

Eurocode 1: Actions on structures —

Part 2: Traffic loads on bridges

ICS 91.010.30; 93.040

National foreword

This British Standard is the UK implementation of EN 1991-2:2003, incorporating corrigendum February 2010. It supersedes DD ENV 1991-3:2000 which is withdrawn. Details of superseded British Standards are given in the table below.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by CEN corrigendum February 2010 is indicated in the text by **[AC1]** **<AC1>**.

The structural Eurocodes are divided into packages by grouping Eurocodes for each of the main materials, concrete, steel, composite concrete and steel, timber, masonry and aluminium; this is to enable a common date of withdrawal (DOW) for all the relevant parts that are needed for a particular design. The conflicting national standards will be withdrawn at the end of the coexistence period, after all the EN Eurocodes of a package are available.

Following publication of the EN, there is a period of 2 years allowed for the national calibration period during which the National Annex is issued, followed by a three year coexistence period. During the coexistence period Member States will be encouraged to adapt their national provisions to withdraw conflicting national rules before the end of the coexistent period. The Commission in consultation with Member States is expected to agree the end of the coexistence period for each package of Eurocodes.

At the end of this coexistence period, the national standard(s) will be withdrawn.

In the UK, the following national standards are superseded by the Eurocode 1 series. These standards will be withdrawn on a date to be announced.

Eurocode	Superseded British Standards
EN 1991-1-1	BS 6399-1:1996
EN 1991-1-2	none
EN 1991-1-3	BS 6399-3:1988
EN 1991-1-4	BS 6399-2:1997, BS 5400-2:1978*
EN 1991-1-5	BS 5400-2:1978*
EN 1991-1-6	none
EN 1991-1-7	none
EN 1991-2	BS 5400-1:1988, BS 5400-2:1978*
EN 1991-3	none
EN 1991-4	none

* N.B. BS 5400-2:1978 will not be fully superseded until publication of Annex A.2 to BS EN 1990:2002.

Amendments/corrigenda issued since publication

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15508 Corrigendum No.1	15 December 2004	Addition of supersession details
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The UK participation in its preparation was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/1, Actions and basis of design loadings.

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

Where a normative part of this EN allows for a choice to be made at the national level, the range and possible choice will be given in the normative text, and a Note will qualify it as a Nationally Determined Parameter (NDP). NDPs can be a specific value for a factor, a specific level or class, a particular method or a particular application rule if several are proposed in the EN.

To enable EN 1991-2 to be used in the UK, the NDPs will be published in a National Annex which will be made available by BSI in due course, after public consultation has taken place.

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

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

English version

Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges

Eurocode 1: Actions sur les structures - Partie 2: Actions sur les ponts, dues au trafic

Eurocode 1: Einwirkungen auf Tragwerke - Teil 2: Verkehrslasten auf Brücken

This European Standard was approved by CEN on 28 November 2002.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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Foreword

This document (EN 1991-2:2003) has been prepared by Technical Committee CEN/TC 250 "Structural Eurocodes", the secretariat of which is held by BSI.

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 March 2004, and conflicting national standards shall be withdrawn at the latest by AC1 March 2010 AC1.

This document supersedes ENV 1991-3:1995.

CEN/TC 250 is responsible for all Structural Eurocodes.

AC1 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 the United Kingdom. AC1

Background of the Eurocode Programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980s.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement¹ between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links *de facto* the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (*e.g.* the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

¹ Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990	Eurocode :	Basis of Structural Design
EN 1991	Eurocode 1:	Actions on structures
EN 1992	Eurocode 2:	Design of concrete structures
EN 1993	Eurocode 3:	Design of steel structures
EN 1994	Eurocode 4:	Design of composite steel and concrete structures
EN 1995	Eurocode 5:	Design of timber structures
EN 1996	Eurocode 6:	Design of masonry structures
EN 1997	Eurocode 7:	Geotechnical design
EN 1998	Eurocode 8:	Design of structures for earthquake resistance
EN 1999	Eurocode 9:	Design of aluminium structures

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes :

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 – Mechanical resistance and stability – and Essential Requirement N°2 – Safety in case of fire ;
- as a basis for specifying contracts for construction works and related engineering services ;
- as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents² referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards³. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving a full compatibility of these technical specifications with the Eurocodes.

² According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

³ According to Art. 12 of the CPD the interpretative documents shall :

- a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;
- b) indicate methods of correlating these classes or levels of requirement with the technical specifications, *e.g.* methods of calculation and of proof, technical rules for project design, etc. ;
- c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National Annex.

The National Annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, *i.e.* :

- values and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,
- country specific data (geographical, climatic, etc.), *e.g.* snow map,
- procedure to be used where alternative procedures are given in the Eurocode.

It may also contain

- decisions on the application of informative annexes,
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and harmonised technical specifications (ENs and ETAs) for products

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works⁴. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes should clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific to EN 1991-2

EN 1991-2 defines models of traffic loads for the design of road bridges, footbridges and railway bridges. For the design of new bridges, EN 1991-2 is intended to be used, for direct application, together with Eurocodes EN 1990 to 1999.

The bases for combinations of traffic loads with non-traffic loads are given in EN 1990, A2.

⁴ see Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1 (Interpretative Document Nr. 1).

