apply to the bogie frame above the primary suspension. They may be reduced linearly to half the value at the bogie centre and should be extrapolated to higher values outboard of the primary suspension. * The value to be used depends on the type of bogie and application and should be consistent with the longitudinal shunt cases (e.g. as indicated in Annex C).		

D.2.3 Design accelerations for equipment attached to the axlebox

This equipment can be obstacle guards or braking system components as well as various other components (e.g. speed sensors).

Table D.2 — Typical accelerations of axlebox-mounted equipment

Direction	Exceptional Acceleration	Fatigue Acceleration
Vertical	± 70 *g*	± 25 *g*
Lateral	± 10 *g*	± 5 *g*
Longitudinal	± 10 *g*	± 5 *g*

The accelerations in the table apply on the centreline of the axle. Depending on the type of axlebox they should be adjusted for other locations (especially if pitch effects are present).

D.3 Loads resulting from viscous dampers

The load resulting from a viscous damper is derived from its reference characteristics. This is often the force applied by the damper when it operates at its definition speed.

Wherever possible the design forces should be based on damper manufacturer's actual data and the expected damper velocities associated with the bogie application. In the absence of more accurate information from the manufacturer, the exceptional load can be taken as twice the reference force, in the direction of the damper axis. The normal service load can be taken as the reference force, in the direction of the damper axis.

D.4 Loads resulting from braking

Braking leads to forces arising from the operation of brake components (e.g. brake shoes on wheels, pads on discs, magnetic track brake units) and associated deceleration forces. The forces to be used for the design of the bogie frame are those that result from the brake system meeting the required braking decelerations for the application. The number of cycles considered should include the effects of wheelslide control systems.

Taking into account system tolerances and operating variables, exceptional loads produced during emergency braking can be equal to 1,3 times the nominal values. For design purposes, normal service loads are usually taken as equal to 1,1 times the nominal forces induced by the service braking.

The above factors can be reduced to 1,2 and 1,0 respectively if the additional variation due to setting tolerances has already been included in the nominal loads. The above factors take account of the snatch effect with most modern systems but an additional factor may need to be applied to the frictional element of the loads to account for high snatch effects during both emergency and normal braking with some systems.

D.5 Loads resulting from traction motors

The exceptional loads may be taken as 1,3 times those produced during starting or dynamic braking with the maximum acceleration or deceleration. Account should also be taken of the high exceptional loads that may be induced because of failure of the traction motors or associated drive system. Any cyclic loading that can result from out-of-balance rotating components should also be considered.

The normal service torque loads may be taken as 1,1 times the nominal loads induced during normal service starting or stopping.

Traction motor inertia loads should be determined on an individual basis depending on the application, the mass and location of the motor and the method of mounting.

D.6 Forces applied on anti-roll systems

The exceptional loads on anti-roll bar systems correspond to the maximum body inclination, with respect to the bogie, which may occur in service.

The normal service loads on anti roll-bar systems can be based on the body-bogie inclination angle derived from the α coefficient given in Annex F.

The loads used should be consistent with the loads and principles used to determine the transverse load cases acting on the bogie frame.

Annex E
(informative)

Analysis methods and acceptance criteria

E.1 General

The bogies of rail vehicles are required to withstand the maximum loads consistent with their operational requirements and achieve the required service life under normal operating conditions with an adequate probability of survival.

It is necessary to demonstrate by analysis that no excessive deflections, permanent deformation or fracture of the structure as a whole, or of any individual element, occurs under the prescribed load cases, assessed against the following criteria:

a) service or cyclic loads, which cause fatigue damage, have to be sustained for the specified life without detriment to the structural safety;

b) exceptional or limit loading, i.e. the maximum loading which has to be sustained and full operational condition maintained: this might include loads resulting from minor derailments at low speed (< 12 km/h) if required by the specification;

c) an acceptable margin of safety such that, if the exceptional or limit load is exceeded, catastrophic failure or collapse will not immediately occur. In many cases bogie frames which satisfy b) will automatically satisfy c), as a consequence of the material properties.

E.2 Loads

All loads used as the basis for bogie design should incorporate any necessary allowance for uncertainties in their values. Within the scope of their application, the loads specified in Annexes C and D include this allowance.

It is important to ensure that the design loads are expressed in a form that is consistent with the method of analysis and the way in which the permissible material stress levels are defined.

E.3 Analysis and acceptance

The application of the basic analysis and acceptance methods depends on the history of the design and its applications, as well as economic factors and time scales. It is strongly recommended that numerical methods such as finite element analysis are used, supplemented by hand calculations, to interpret stresses appropriate to the joint types and fatigue life assessment codes, etc.

The analysis should be carried out as required by the design and validation process as specified in EN 15827. For the convenience of the user this process is reproduced in the following clauses.

E.4 Structural acceptance criteria

E.4.1 Principle

The requirement covered by EN 15827 is the demonstration of structural integrity which is essential for safe operation and compliance with the Essential Requirements of the TSIs and applies to all bogie component parts. Therefore, the associated design and validation process needs to follow a consistent and thorough approach. It was necessary to specify the acceptance process in EN 15827 as it is not available in any normative reference.

The requirement, which is also compatible with that specified in EN 12663 for vehicle bodies (the other major part of a vehicle where structural integrity is foremost), is reproduced in the following clauses. Demonstration of structural integrity is based on a combination of static strength and fatigue life assessments using numerical analysis and/or testing.

The reliability of the input data (i.e. loads/geometry) and the assessment method together with the level of utilisation are used as a basis to define the level of testing (both laboratory and track tests) and manufacturing quality inspection requirements.

Acceptance criteria for tests need to consider additional parameters (e.g. statistical variations and simplifications necessary for the test arrangement).

If the normative standards covering bogie components (e.g. as for axles) contain specific acceptance criteria related to the strength these should be followed. These criteria do not conflict with the requirements given below but represent a simplification of the general design criteria because of the nature of the component and the dominant loading. If there are no such criteria then the acceptance criteria outlined below is to be adopted.

If the analytical acceptance criteria cannot be achieved for the structure as a whole (e.g. when the acceptance criteria has been exceeded locally in the analytical procedure) it is permissible to carry out a test that reproduces the design case or the real operating conditions. If the test result meets the acceptance criteria (which shall be adjusted as indicated above) then the requirement can be considered proven.

The acceptance strategy may involve variations such as adopting a high safety factor with minimal type testing or a low safety factor and extensive type testing.

E.4.2 Utilisation

The utilisation of the component shall be less than or equal to 1 according to the following general equation:

$$U = \frac{R_{\mathrm{d}}\, S}{R_{\mathrm{C}}} \leq 1 \qquad \text{(E.1)}$$

where

U is the utilisation of the component;

R_{d} is the determined result from analysis or test;

S is the design safety factor (see E.4.3);

R_{c} is the physical limit value of the material (including all appropriate local effects such as surface finish, thickness, etc.)

NOTE In some design codes the safety factor is not explicitly defined but is effectively implemented within the applied load, or by a reduction in the permissible value, or a combination of both.

E.4.3 Safety factor

The safety factor shall cover the following uncertainties in the design, manufacturing and validation process:

— dimensional tolerances
It is normally acceptable to base analysis on the nominal component dimensions. It is necessary to consider minimum dimensions only if there is a large tolerance on thickness (e.g. with castings), there is subsequent machining, or significant reductions in thickness (due to wear etc.) are inherent in the

operation of the component. Adequate protection against corrosion will be an integral part of the vehicle specification. The loss of material by this cause can normally be neglected.

— manufacturing process
The performance characteristics exhibited by materials in actual components may differ from those derived from test samples. Such differences are due to variations in the manufacturing processes and workmanship, which cannot be detected in any practicable quality control procedure.

NOTE 1 The variations in the manufacturing process with respect to weld quality may be taken into consideration by the adoption of an appropriate inspection frequency as defined by EN 15085 without further allowance.

— analytical accuracy
Every analytical procedure incorporates approximations and simplifications. It is within the responsibility of the supplier to apply appropriate assumptions in the application of analytical procedures to the design and validation process.

The value of the safety factor shall consider the following with respect to criticality of the component failure:

— consequence of failure;

— redundancy;

— accessibility for inspection;

— level/frequency of quality control;

— detection of component failure;

— maintenance interval.

The safety factor, designated S (≥ 1,0), shall be applied when determining the utilisation. It shall be consistent with the assessment method being used.

NOTE 2 When established methods of analysis are being used that have produced safe designs in the past, the safety factor can be based on this experience. If the methods have a conservatism included in the approach then the safety factor may be an inherent part of the method and S can be taken as 1,0.

E.4.4 Material strength

E.4.4.1 Requirement

Structural integrity shall be demonstrated for all components with respect to:

— static strength – i.e. assessment against instability, rupture and permanent deformation which infringes the functionality of the component;

— fatigue strength – i.e. assessment against fatigue failure (crack initiation) resulting from cyclic loading.

The material performance criteria shall be based on current European, national or international standards, or alternative sources of equivalent standing. Where no such data is available from standards other data can be used provided it is verified and supported by an appropriate quality control process (equivalent to that adopted in the material standards) to ensure the strength values used in the assessment correspond to the minimum for the material. The material properties shall be compatible with the assessment method applied and the operating conditions as defined in the specification (e.g. applications with extreme low temperatures).

The methods and criteria that are applied in the processes described below are based on accepted industry practice and state of the art knowledge. The same criteria shall be applicable during design and validation testing.

The approach described in this chapter is fully applicable to ferrous and most other metallic materials. For other types of material this approach might need to be adapted and equivalent appropriate assessment methods and criteria applied that are based on the same basic principles.

E.4.4.2 Static strength

E.4.4.2.1 Requirement

The static strength requirements correspond to the exceptional load conditions under which the bogie/running gear shall remain fully functional. It shall be demonstrated by analysis and/or testing, that no permanent deformation, instability or fracture of the structure as a whole, or of any individual element, will occur under the exceptional design load cases.

Where static strength properties for a grade of material are defined by a range of values the lower limit values shall be used for design purposes.

E.4.4.2.2 Permanent deformation

The acceptance criterion for the avoidance of permanent deformation is normally taken as the material yield/proof strength (R_{eH} or $R_{p0,2}$ according to EN ISO 6892-1) A safety factor S_1, as defined in E.4.3, shall be incorporated when comparing the permissible stress to the determined stress.

For the case of a linear static stress analysis the following applies:

$$U = \frac{\sigma_c S_1}{R_{eH}} \leq 1 \qquad \text{(E.2)}$$

where

R_{eH} is the material proof or yield stress in N/mm^2. If R_{eH} is not available then $R_{p0,2}$ shall be used;

σ_c is the determined stress, in N/mm^2;

S_1 is the safety factor according to E.4.3.

An appropriate failure criterion shall be chosen for the determination of the stress (σ_c) depending on the type of material. For example, for a ductile material it is common to use the Von Mises stress criteria and for high strength brittle materials it is common to use principal stress criteria. The criteria to be used for the choice of the failure mode shall be based on the material ductility and the crack initiation mechanism.

In cases where local plasticity occurs, it shall be demonstrated that the functionality and durability of the structure is not impaired under the exceptional load cases. In determining the stress levels in ductile materials with a linear analysis, the occurrence of stresses above the yield limit shall not automatically imply that the function of the structure is impaired. If the analysis does incorporate local stress concentrations, then it is permissible for the theoretical stress to exceed the yield strength or 0,2 % proof strength of the material. The areas of local plastic deformation associated with stress concentrations shall be sufficiently small so as not to cause any significant permanent deformation (see definition) when the load is removed. The avoidance of significant permanent deformation can be demonstrated by the following approaches as appropriate:

— analytical verification indicating the size of the affected area is sufficiently small to avoid significant permanent deformation;

— use of a plastic shape factor to demonstrate full section plasticity has not taken place; this factor can be determined by analytical methods, non-linear numerical simulations or tests with overload, up to a destructive test.

— the use of realistic or simplified non linear material behaviour to demonstrate that the total maximum strain of the respective material is not exceeded and the permanent deformation is acceptable after removal of the load i.e. still within geometrical tolerances;

— by test to demonstrate that after several load applications the stress/strain behaviour in the measurement positions show a linear behaviour and the permanent deformation is acceptable after removal of the load (i.e. still within geometrical tolerances).

NOTE The determination of allowable values for ultimate total stain and allowable residual strain should be based on the guidance of technical literature considering the type of material and the application.

E.4.4.2.3 Ultimate strength and stability

It is necessary to provide a margin of safety between the maximum design load and the ultimate load. This can be achieved by introducing a safety factor, S_2, such that the ratio between material ultimate strength and calculated stress shall be greater than or equal to S_2 by satisfying:

$$U = \frac{\sigma_c \, S_2}{R_m} \leq 1 \qquad \text{(E.3)}$$

where

R_m is the material ultimate strength, in N/mm^2;

σ_c is the determined stress, in N/mm^2;

S_2 is the safety factor for ultimate strength.

For most applications S_2 = 1,5 is a reasonable value, but this can be adjusted in special cases.

As an alternative to a linear analysis using the above equation, a non-linear analysis with a realistic or simplified material law or a (destructive) test can be performed. Then the required safety factor shall be applied according to the following equation:

$$U = \frac{L_E \, S_2}{L_C} \leq 1 \qquad \text{(E.4)}$$

where

L_E is the maximum exceptional design load;

L_C is the ultimate load (i.e. the onset of fracture or instability) determined by analysis or by test;

S_2 is the ultimate safety factor for exceptional loads.

There may be internal load effects that shall remain constant (for example shrink fits, bolt pre-load, pre-load due to static masses, etc.) when considering the applied loads that constitute the exceptional load cases.

E.4.4.3 Fatigue strength

E.4.4.3.1 General requirement

The behaviour of materials under fatigue loading shall be based on current European or national standards, or alternative sources of equivalent standing, wherever such sources are available. For the design assessment verified data shall be used. If such data is not available, it shall be determined by suitable tests appropriate to the application.

Fatigue strength shall be evaluated using S-N curves derived in accordance with the following:

— a survival probability of at least 95 %;

— classification of details according to the component or joint geometry (including stress concentration);

— interpretation of the limiting values from small-scale samples by the use of a test techniques and previous experience to guarantee applicability to full size components.

The fatigue strength shall be demonstrated by one of the following methods:

— endurance limit approach (see E.4.4.3.2);

— cumulative damage approach (see E.4.4.3.3):

— other established methods.

The methods can be applied to predicted and/or measured stresses resulting from analysis and testing respectively.

The nature and quality of the available data influence the choice of method to be used. The material performance data shall take into account residual stress in the structure as a result of fabrication processes such as fusion welding. It is permissible to take advantage of techniques to reduce the influence of residual stress such as stress relieving, shot blasting and ultrasonic impact treatments where evidence of their benefit can be verified.