Complementary rules may be specified for individual projects :

- when traffic loads need to be considered which are not defined in this Part of Eurocode 1 (*e.g.* site loads, military loads, tramway loads) ;
- for bridges intended for both road and rail traffic ;
- for actions to be considered in accidental design situations ;
- for masonry arch bridges.

For road bridges, Load Models 1 and 2, defined in 4.3.2 and 4.3.3, and taken into account with adjustment factors α and β equal to 1, are deemed to represent the most severe traffic met or expected in practice, other than that of special vehicles requiring permits to travel, on the main routes of European countries. The traffic on other routes in these countries and in some other countries may be substantially lighter, or better controlled. However it should be noted that a great number of existing bridges do not meet the requirements of this EN 1991-2 and the associated Structural Eurocodes EN 1992 to EN 1999.

It is therefore recommended to the national authorities that values of the adjustment factors α and β be chosen for road bridge design corresponding possibly to several classes of routes on which the bridges are located, but remain as few and simple as possible, based on consideration of the national traffic regulations and the efficiency of the associated control.

For railway bridges, Load Model 71 (together with Load Model SW/0 for continuous bridges), defined in 6.3.2, represent the static effect of standard rail traffic operating over the standard-gauge or wide-gauge European mainline-network. Load Model SW/2, defined in 6.3.3, represents the static effect of heavy rail traffic. The lines, or sections of lines, over which such loads shall be taken into account are defined in the National Annex (see below) or for the individual project.

Provision is made for varying the specified loading to cater for variations in the type, volume and maximum weight of rail traffic on different railways, as well as for different qualities of track. The characteristic values given for Load Models 71 and SW/0 may be multiplied by a factor α for lines carrying rail traffic which is heavier or lighter than the standard.

In addition two other load models are given for railway bridges :

- load model "unloaded train" for checking the lateral stability of single track bridges and
- load model HSLM to represent the loading from passenger trains at speeds exceeding 200 km/h.

Guidance is also given on aerodynamic actions on structures adjacent to railway tracks as a result of passing trains and on other actions from railway infrastructure.

Bridges are essentially public works, for which :

- the European Directive 89/440/EEC on contracts for public works is particularly relevant, and
- public authorities have responsibilities as owners.

Public authorities may also have responsibilities for the issue of regulations on authorised traffic (especially on vehicle loads) and for delivery and control dispensations when relevant, *e.g.* for special vehicles.

EN 1991-2 is therefore intended for use by :

- committees drafting standards for structural design and related product, testing and execution standards ;
- clients (*e.g.* for the formulation of their specific requirements on traffic and associated loading requirements) ;
- designers and constructors ;
- relevant authorities.

[AC1] Where a Table or a Figure **[AC1]** are part of a NOTE, the Table or the Figure number is followed by (n) (*e.g.* Table 4.5(n)).

National Annex for EN 1991-2

This Standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices have to be made. Therefore the National Standard implementing EN 1991-2 should have a National Annex containing all Nationally Determined Parameters to be used for the design of bridges to be constructed in the relevant country.

National choice is allowed in EN 1991-2 through the following clauses :

Section 1 : General	
1.1(3)	Complementary rules for retaining walls, buried structures and tunnels.

Section 2 : Classification of actions	
2.2(2) NOTE 2	Use of infrequent values of loading for road bridges
2.3(1)	Definition of appropriate protection against collisions
2.3(4)	Rules concerning collisions forces from various origins

Section 3 : Design situations	
(5)	Rules for bridges carrying both road and rail traffic

Section 4 : Road traffic actions and other actions specifically for road bridges	
4.1(1) NOTE 2	Road traffic actions for loaded lengths greater than 200m
4.1(2) NOTE 1	Specific load models for bridges with limitation of vehicle weight
4.2.1(1) NOTE 2	Definition of complementary load models
4.2.1(2)	Definition of models of special vehicles
4.2.3(1)	Conventional height of kerbs
4.3.1(2) NOTE 2	Use of LM2
4.3.2(3) NOTES 1 & 2	Values of α factors

4.3.2(6)	Use of simplified alternative load models
4.3.3(2)	Values of β factor
4.3.3(4) NOTE 2	Selection of wheel contact surface for LM2
4.3.4(1)	Definition of Load Model 3 (special vehicles)
4.4.1(2) NOTE 2	Upper limit of the braking force on road bridges
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Section 1 General

1.1 Scope

(1) EN 1991-2 defines imposed loads (models and representative values) associated with road traffic, pedestrian actions and rail traffic which include, when relevant, dynamic effects and centrifugal, braking and acceleration actions and actions for accidental design situations.

(2) Imposed loads defined in EN 1991-2 are intended to be used for the design of new bridges, including piers, abutments, upstand walls, wing walls and flank walls etc., and their foundations.

(3) The load models and values given in EN 1991-2 should be used for the design of retaining walls adjacent to roads and railway lines.

NOTE For some models only, applicability conditions are defined in EN 1991-2. For the design of buried structures, retaining walls and tunnels, provisions other than those in EN 1990 to EN 1999 may be necessary. Possible complementary conditions may be defined in the National Annex or for the individual project.

(4) EN 1991-2 is intended to be used in conjunction with EN 1990 (especially A2) and EN 1991 to EN 1999.

(5) Section 1 gives definitions and symbols.

(6) Section 2 defines loading principles for road bridges, footbridges (or cycle-track bridges) and railway bridges.

(7) Section 3 is concerned with design situations and gives guidance on simultaneity of traffic load models and on combinations with non-traffic actions.