Test methods to demonstrate the fatigue performance or to verify the analysis results may be part of the validation plan described in 6.2.

Other established methods of carrying out life assessment and determining safe inspection intervals, such as a fracture mechanics approach, can be used in the design and validation processes when appropriate.

E.4.4.3.2 Endurance limit approach

This approach can be used for areas where all dynamic stress cycles remain below the material endurance limit. Where a material has no defined endurance limit or some repetitive stress cycles exceed the limit, the cumulative damage approach shall be followed.

The required fatigue strength is demonstrated provided the stress, due to all appropriate combinations of the fatigue load cases or measurement results determined in accordance with 6.2 remain below the material endurance limit.

NOTE It is permissible for stress cycles due to exceptional load cases to exceed the endurance limit since, by definition, they do not occur sufficiently often to significantly affect the fatigue life.

E.4.4.3.3 Cumulative damage approach

This approach is an alternative to the endurance limit approach. Representative histories for each load case shall be expressed in terms of magnitude and number of cycles. Due regard shall be given to combinations of loads which act in unison. The damage due to each such case in turn is then assessed, using an appropriate material stress - cycle diagram (Wöhler Curve), and the total damage determined in accordance with an established damage accumulation hypothesis (such as Palmgren-Miner).

It is permissible to simplify the load histories and combinations, provided this does not affect the validity of the results.

The required fatigue strength is demonstrated provided the total damage at each critical detail, due to all appropriate combinations of the fatigue load cases, is below unity (1,0). Similarly, the cumulative damage at such details, as determined from stress cycles measured during tests (as required in 6.2.3 and 6.2.5) shall remain below unity when the duration is extrapolated to represent the full vehicle life.

NOTE Some fatigue design codes/standards recommend that a lower cumulative damage summation limit should be applied (< 1,0). The use of a lower value should be consistent with the code/standard being adopted.

E.4.4.4 Stiffness criteria

Stiffness requirements arise in two main areas.

The first requirement is that deflections under load have to be confined to levels that will not impair functionality. This limitation applies to the structure as a whole and the need to constrain all movements to the permissible vehicle envelope (loading gauge). Deflection limits can also be relevant at a global or detailed level to the functioning of equipment and mechanisms, etc. that are carried by or form an integral part of the bogies/running gear.

The second requirement is to ensure that the stiffnesses of the bogie structural components and equipment attachments are such that no unacceptable structural resonances occur. In this context the body/bogie connection needs to be designed so that bogie natural vibration modes are separated or otherwise decoupled from those of the vehicle body.

Where such requirements involve a scope of supply other than that of the supplier of the bogie it is necessary for the parameters associated with these requirements to be part of the specification.

Annex F
(informative)

Examples of static test programmes

F.1 General

The validation objectives that can be achieved by static laboratory tests are:

— determination of real strain at the measurement locations under synthetic loads;

— determination of functional parameters of the structural components (e.g. the torsional stiffness of the bogie frame);

— verification of static strength requirements (including where verification by simulation is not possible or not practicable);

— verification of the simulation model;

— verification of the test set-up (including the test set-up for the fatigue test);

— design life estimation based on real measured strain under synthetic loads and a theoretical fatigue hypothesis.

The limitations of static laboratory tests are:

— the test are performed with synthetic loads, therefore the results of the tests can never have a better level of confidence as the underlying load assumptions;

— loads that are applied are restricted to the technical limits of the test set-up;

— design life estimations are based on a theoretical fatigue hypothesis, therefore it has a level of confidence limited by the design life hypothesis itself (including uncertainties in the classification of the assessed detail).

The static test programmes, described below by way of example, are derived from the values of loads given in Annexes C and D, which are based on [9], [10], [11] and [14], and the limitations regarding the use of these load cases has already been discussed. Bogies for other types of vehicle and/or running under different service conditions, may require different test programmes.

Inertia forces acting on the bogie frame cannot be simulated directly during a static test; therefore the transverse forces applied to the bogie frame to balance the forces that simulate the force in the primary suspension are generally too large. The effect of the bogie inertia can be represented/approximated by additional applied loads. Alternatively, if as a result of the test arrangement the acceptance criteria are exceeded on the components of the secondary suspension, the assessment of the affected locations can be done separately with realistic forces.

Generally these tests consist of strain measurements in the highly stressed areas of the bogie frame by means of electric resistance strain gauges, which are of the unidirectional type for all points where stress is in only one direction and of the tri-directional type for all other points.

The following examples illustrate the scope of factors which should be considered. Those based on UIC requirements for coaches and wagons illustrate two commonly used bogie designs:

— bogies where the body load is supported by a secondary suspension evenly distributed on both side frames;

— bogies with a central pivot and two sidebearers.

F.2 Static test programme for bogies of passenger rolling stock with body supported directly to the sideframes (categories B-I and B-II)

F.2.1 Tests under exceptional loads

F.2.1.1 General

Two cases are to be considered: the exceptional loads resulting from bogie running and those coming from components attached to the bogie frame. The stresses measured during these various tests are compared to the yield (or proof) limit of the material. Furthermore, there should be no permanent deformation after removal of these loads. If necessary the deflections under load should be compared with the maximum allowable deflections.

F.2.1.2 Exceptional loads due to bogie running

The bogie frame is subjected to the exceptional loads and their combinations as determined in the design load cases. Furthermore, whilst under the load corresponding to an empty vehicle, the frame is also subjected to the exceptional twist owing to a service track derailment as indicated in Annex C.

F.2.1.3 Loads coming from components fitted to the bogie frame

Generally, whilst the frame is subjected to the exceptional vertical load $F_{z\,max}$, the various exceptional loads as referred to in Annex D (e.g. loads resulting from braking, dampers, body roll, masses attached to the frame) are applied separately or in combination as appropriate to the actual exceptional operational conditions.

F.2.2 Tests under normal service loads

F.2.2.1 General

Two cases are to be considered: the loads resulting from bogie running and those caused by components attached to the bogie frame.

F.2.2.2 Loads resulting from bogie running

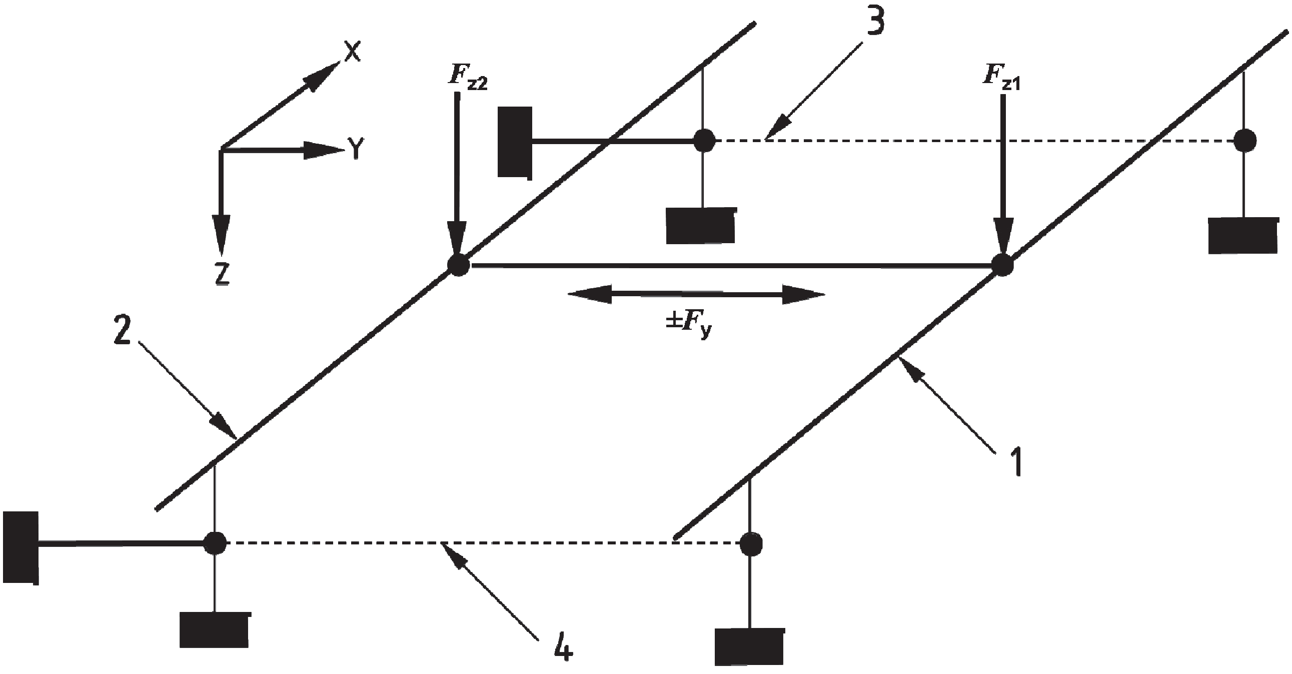
The test consists of different phases, each of which corresponds to a load state that could be applied easily to the bogie frame. The loads are derived from normal service forces and track twist as defined in Annex C: F_{z1}, F_{z2}, F_{y1}, F_{x1} etc. plus the twist moment. Roll and bouncing which induce quasi-static and dynamic variations of vertical forces are represented by coefficients α and β, respectively. Generally these coefficient values are 0,1 for α and 0,2 for β. These values may be modified according to operating conditions (e.g. track quality, cant deficiency, centre of gravity position, track gauge, pendular/tilting train).

The static test corresponding to vertical and transverse force combinations is defined by the nine cases in Table F.1.

Table F.1 — Load cases for static tests corresponding to vertical and transverse force combinations

Load case	F_{z1}	F_{z2}	F_y
1	$F_z/2$	$F_z/2$	0
2	$(1+\alpha-\beta)F_z/2$	$(1-\alpha-\beta)F_z/2$	0
3	$(1+\alpha-\beta)F_z/2$	$(1-\alpha-\beta)F_z/2$	$+F_y$
4	$(1+\alpha+\beta)F_z/2$	$(1-\alpha+\beta)F_z/2$	0
5	$(1+\alpha+\beta)F_z/2$	$(1-\alpha+\beta)F_z/2$	$+F_y$
6	$(1-\alpha-\beta)F_z/2$	$(1+\alpha-\beta)F_z/2$	0
7	$(1-\alpha-\beta)F_z/2$	$(1+\alpha-\beta)F_z/2$	$-F_y$
8	$(1-\alpha+\beta)F_z/2$	$(1+\alpha+\beta)F_z/2$	0
9	$(1-\alpha+\beta)F_z/2$	$(1+\alpha+\beta)F_z/2$	$-F_y$

Figure F.1 shows the bogie loading arrangement.



Key

1 side 1   2 side 2

3 axle 1   4 axle 2

Figure F.1 — Sideframe bogie loading arrangement

The results of the measurements carried out during this test are analysed by recording the stresses in all points for each load case.

These values are compared with the fatigue limits of the material. The method to be used should be consistent with the requirements of EN 15827 and Annex E. This static test is completed by the superposition of twist, as defined in C.2.2, in both directions, to the load case numbers 3, 5, 7 and 9 in Table F.1.

For the load cases resulting from longitudinal forces, the bogie frame is subjected to the vertical forces F_{z1} and F_{z2}, and the longitudinal forces are applied in each direction as illustrated in the Table F.2.

Table F.2 — Load cases resulting from longitudinal forces

Load case	F_{z1}	F_{z2}	F_x
1	$F_z/2$	$F_z/2$	0
2	$F_z/2$	$F_z/2$	$+F_{x1}$
3	$F_z/2$	$F_z/2$	$-F_{x1}$

The results from these three tests are analysed in the same way as those for the vertical and transverse forces.

Another way to analyse the results is to calculate the cumulative damage for the load cases and the relevant numbers of cycles as stated in the specification.

F.2.2.3 Loads due to components fitted to the bogie frame

The tests to incorporate loads due to attached components are to be carried out in accordance with the following requirements:

— the forces to consider are those indicated in Annex D;

— the bogie frame is subjected to the two vertical forces F_{z1} and F_{z2} of Table F.2;

— the loads due to dampers, attached masses, traction or brakes or anti-roll bars are applied alternately in opposite directions (this allows a load case table similar to that given for the longitudinal forces to be drawn up for each test);

— the strain measurement results are analysed as described previously.

F.3 Static test programme for bogies with central pivot and two sidebearers (category B-V)

F.3.1 Bogie types

The load cases below are specified for 2-axle bogies. For a 3-axle bogie the same global loads generally apply with the loads distributed as determined in Annex C.

F.3.2 Tests under exceptional loads

These tests are identical to those described in F.2.1 except as indicated above.

F.3.3 Tests under normal service loads

F.3.3.1 General

Two cases are to be considered: the loads due to bogie running and those coming from components attached to the bogie frame.

F.3.3.2 Loads resulting from bogie running

The test comprises different stages, each of which corresponds to a load case which can be easily applied to the bogie frame. The loads are derived from normal service loads and track twist stated in Annex C: F_{zp}, F_{z1}, F_{z2}, F_{y1}, F_{x1} etc. plus the twist moment. As indicated in C.3.4 the roll coefficient α is generally 0,2 and the β coefficient, which can be assumed to be 0,3, represents the bouncing effect.

The static test is conducted in the same way as the one defined in F.2.2, taking into account the values in Table F.3, which specify the different load cases.