(8) Section 4 defines :

- imposed loads (models and representative values) due to traffic actions on road bridges and their conditions of mutual combination and of combination with pedestrian and cycle traffic (see section 5) ;
- other actions specifically for the design of road bridges.

(9) Section 5 defines :

- imposed loads (models and representative values) on footways, cycle tracks and footbridges ;
- other actions specifically for the design of footbridges.

(10) Sections 4 and 5 also define loads transmitted to the structure by vehicle restraint systems and/or pedestrian parapets.

(11) Section 6 defines :

- imposed actions due to rail traffic on bridges ;
- other actions specifically for the design of railway bridges and structures adjacent to the railway.

1.2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications, are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1317	Road restraint systems Part 1 : Terminology and general criteria for test methods Part 2 : Performance classes, impact test acceptance criteria and test methods for safety barriers Part 6 : Pedestrian restraint systems, pedestrian parapetparpets
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NOTE The Eurocodes were published as European Prestandards. The following European Standards which are published or in preparation are cited in normative clauses or in NOTES to normative clauses :

EN 1990	Eurocode : Basis of Structural Design
EN 1991-1-1	Eurocode 1 : Actions on structures : Part 1-1 : General actions - Densities, self-weight imposed loads for buildings
EN 1991-1-3	Eurocode 1 : Actions on structures : Part 1-3 : General actions - Snow loads
prEN 1991-1-4	Eurocode 1 : Actions on structures : Part 1-4 : General actions - Wind actions
prEN 1991-1-5	Eurocode 1 : Actions on structures : Part 1-5 : General actions - Thermal actions
prEN 1991-1-6	Eurocode 1 : Actions on structures : Part 1-6 : General actions - Actions during execution
prEN 1991-1-7	Eurocode 1 : Actions on structures : Part 1-7 : General actions - Accidental actions
EN 1992	Eurocode 2 : Design of concrete structures
EN 1993	Eurocode 3 : Design of steel structures
EN 1994	Eurocode 4 : Design of composite steel and concrete structures
EN 1995	Eurocode 5 : Design of timber structures
EN 1997	Eurocode 7 : Geotechnical design
EN 1998	Eurocode 8 : Design of structures for earthquake resistance
EN 1999	Eurocode 9 : Design of aluminium structures

1.3 Distinction between Principles and Application Rules

(1) Depending on the character of the individual clauses, distinction is made in EN 1991-2 between Principles and Application Rules.

(2) The Principles comprise :

- general statements and definitions for which there is no alternative, as well as ;
- requirements and analytical models for which no alternative is permitted unless specifically stated.

(3) The Principles are identified by the letter P following the paragraph number.

(4) The Application Rules are generally recognised rules which comply with the Principles and satisfy their requirements.

(5) It is permissible to use alternative design rules different from the Application Rules given in EN 1991-2 for works, provided that it is shown that the alternative rules accord with the relevant Principles and are at least equivalent with regard to the structural safety, serviceability and durability which would be expected when using the Eurocodes.

NOTE If an alternative design rule is substituted for an Application Rule, the resulting design cannot be claimed to be wholly in accordance with EN 1991-2 although the design will remain in accordance with the Principles of EN 1991-2. When EN 1991-2 is used in respect of a property listed in an annex Z of a product standard or an ETAG⁵, the use of an alternative design rule may not be acceptable for CE marking.

(6) In EN 1991-2, the Application Rules are identified by a number in brackets *e.g.* as this clause.

1.4 Terms and definitions

NOTE 1 For the purposes of this European Standard, general definitions are provided in EN 1990 and additional definitions specific to this Part are given below.

NOTE 2 Terminology for road restraint systems is derived from EN 1317-1.

1.4.1 Harmonised terms and common definitions

1.4.1.1

deck

parts of a bridge which carry the traffic loading over piers, abutments and other walls, pylons being excluded

1.4.1.2

road restraint system

general name for vehicle restraint system and pedestrian restraint system used on the road

NOTE Road restraint systems may be, according to use :

- permanent (fixed) or temporary (demountable, *i.e.* they are removable and used during temporary road works, emergencies or similar situations),
- deformable or rigid,
- single-sided (they can be hit on one side only) or double-sided (they can be hit on either side).

⁵ ETAG : European Technical Approval Guideline

1.4.1.3

safety barrier

road vehicle restraint system installed alongside, or on the central reserve, of a road

1.4.1.4

vehicle parapet

safety barrier installed on the edge, or near the edge, of a bridge or on a retaining wall or similar structure where there is a vertical drop and which may include additional protection and restraint for pedestrians and other road users

1.4.1.5

pedestrian restraint system

system installed to retain and to provide guidance for pedestrians

1.4.1.6

pedestrian parapet

pedestrian or “other user” restraint system along a bridge or on top of a retaining wall or similar structure and which is not intended to act as a road vehicle restraint system

1.4.1.7

pedestrian guardrail

pedestrian or “other user” restraint system along the edge of a footway or footpath intended to restrain pedestrians and other users from stepping onto or crossing a road or other area likely to be hazardous

NOTE “Other user” may include provision for equestrians, cyclists and cattle.