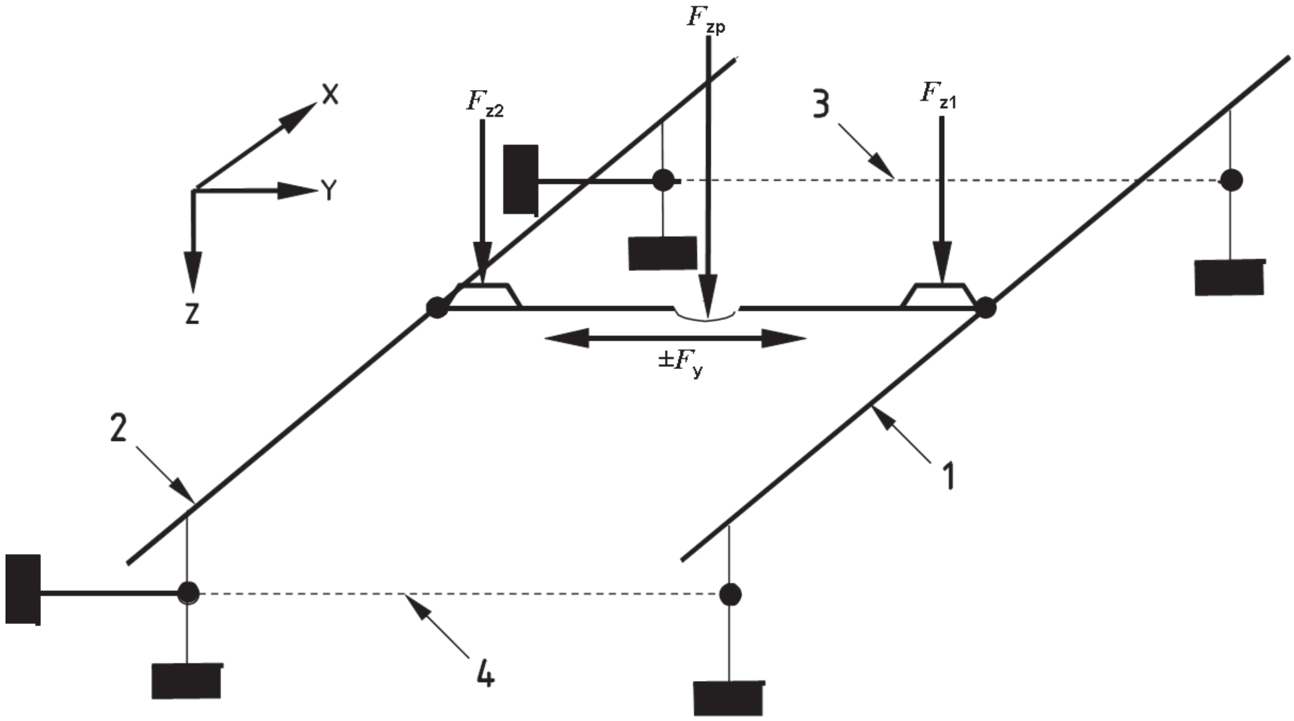
Table F.3 — Loads cases for tests under normal service loads resulting from bogie running

	Force on sidebearer 1 F_{z1}	Force on pivot F_{zp}	Force on sidebearer 2 F_{z2}	Transverse force F_y
1	0	F_z	0	0
2	0	$(1+\beta)F_z$	0	0
3	0	$(1-\beta)F_z$	0	0
4	0	$(1-\alpha)(1+\beta)F_z$	$\alpha(1+\beta)F_z$	F_y
5	$\alpha(1+\beta)F_z$	$(1-\alpha)(1+\beta)F_z$	0	$-F_y$
6	0	$(1-\alpha)(1-\beta)F_z$	$\alpha(1-\beta)F_z$	F_y
7	$\alpha(1-\beta)F_z$	$(1-\alpha)(1-\beta)F_z$	0	$-F_y$

Figure F.2 shows the bogie loading arrangement.

The test is completed by the superposition of twist as defined in C.3.4, in both directions on the four load cases 4, 5, 6 and 7 from Table F.3.

For longitudinal forces, the performance of the test is the same as that described in F.2.2, the bogie being vertically loaded on the pivot with $F_{zp} = F_z$.



Key

1 side 1 2 side 2

3 axle 1 4 axle 2

Figure F.2 — Centre pivot bogie loading arrangement

F.3.3.3 Loads due to components attached to the bogie frame:

The test is conducted as described in F.2.2.3, the bogie being vertically loaded on the pivot with $F_{zp} = F_z$ and the forces due to the components being those indicated in Annex D.

F.4 Static test programme for bogies of locomotives

This test follows the procedure set out in F.2.

F.5 Static test programme for bogies of light rail vehicles and trams

F.5.1 General

The static tests reproduce the same loads as applied in the stress analysis according to Annex C.

F.5.2 Tests under exceptional loads

The bogie frame is subjected to the exceptional load cases derived from the accelerations, etc. given in Table F.4. In addition these load cases are also be applied in combination with the following loads from components attached to the bogie frame:

— gear-box and motor with a vertical acceleration. (see D.2.2 and D.2.3);

— 1,3 times emergency braking loads (see D.4);

— 1,3 times maximum acceleration or deceleration (see D.5).

Table F.4 — Exceptional loads

Load case	Vehicle body masses					Bogie masses			
	a_{zc} (m/s^2)	a_{yc} (m/s^2)	a_{ycc} (m/s^2)	a_{xc} (m/s^2)	q (N/m^2)	a_{zb} (m/s^2)	a_{yb} (m/s^2)	a_{ycb} (m/s^2)	a_{xb} (m/s^2)
Switches	3,2	2,2	—	Emergency braking rate	600 [a]	30	16	—	Emergency braking rate
Running through Curves	1,6	1,3	2,0	Emergency braking rate	600 [a]	12	6,5	2	Emergency braking rate
[a] Wind speed of 105 km/h.									

F.5.3 Tests under normal service loads

The bogie frame is subjected to the normal service load cases derived from the accelerations, etc. given in Table F.5. In addition these load cases are to be applied in combination with the following loads from components attached to the bogie frame:

— gear box and motor with a vertical acceleration. (see D.2.2 and D.2.3);

— 1,1 times normal service braking loads (see D.4);

— 1,1 times normal service acceleration or deceleration (see D.5).

Table F.5 — Normal service loads

Load case	Vehicle body masses					Bogie masses			
	a_{zc} (m/s^2)	a_{yc} (m/s^2)	a_{ycc} (m/s^2)	a_{xc} (m/s^2)	q (N/m^2)	a_{zb} (m/s^2)	a_{yb} (m/s^2)	a_{ycb} (m/s^2)	a_{xb} (m/s^2)
Switches	2,4	1,6	—	—	200 [a]	25	12	—	—
Straight track	1,2	0,9	—	Service braking rate	—	8,5	4,5	—	Service braking rate
Running through curves	1,2	0,9	1,0	Service braking rate	—	8,5	4,5	1,0	Service braking rate
[a] Wind speed of 60 km/h.									

Annex G
(informative)

Examples of fatigue test programmes

G.1 General

The validation objectives that can be achieved by fatigue tests are:

- verification and/or determination of the fatigue behaviour of structural components under synthetic loads;
- verification of design assumptions concerning fatigue behaviour of the actual details and their manufactured level of quality (e.g. verification of assessment classification and empirical assessment of manufacturing imperfections).

A fatigue test is the only kind of type test that produces actual physical fatigue damage on the whole structure.

The limitations of laboratory fatigue tests are:

- the tests are performed with synthetic loads, therefore the results of the tests can never have a better level of confidence than the underlying load assumptions;
- the loads that are applied during the test are restricted to the technical limits of the test set-up (e.g. usually the real load distribution is much more complex than a test set up with a limited number of actuators can simulate, especially with respect to inertia loads);
- the jigs are usually a simplification of the real mechanical system of the bogie (e.g. the suspension characteristics in the test set-up often have a higher stiffness to increase the possible test frequency and achieve a practical time schedule).

The fatigue tests on the bogie frame comprise a main test and possibly additional specific tests.

The main test is intended to confirm that the frame strength is sufficient with regard to the main loads acting on it. The main loads are those inducing stresses in the entire frame structure, i.e. vertical forces, transverse forces and twist input.

The test programme should be adapted, if necessary, particularly if indicated by the results of analysis or static tests. Additional tests that correspond to forces with only local effects on the bogie frame, e.g. dampers, brakes, longitudinal forces, masses attached to the frame may be required.

The examples of the fatigue test programmes described below are relevant only to the main bogie frame when the values of loads given in annexes C and D are applicable (and consequently have the same limitations). They are based on [9], [10] and [11] for coaches, wagons and locomotives, and [14] for light rail vehicles and trams. Their composition takes into account the following:

- in the tests derived from [9], [10] and [11], only the lateral loads encountered when negotiating curves or switches are simulated; this is because it is well known that in general the loads due to straight track or large radius curves include very low quasi-static and dynamic components;
- generally, for reasons of cost and time, only one bogie frame is tested for fatigue. Once the specimen is proven to conform to the initial requirements, the test loads are increased in successive steps to determine the safety margin available to accommodate normal scatter in fatigue strength. Figure G.1 illustrates this principle.

Other types of bogies and/or those running under different service conditions may require different load cases and test programmes.

G.2 Fatigue test programme for bogies with the body supported directly on the sideframes (categories B-I and B-II)

The programme consists of the repetition of cycles based on vertical and transverse forces. The vertical forces, applied on both sideframes comprise:

— a static part: $F_{z1} = F_{z2} = F_z/2$ (as defined in C.2.2) (G.1)

— a quasi-static part: $F_{z1qs} = F_{z2qs} = \pm\ \alpha F_z/2$ (see F.2.2 for definition of α) (G.2)

— a dynamic part: $F_{z1d} = F_{z2d} = \pm \beta F_z/2$ (see F.2.2 for definition of β) (G.3)

The transverse forces, applied on each axle, comprise:

— a quasi-static part: $F_{y1qs} = F_{y2qs} = \pm 0{,}063(F_z + m^+ g)$ (G.4)

— a dynamic part: $F_{y1d} = F_{y2d} = \pm 0{,}063(F_z + m^+ g)$ (G.5)

The variation of these forces with respect to time is indicated in Figure G.2.

The quasi-static load cycles are normally reversed every 10 to 20 dynamic cycles and the number of these cycles will be proportionately less than the number of dynamic cycles indicated in Figure G.1.

The load cycle due to twist is composed of loads (or equivalent displacements) at the primary suspension locations to give a twist of + θ_y followed by a twist - θ_y across the bogie frame and should be reversed in sequence with the quasi-static loads.

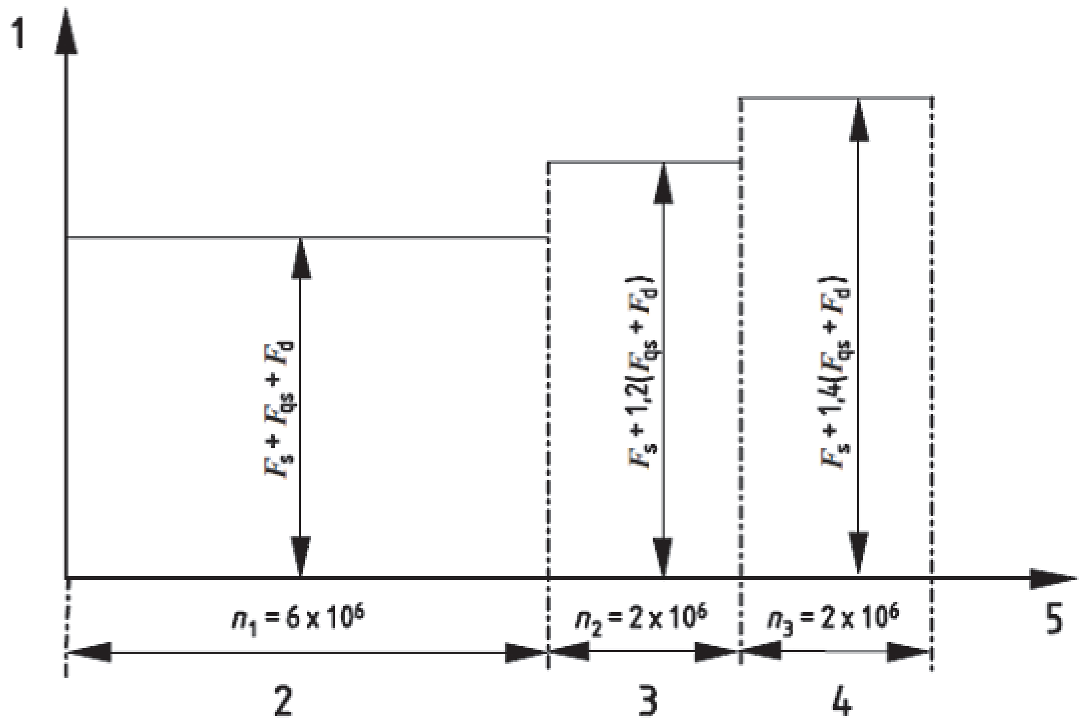
The fatigue tests also include dynamic twist loads. The twist applied to the bogie frame is the induced loading taken by the frame when the bogie, complete with suspension, negotiates a track twist of 0,5 %.

The fatigue test programme comprises three stages as indicated in Figure G.1:

— the first consists of 6×10^6 cycles of application of the vertical and transverse forces, and $0{,}6 \times 10^6$ cycles of application of the twist loads;

— the second consists of 2×10^6 cycles of application of the vertical and transverse forces derived from those used for the first step, with the static parts remaining as before and the quasi-static and dynamic parts multiplied by 1,2, then application of the twist loads, multiplied by 1,2, for $0{,}2 \times 10^6$ cycles.

— the third is identical to the second, except that the coefficient of 1,2 is replaced by 1,4.