1.4.1.8

noise barrier

screen to reduce transmission of noise

1.4.1.9

inspection gangway

permanent access for inspection, not open for public traffic

1.4.1.10

movable inspection platform

part of a vehicle, distinct from the bridge, used for inspection

1.4.1.11

footbridge

bridge intended mainly to carry pedestrian and/or cycle-track loads, and on which neither road traffic loads, except those permitted vehicles *e.g.* maintenance vehicles, nor any railway load are permitted

1.4.2 Terms and definitions specifically for road bridges

1.4.2.1

carriageway

for application of sections 4 and 5, the part of the road surface, supported by a single structure (deck, pier, etc.), which includes all physical traffic lanes (*i.e.* as may be marked on the road surface), hard shoulders, hard strips and marker strips (see 4.2.3(1))

1.4.2.2

hard shoulder

surfaced strip, usually of one traffic lane width, adjacent to the outermost physical traffic lane, intended for use by vehicles in the event of difficulty or during obstruction of the physical traffic lanes

1.4.2.3

hard strip

surfaced strip, usually less than or equal to 2 m wide, located alongside a physical traffic lane, and between this traffic lane and a safety barrier or vehicle parapet

1.4.2.4

central reservation

area separating the physical traffic lanes of a dual-carriageway road. It generally includes a median strip and lateral hard strips separated from the median strip by safety barriers.

1.4.2.5

notional lane

strip of the carriageway, parallel to an edge of the carriageway, which in section 4 is deemed to carry a line of cars and/or lorries

1.4.2.6

remaining area

difference, where relevant, between the total area of the carriageway and the sum of the areas of the notional lanes (see Figure 4.1)

1.4.2.7

tandem system

assembly of two consecutive axles considered to be simultaneously loaded

1.4.2.8

abnormal load

vehicle load which may not be carried on a route without permission from the relevant authority

1.4.3 Terms and definitions specifically for railway bridges

1.4.3.1

tracks

tracks include rails and sleepers. They are laid on a ballast bed or are directly fastened to the decks of bridges. The tracks may be equipped with expansion joints at one end or both ends of a deck. The position of tracks and the depth of ballast may be modified during the lifetime of bridges, for the maintenance of tracks.

1.4.3.2

footpath

strip located alongside the tracks, between the tracks and the parapets

1.4.3.3

resonant speed

traffic speed at which a frequency of loading (or a multiple of) matches a natural frequency of the structure (or a multiple of)

1.4.3.4

frequent operating speed

most probable speed at the site for a particular type of Real Train (used for fatigue considerations)

1.4.3.5

maximum line speed at the site

maximum permitted speed of traffic at the site specified for the individual project (generally limited by characteristics of the infrastructure or railway operating safety requirements)

1.4.3.6

maximum permitted vehicle speed

maximum permitted speed of Real Trains due to vehicle considerations and generally independent of the infrastructure

1.4.3.7

maximum nominal speed

generally the Maximum Line Speed at the Site. Where specified for the individual project, a reduced speed may be used for checking individual Real Trains for their associated maximum permitted vehicle speed.

1.4.3.8

maximum design speed

generally $1,2 \times$ Maximum Nominal Speed

1.4.3.9

maximum train commissioning speed

maximum speed used for testing a new train before the new train is brought into operational service and for special tests etc. The speed generally exceeds the Maximum Permitted Vehicle Speed and the appropriate requirements are to be specified for the individual project.

1.5 Symbols

For the purposes of this European Standard, the following symbols apply.

1.5.1 Common symbols

NOTE Symbols used in one place only are not systematically repeated below.

Latin upper case letters

L In general, loaded length

Latin lower case letters

gri Group of loads, i is a number ($i = 1$ to n)
 r Horizontal radius of a carriageway or track centre-line, distance between wheel loads (Figure 6.3)

1.5.2 Symbols specifically for sections 4 and 5

Latin upper case letters

Q_{ak} Characteristic value of a single axle load (Load Model 2) for a road bridge (see 4.3.3)
 Q_{flk} Characteristic horizontal force on a footbridge
 Q_{fwk} Characteristic value of the concentrated load (wheel load) on a footbridge (see 5.3.2.2)
 Q_{ik} Magnitude of characteristic axle load (Load Model 1) on notional lane number i ($i = 1, 2, \dots$) of a road bridge
 Q_{lk} Magnitude of the characteristic longitudinal forces (braking and acceleration forces) on a road bridge
 Q_{serv} Load model corresponding to a service vehicle for footbridges
 Q_{tk} Magnitude of the characteristic transverse or centrifugal forces on road bridges
 Q_{trk} Transverse braking force on road bridges
 TS Tandem system for Load Model 1
 UDL Uniformly distributed load for Load Model 1

Latin lower case letters

f_h	In general, natural horizontal frequency of a bridge
f_v	In general, natural vertical frequency of a bridge
n_1	Number of notional lanes for a road bridge
q_{eq}	Equivalent uniformly distributed load for axle loads on embankments (see 4.9.1)
q_{fk}	Characteristic vertical uniformly distributed load on footways or footbridges
q_{ik}	Magnitude of the characteristic vertical distributed load (Load Model 1) on notional lane number i ($i = 1, 2, \dots$) of a road bridge
q_{rk}	Magnitude of the characteristic vertical distributed load on the remaining area of the carriageway (Load Model 1)
w	Carriageway width for a road bridge, including hard shoulders, hard strips and marker strips (see 4.2.3(1))
w_1	Width of a notional lane for a road bridge

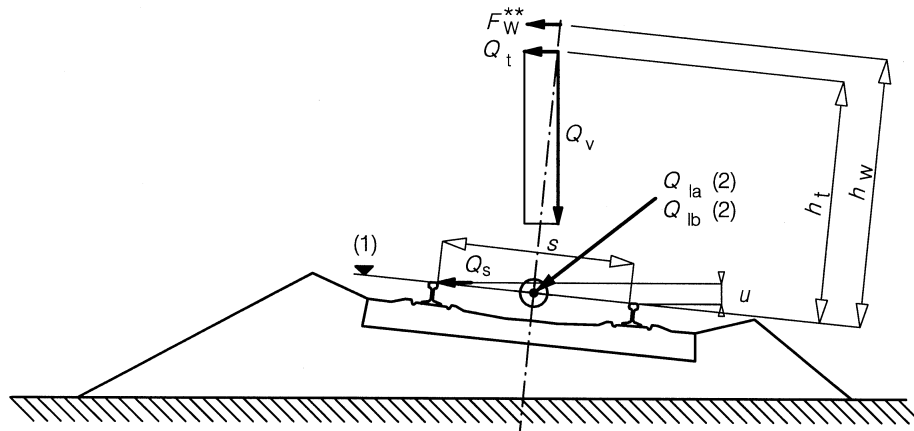
Greek upper case letters

$\Delta\phi_{fat}$	Additional dynamic amplification factor for fatigue near expansion joints (see 4.6.1(6))
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Greek lower case letters

α_{Qi}, α_{qi}	adjustment factors of some load models on lanes i ($i = 1, 2, \dots$), defined in 4.3.2
α_{qr}	Adjustment factor of load models on the remaining area, defined in 4.3.2
β_Q	Adjustment factor of Load Model 2 defined in 4.3.3
ϕ_{fat}	Dynamic amplification factor for fatigue (see annex B)

1.5.3 Symbols specifically for section 6



Key

- (1) Running surface
- (2) Longitudinal forces acting along the centreline of the track

Figure 1.1 - Notation and dimensions specifically for railways

Latin upper case letters

$A_{(L/\lambda)}G_{(\lambda)}$	Aggressivity (see Equations E.4 and E.5)
D	Coach or vehicle length
D_{IC}	Intermediate coach length for a Regular Train with one axle per coach
E_{cm}	Secant modulus of elasticity of normal weight concrete
F_L	Total longitudinal support reaction
F_{Qk}	Characteristic longitudinal force per track on the fixed bearings due to deformation of the deck
F_{Tk}	Longitudinal force on a fixed bearing due to the combined response of track and structure to temperature
F_W^{**}	Wind force compatible with rail traffic
F_{li}	Individual longitudinal support reaction corresponding to the action i
G	Self-weight (general)
H	Height between (horizontal) axis of rotation of the (fixed) bearing and the upper surface of the deck (underside of ballast beneath tracks)
K	Total longitudinal support stiffness
K_2	Longitudinal support stiffness per track per m, 2E3 kN/m
K_5	Longitudinal support stiffness per track per m, 5E3 kN/m
K_{20}	Longitudinal support stiffness per track per m, 20E3 kN/m
L	Length (general)
L_T	Expansion length
L_{TP}	Maximum permissible expansion length
L_f	Influence length of the loaded part of curved track
L_i	Influence length
L_Φ	"determinant" length (length associated with Φ)

M	Number of point forces in a train
N	Number of regularly repeating coaches or vehicles, or number of axles, or number of equal point forces
P	Point force Individual axle load
Q	Concentrated force or variable action (general)
Q_{A1d}	Point load for derailment loading
Q_h	Horizontal force (general)
Q_k	Characteristic value of a concentrated force or a variable action (<i>e.g.</i> characteristic value of a vertical loading on a non-public footpath)
Q_{lak}	Characteristic value of traction force
Q_{lbk}	Characteristic value of braking force
Q_r	Rail traffic action (general, <i>e.g.</i> resultant of wind and centrifugal force)
Q_{sk}	Characteristic value of nosing force
Q_{tk}	Characteristic value of centrifugal force
Q_v	Vertical axle load
Q_{vi}	Wheel load
Q_{vk}	Characteristic value of vertical load (concentrated load)
ΔT	Temperature variation
ΔT_D	Temperature variation of the deck
ΔT_N	Temperature variation
ΔT_R	Temperature variation of the rail
V	Speed in km/h Maximum Line Speed at the Site in km/h
X_i	Length of sub-train consisting of i axles

Latin lower case letters

a	Distance between rail supports, length of distributed loads (Load Models SW/0 and SW/2)
a_g	Horizontal distance to the track centre
a'_g	Equivalent horizontal distance to the track centre
b	Length of the longitudinal distribution of a load by a sleeper and ballast
c	Space between distributed loads (Load Models SW/0 and SW/2)
d	Regular spacing of groups of axles Spacing of axles within a bogie Spacing of point forces in HSLM-B
d_{BA}	Spacing of axles within a bogie
d_{BS}	Spacing between centres of adjacent bogies
e	Eccentricity of vertical loads, eccentricity of resulting action (on reference plane)
e_c	Distance between adjacent axles across the coupling of two individual regular trainsets
f	Reduction factor for centrifugal force
$f_{ck}, f_{ck, cube}$	Concrete compressive cylinder/ cube strength
g	Acceleration due to gravity