Key

1 force magnitude

2 1st load sequence

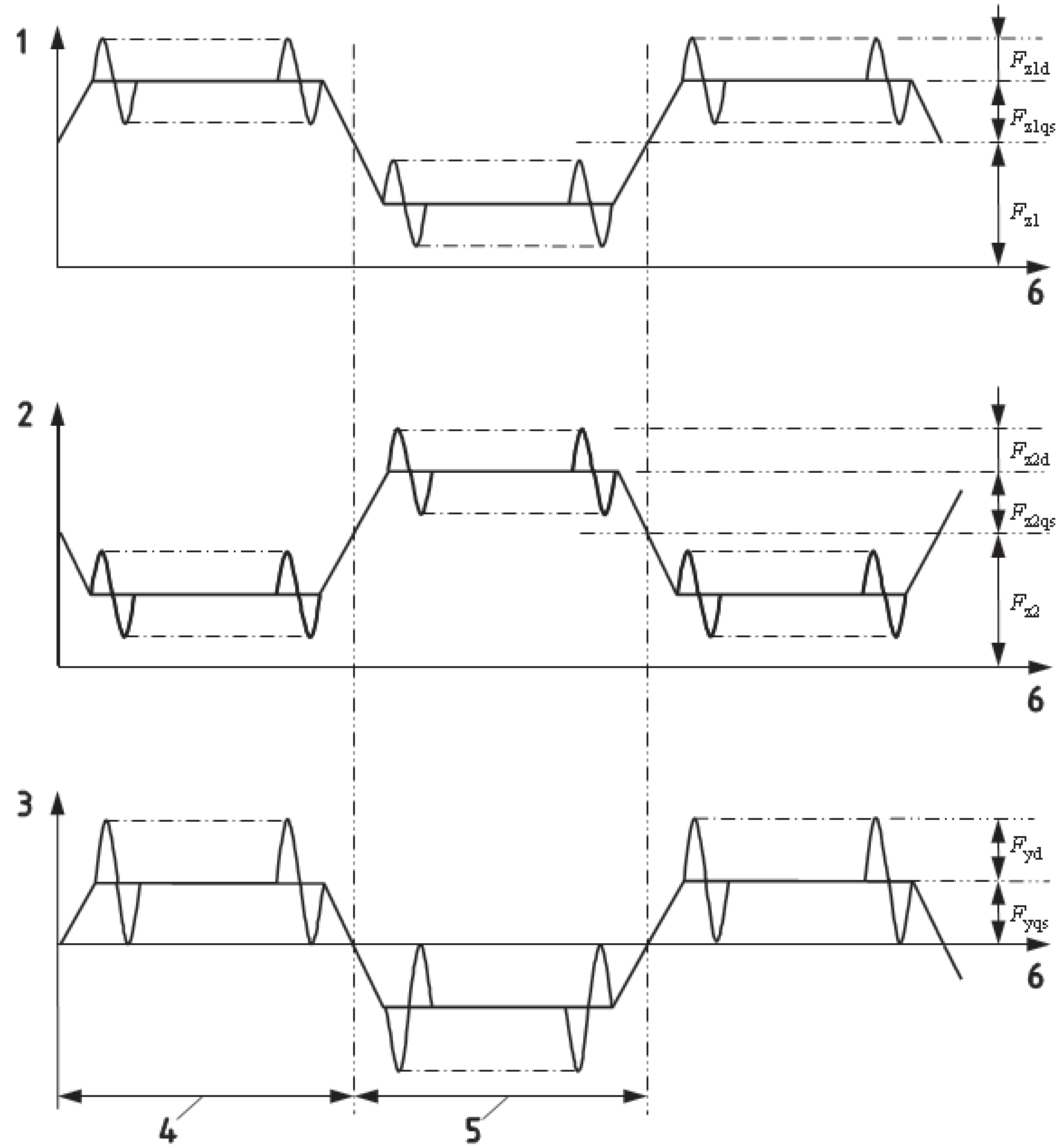
3 2nd load sequence

4 3rd load sequence

5 cycles

Figure G.1 — Variation of vertical and transverse force magnitudes during test

The dynamic components of the vertical and transverse forces are applied in phase, at the same frequency in such a way as to allow a simulation of the loads acting on the bogie frame. The same applies to the quasi-static components, at a frequency corresponding to the change in curving direction. The curving direction is normally changed alternately, every ten to twenty cycles of the dynamic components. The principle of these tests is illustrated by Figure G.2, which shows the variation with time of the various forces.



Key

1 force applied to sideframe 1, F_{z1}

2 force applied to sideframe 2, F_{z2}

3 transverse force, F_y

4 right curve, n cycles

5 left curve, n cycles

6 cycles

F_{z1d} vertical dynamic force, sideframe 1

F_{z2d} vertical dynamic force, sideframe 2

F_{z1qs} vertical quasi static force, sideframe 1

F_{z1qs} vertical quasi static force, sideframe 2

F_{yd} transverse dynamic force

F_{yqs} transverse quasi static force

Figure G.2 — Variation of vertical and transverse forces with respect to time

The bogie frame is considered to be sufficiently strong if both the following conditions are fulfilled:

— no cracks are revealed at the end of the first two steps;

— during the third step very small cracks are permitted which, if they appeared in service, would not necessitate immediate repair.

This test programme can also be used for other categories of bogie if they have the same type of suspension configuration. The relative number of quasi-static and dynamic cycles may need to change for different applications.

G.3 Fatigue test programme for a freight bogie with a central pivot and two sidebearers (category B-V)

G.3.1 General

The test is performed according to the same principles as stated in G.2. Only the vertical forces are different, as shown in G.3.2 and G.3.3, because of their distribution between pivot and sidebearers.

The variation of these forces with respect to time is as indicated in Figure G.3.

G.3.2 Vertical loads

For the pivot the vertical loads comprise:

— a static component $F_{zp} = F_z (1 - \alpha)$ (G.6)

— a dynamic component $F_{zpd} = \pm \beta F_z (1 - \alpha)$ (G.7)

For each sidebearer (alternately) the vertical loads comprise

— a quasi static component $F_{z1qs} = F_{z2qs} = \pm \alpha F_z$ (G.8)

— a dynamic component $F_{y1d} = F_{y2d} = \pm \beta F_z$ (G.9)

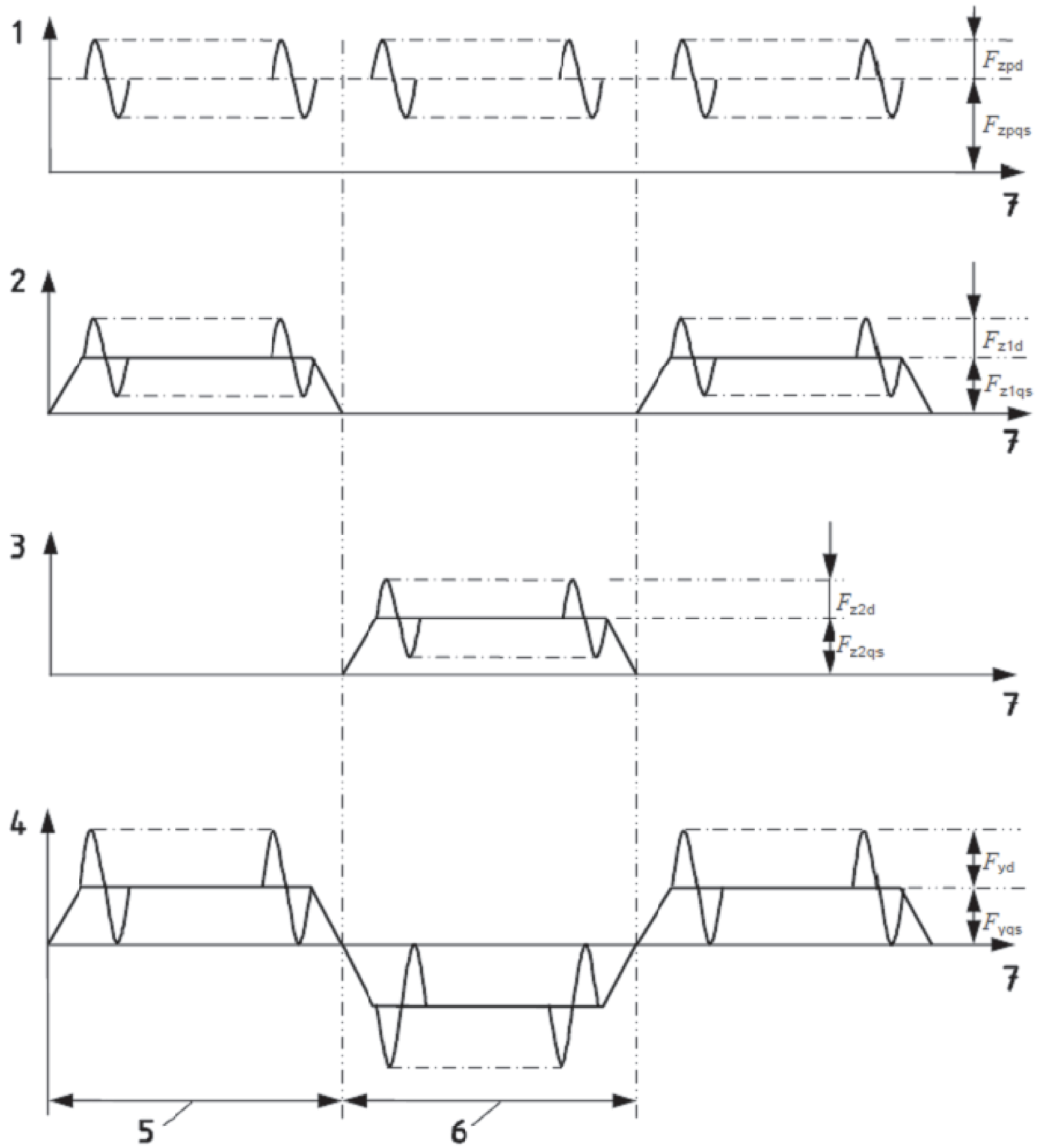
G.3.3 Transverse loads

Transverse loads are applied to each axle and comprise:

— a quasi static component $F_{y1qs} = F_{y2qs} = \pm\, 0{,}05 F_z + m^+ g$ (G.10)

— a dynamic component $F_{y1d} = F_{y2d} = \pm\, 0{,}05 F_z + m^+ g$ (G.11)

For 3-axle bogies the transverse loads are distributed as indicated in F.3.1.