h	Height (general) Height of cover including ballast from the top of the deck to the top of a sleeper
h_g	Vertical distance from the running surface to the underside of the structure above the track
h_t	Height of centrifugal force over the running surface
h_w	Height of wind force over the running surface
k	Longitudinal plastic shear resistance of the track
k_1	Train shape coefficient
k_2	Multiplication factor for slipstream actions on vertical surfaces parallel to the tracks
k_3	Reduction factor for slipstream actions on simple horizontal surfaces adjacent to the track
k_4	Multiplication factor for slipstream actions on surfaces enclosing the tracks (horizontal actions)
k_5	Multiplication factor for slipstream actions on surfaces enclosing the tracks (vertical actions)
k_{20}	Longitudinal plastic shear resistance of track, 20kN per m of track
k_{40}	Longitudinal plastic shear resistance of track, 40kN per m of track
k_{60}	Longitudinal plastic shear resistance of track, 60kN per m of track
n_0	First natural bending frequency of the unloaded structure
n_T	First natural torsional frequency of the structure
q_{A1d}, q_{A2d}	Distributed loading for derailment loading
q_{fk}	Characteristic value of vertical loading on non-public footpath (uniformly distributed load)
q_{ik}	Characteristic value of equivalent distributed aerodynamic action
q_{lak}	Characteristic value of distributed traction force
q_{lbk}	Characteristic value of distributed braking force
q_{tk}	Characteristic value of distributed centrifugal force
q_{v1}, q_{v2}	Vertical load (uniformly distributed load)
q_{vk}	Characteristic value of vertical load (uniformly distributed load)
r	Radius of track curvature
	Transverse distance between wheel loads
s	Gauge
u	Cant, relative vertical distance between the uppermost surface of the two rails at a particular location along the track
v	Maximum Nominal Speed in m/s Maximum Permitted Vehicle Speed in m/s Speed in m/s
v_{DS}	Maximum Design Speed in m/s
v_i	Resonant speed in m/s
y_{dyn}, y_{stat}	Maximum dynamic response and maximum corresponding static response at any particular point

Greek upper case letters

Θ	End rotation of structure (general)
$\Phi(\Phi_2, \Phi_3)$	Dynamic factor for railway Load Models 71, SW/0 and SW/2

Greek lower case letters

α	Load classification factor Coefficient for speed Linear temperature coefficient for thermal expansion
β	Ratio of the distance between the neutral axis and the surface of the deck relative to height H
δ	Deformation (general) Vertical deflection
δ_0	Deflection at midspan due to permanent actions
δ_B	Longitudinal relative displacement at the end of the deck due to traction and braking
δ_H	Longitudinal relative displacement at the end of the deck due to deformation of the deck
δ_h	Horizontal displacement Horizontal displacement due to the longitudinal displacement of the foundations of the substructure
δ_p	Horizontal displacement due to the longitudinal deformation of the substructure
δ_v	Vertical relative displacement at the end of the deck
δ_φ	Horizontal displacement due to longitudinal rotation of foundation
γ_{Ff}	Partial safety factor for fatigue loading
γ_{Mf}	Partial safety factor for fatigue strength
$\varphi, \varphi', \varphi''$	Dynamic enhancement of static loading for Real Trains
φ'_{dyn}	Dynamic enhancement of static loading for a Real Train determined from a dynamic analysis
κ	Coefficient relating to the stiffness of an abutment relative to the piers
λ	Damage equivalent factor for fatigue Excitation wavelength
λ_C	Critical wavelength of excitation
λ_i	Principal wavelength of excitation
λ_v	Wavelength of excitation at the Maximum Design Speed
ρ	Density
σ	Stress
$\sigma_A, \sigma_B,$	Pressure on the upper surface of the deck from rail traffic actions
σ_M	
$\Delta\sigma_{71}$	Stress range due to the Load Model 71 (and where required SW/0)
$\Delta\sigma_C$	Reference value of fatigue strength
ξ	Reduction factor for the determination of the longitudinal forces in the fixed bearings of one-piece decks due to traction and braking
ζ	Lower limit of percentage of critical damping (%), or damping ratio
ζ_{TOTAL}	Total damping (%)
$\Delta\zeta$	Additional damping (%)

Section 2 Classification of actions

2.1 General

- (1) The relevant traffic actions and other specific actions on bridges should be classified in accordance with EN 1990, section 4 (4.1.1).
- (2) Traffic actions on road bridges, footbridges and railway bridges consist of variable actions and actions for accidental design situations, which are represented by various models.
- (3) All traffic actions should be classified as free actions within the limits specified in sections 4 to 6.
- (4) Traffic actions are multi-component actions.

2.2 Variable actions

- (1) For normal conditions of use (*i.e.* excluding any accidental situation), the traffic and pedestrian loads (dynamic amplification included where relevant) should be considered as variable actions.
- (2) The various representative values are :
 - characteristic values, which are either statistical, *i.e.* corresponding to a limited probability of being exceeded on a bridge during its design working life, or nominal, see EN 1990, 4.1.2(7) ;
 - frequent values ;
 - quasi-permanent values.

NOTE 1 In Table 2.1, some information is given on the bases for the calibration of the main Load Models (fatigue excluded) for road bridges and footbridges. Rail loading and the associated γ and ψ factors have been developed using Method (a) in Figure C.1 of EN 1990.