Key

1 force applied to centre pivot, F_{zp}

2 force applied to sidebearer 1, F_{z1}

3 force applied to sidebearer 2, F_{z2}

4 transverse force, F_y

5 right curve, n cycles

6 left curve, n cycles

7 cycles

F_{zpd} vertical dynamic force, centre pivot

F_{zpqs} vertical quasi static force, centre pivot

F_{z1d} vertical dynamic force, sidebearer 1

F_{z1qs} vertical quasi static force, sidebearer 1

F_{z2d} vertical dynamic force, sidebearer 2

F_{z2qs} vertical quasi static force, sidebearer 2

F_{yd} transverse dynamic force

F_{yqs} transverse quasi static force

Figure G.3 — Variation of vertical and transverse forces with respect to time

G.4 Fatigue test programme for locomotive bogies (category B-VII)

This follows the same procedure as that described in G.2.

G.5 Fatigue test programme for bogies of light rail vehicles and trams (category B-IV)

The fatigue test programme should represent the fatigue load cases used for the design with appropriate numbers of load case applications.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2008/57/EC

This European Standard has been prepared under mandates given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the Directive 2008/57/EC.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 for Freight Wagons and Table ZA.2 for Locomotives and Passenger Rolling Stock for Conventional Rail confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard, the CR TSI RST Freight Wagons dated July 2006, published in the OJEU on 8 December 2006 and its intermediate revision published in the OJEU on 14 February and Directive 2008/57/EC

Clause/ subclauses of this European Standard	**Chapter/§of the TSI**	**Corresponding text, articles/§/annexes of the Directive 2008/57/EC**	Comments
Clauses 1 to 7 inclusive Annex A Annex B Annex C.1, C.3 Annex D.1-D.4, D.6 Annex E Annex F.1, F.3 Annex G.1, G.3 of this European Standard are applicable	4.Characterisation of the subsystem 4.2. Functional and technical specifications of the subsystem § 4.2.2.3.2.5 Structures and mechanical parts, Strength of main vehicle structure and securing of freight, Equipment attachment (including body/bogie) §4.2.3.4.1 Vehicle track interaction and gauging, Vehicle dynamic behaviour, General §4.2.6.1 Environmental conditions, General 5 Interoperability constituents §5.3.2.1 List of constituents, Vehicle track interaction, Bogie and running gear §5.4.2.1 Constituents performances and specifications, Vehicle track interaction, Bogie and running gear 6 Assessment of conformity and/or suitability for use of the constituents and verification of the subsystem	Annex III, Essential Requirements, 1 General Requirements 1.1 Safety Clauses 1.1.1, 1.1.2, 1.1.3 1.5 Technical compatibility 2 Requirements Specific to each Subsystem 2.4 Rolling Stock 2.4.2 Reliability and availability 2.4.3 Technical compatibility §3	The standard does not meet the Essential Requirement 1.2 Reliability and availability

Table ZA.1 *(continued)*

	§6.1.3.2.1: Specification for assessment of IC's, Vehicle track interaction and gauging, Bogie and running gear Annex J Vehicle track interaction and gauging, bogie and running gear Annex Q Assessment procedures, interoperability constituents Annex Y Constituents, bogies and running Gear Annex Z Structure and mechanical parts, Impact (buffing) test		

Table ZA.2 — Correspondence between this European Standard, the CR TSI Locomotives and Passenger RST (final draft ST05EN05 dated 10 June 2010) accepted by RISC in June 2010 and Directive 2008/57/EC

Clause/ subclauses of this European Standard	Chapter/§of the TSI	Corresponding text, articles/§/annexes of the Directive 2008/57/EC	Comments
The whole standard is applicable	4.Characterisation of the Rolling stock subsystem 4.2 Functional and technical specifications of the subsystem 4.2.3 Track interaction and gauging 4.2.3.5 Running gear § 4.2.3.5.1 Structural design of bogie frame §4.2.3.7 Life guards	Annex III, Essential Requirements 1. General requirements 1.1. Safety Clauses 1.1.1, 1.1.2, 1.1.3 1.5. Technical compatibility 2. Requirements specific to each subsystem 2.4. Rolling stock 2.4.2. Reliability and availability 2.4.3. Technical compatibility § 3	This TSI refers in its subclause 4.2.3.5.1 to the EN 13749:2005, Clause 7, 9.2 and Annex C. Therefore these parts of the EN 13749:2005 are mandatory. They respectively correspond to the following part of this new version of EN 13749. Clause 4, 6.2 and Annex C. Clause 5 of EN 13749:2005 referenced in the note of the TSI is included in A.6 of this new version of EN 13749 The standard does not meet the Essential Requirement 1.2 Reliability and availability

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Bibliography

[1] EN 12663-1:2010, *Railway applications — Structural requirements for railway vehicle bodies — Part 1: Locomotives and passenger rolling stock (and alternative methods for freight wagons)*

[2] EN 12663-2:2010, *Railway applications — Structural requirements for railway vehicle bodies — Part 2: Freight wagons*

[3] EN 13103:2001, *Railway applications — Wheelsets and bogies — Non-powered axles — Design method*

[4] EN 13104:2001, *Railway applications — Wheelsets and bogies — Powered axles — Design method*

[5] EN 13979-1:2003 *Railway applications — Wheelsets and bogies — Monobloc wheels — Technical approval procedure — Part 1: Forged and rolled wheels*

[6] EN 50125-1: *Railway applications — Environmental conditions for equipment — Part 1: Equipment on board rolling stock*

[7] NF F 01 301, *Matérial roulant ferroviaire; Masses et états de charge des véhicules moteurs et des véhicules remorqués à voyageurs*

[8] Railway Group Standard GM/RT2100, *'Structural Requirements for Railway Vehicles', Issue 3, April 2000, Safety and Standards Directorate, Railtrack*

[9] UIC Leaflet 515, *Coaches — Running gear*

[10] UIC Leaflet 510-3, *Wagons — Strength testing of 2 and 3-axle bogies on test rig*

[11] UIC Leaflet 615-4, *Motive power units — Bogies and running gear — Bogie frame structure strength tests*

[12] Engineering Standard E6325 A1. *'Passenger Rolling Stock Loadings', London Underground Limited*

[13] Specification of Société des Transports Intercommunaux Bruxelles/Maatschappij voor het Intercommunaal Vervoer te Brussel (STIB/MIVB)

[14] VDV 152, *Empfehlungen für die Festigkeitsauslegung von Personenfahrzeugen nach BOStrab*

[15] EN 12082, *Railway applications — Axleboxes — Performance testing*

[16] EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1:2009)*

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