Table 2.1 – Bases for the calibration of the main Load Models (fatigue excluded)

Traffic Load Models	Characteristic values	Frequent values	Quasi-permanent values
Road bridges			
LM1 (4.3.2)	1000 year return period (or probability of exceedance of 5% in 50 years) for traffic on the main roads in Europe (α factors equal to 1, see 4.3.2).	1 week return period for traffic on the main roads in Europe (α factors equal to 1, see 4.3.2).	Calibration in accordance with definition given in EN 1990.
LM2 (4.3.3)	1000 year return period (or probability of exceedance of 5% in 50 years) for traffic on the main roads in Europe (β factor equal to 1, see 4.3.3).	1 week return period for traffic on the main roads in Europe (β factor equal to 1, see 4.3.3).	Not relevant
LM3 (4.3.4)	Set of nominal values. Basic values defined in annex A are derived from a synthesis based on various national regulations.	Not relevant	Not relevant
LM4 (4.3.5)	Nominal value deemed to represent the effects of a crowd. Defined with reference to existing national standards.	Not relevant	Not relevant
Footbridges			
Uniformly distributed load (5.3.2.1)	Nominal value deemed to represent the effects of a crowd. Defined with reference to existing national standards.	Equivalent static force calibrated on the basis of 2 pedestrians/m ² (in the absence of particular dynamic behaviour). It can be considered, for footbridges in urban areas, as a load of 1 week return period.	Calibration in accordance with definition given in EN 1990.
Concentrated load (5.3.2.2)	Nominal value. Defined with reference to existing national standards.	Not relevant	Not relevant
Service vehicle (5.3.2.3)	Nominal value. As specified or given in 5.6.3.	Not relevant	Not relevant

NOTE 2 For road bridges, the National Annex may impose the use of infrequent values which are intended to correspond approximately to a mean return period of one year for traffic on the main roads in Europe. See also EN 1992-2, EN1994-2 and EN 1990, A2.

(3) For calculation of fatigue lives, separate models, associated values and, where relevant, specific requirements are given in 4.6 for road bridges, in 6.9 for railway bridges, and in the relevant annexes.

2.3 Actions for accidental design situations

(1) Road vehicles and trains may generate actions due to collision, or their accidental presence or location. These actions should be considered for the structural design where appropriate protection is not provided.

NOTE Appropriate protection may be defined in the National Annex or for the individual project.

(2) Actions for accidental design situations described in this Part of EN 1991 refer to common situations. They are represented by various load models defining design values in the form of static equivalent loads.

(3) For actions due to road vehicles under road bridges, footbridges and railway bridges during accidental design situations, see **AC1** 4.7.2, 5.6.2 and 6.7.2 **AC1**.

(4) Collision forces due to boats, ships or aeroplanes, for road bridges, footbridges and railway bridges (*e.g.* over canals and navigable water), should be defined where appropriate.

NOTE The National Annex may define the collision forces. Recommended values for boat and ship impacts are given in EN 1991-1-7. Additional requirements may be specified for the individual project.

(5) Actions for accidental design situations due to road vehicles on road bridges and footbridges are defined in 4.7.3 and 5.6.3 respectively.

(6) Actions for accidental design situations due to trains or railway infrastructure are defined in 6.7. They are applicable where relevant to road bridges, footbridges and railway bridges.

Section 3 Design situations

(1)P Selected design situations shall be taken into account and critical load cases identified. For each critical load case, the design values of the effects of actions in combination shall be determined.

NOTE For bridges for which signalling is used to limit the weight of vehicles, an accidental design situation may have to be taken into account, corresponding to the crossing of the bridge by one vehicle in breach of warnings.

(2) The various traffic loads to be taken into account as simultaneous when using groups of loads (combinations of action components) are given in the following sections ; each of which should be considered in design calculations, where relevant.

(3)P The combination rules, depending on the calculation to be undertaken, shall be in accordance with EN 1990.

NOTE For seismic combinations for bridges and associated rules, see EN 1998-2.

(4) Specific rules for the simultaneity with other actions for road bridges, footbridges, and railway bridges are given in EN 1990, A2.

(5) For bridges intended for both road and rail traffic, the simultaneity of actions and the particular required verifications should be specified.

NOTE The particular rules may be defined in the National Annex or for the individual project.

Section 4 Road traffic actions and other actions specifically for road bridges

4.1 Field of application

(1) Load models defined in this section should be used for the design of road bridges with loaded lengths less than 200 m.

NOTE 1 200 m corresponds to the maximum length taken into account for the calibration of Load Model 1 (see 4.3.2). In general, the use of Load Model 1 is safe-sided for loaded lengths over 200 m.

NOTE 2 Load models for loaded lengths greater than 200 m may be defined in the National Annex or for the individual project.

(2) The models and associated rules are intended to cover all normally foreseeable traffic situations (*i.e.* traffic conditions in either direction on any lane due to the road traffic) to be taken into account for design (see however (3) and the notes in 4.2.1).

NOTE 1 Specific models may be defined in the National Annex or for the individual project to be used for bridges equipped with appropriate means including road signs intended to strictly limit the weight of any vehicle (*e.g.* for local, agricultural or private roads).

NOTE 2 Load models for abutments and walls adjacent to bridges are defined separately (see 4.9). They derive from the road traffic models without any correction for dynamic effects. For frame bridges, loads on road embankments may also give rise to action effects in the bridge structure.

(3) The effects of loads on road construction sites (*e.g.* due to scrapers, lorries carrying earth, etc.) or of loads specifically for inspection and tests are not intended to be covered by the load models and should be separately specified, where relevant.

4.2 Representation of actions

4.2.1 Models of road traffic loads

(1) Loads due to the road traffic, consisting of cars, lorries and special vehicles (*e.g.* for industrial transport), give rise to vertical and horizontal, static and dynamic forces.

NOTE 1 The load models defined in this section do not describe actual loads. They have been selected and calibrated so that their effects (with dynamic amplification included where indicated) represent the effects of the actual traffic in the year 2000 in European countries.

NOTE 2 The National Annex may define complementary load models, with associated combination rules where traffic outside the scope of the load models specified in this section needs to be considered.

NOTE 3 The dynamic amplification included in the models (fatigue excepted), although established for a medium pavement quality (see annex B) and pneumatic vehicle suspension, depends on various parameters and on the action effect under consideration. Therefore, it cannot be represented by a unique factor. In some unfavourable cases, it may reach 1,7 (local effects), but still more unfavourable values can be reached for poorer pavement quality, or if there is a risk of resonance. These cases can be avoided by appropriate quality and design measures. Therefore, an additional dynamic amplification may have to be taken into account for particular calculations (see 4.6.1.(6)) or for the individual project.

(2) Where vehicles which do not comply with National regulations concerning limits of weights and, possibly, dimensions of vehicles not requiring special permits, or military loads, have to be taken into account for the design of a bridge, they should be defined.

NOTE The National Annex may define these models. Guidance on standard models for special vehicles and their application is given in annex A. See 4.3.4.

4.2.2 Loading classes

(1) The actual loads on road bridges result from various categories of vehicles and from pedestrians.

(2) Vehicle traffic may differ between bridges depending on its composition (*e.g.* percentages of lorries), its density (*e.g.* average number of vehicles per year), its conditions (*e.g.* jam frequency), the extreme likely weights of vehicles and their axle loads, and, if relevant, the influence of road signs restricting carrying capacity.

These differences should be taken into account through the use of load models suited to the location of a bridge (*e.g.* choice of adjustment factors α and β defined in 4.3.2 for Load Model 1 and in 4.3.3 for Load Model 2 respectively).

4.2.3 Divisions of the carriageway into notional lanes

(1) The carriageway width, w , should be measured between kerbs or between the inner limits of vehicle restraint systems, and should not include the distance between fixed vehicle restraint systems or kerbs of a central reservation nor the widths of these vehicle restraint systems.

NOTE The National Annex may define the minimum value of the height of the kerbs to be taken into account. The recommended minimum value of this height is 100 mm.

(2) The width w_l of notional lanes on a carriageway and the greatest possible whole (integer) number n_l of such lanes on this carriageway are defined in Table 4.1.

Table 4.1 - Number and width of notional lanes

Carriageway width w	Number of notional lanes	Width of a notional lane w_l	Width of the remaining area
$w < 5,4$ m	$n_l = 1$	3 m	$w - 3$ m
$5,4 \text{ m} \leq w < 6$ m	$n_l = 2$	$\frac{w}{2}$	0
$6 \text{ m} \leq w$	$n_l = \text{Int}\left(\frac{w}{3}\right)$	3 m	$w - 3 \times n_l$
NOTE For example, for a carriageway width equal to 11m, $n_l = \text{Int}\left(\frac{w}{3}\right) = 3$, and the width of the remaining area is $11 - 3 \times 3 = 2$ m.			

(3) For variable carriageway widths, the number of notional lanes should be defined in accordance with the principles used for Table 4.1.

NOTE For example, the number of notional lanes will be :

- 1 where $w < 5,4$ m
- 2 where $5,4 \leq w < 9$ m
- 3 where $9 \leq w < 12$ m, etc.

(4) Where the carriageway on a bridge deck is physically divided into two parts separated by a central reservation, then :

- (a) each part, including all hard shoulders or strips, should be separately divided into notional lanes if the parts are separated by a permanent road restraint system ;
- (b) the whole carriageway, central reservation included, should be divided into notional lanes if the parts are separated by a temporary road restraint system.

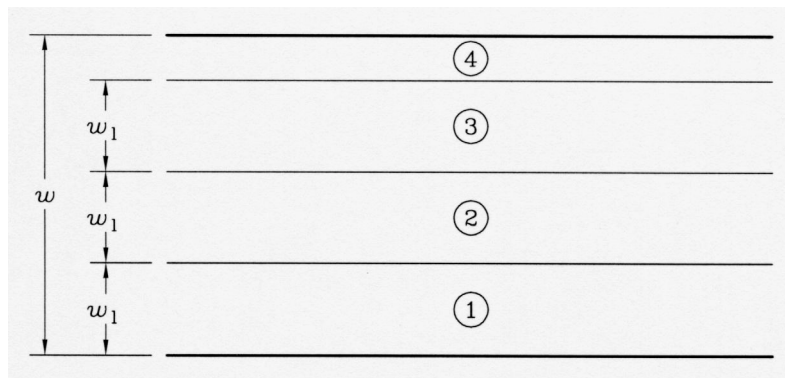
NOTE The rules given in 4.2.3(4) may be adjusted for the individual project, allowing for envisaged future modifications of the traffic lanes on the deck, *e.g.* for repair.

4.2.4 Location and numbering of the lanes for design

The location and numbering of the lanes should be determined in accordance with the following rules :

- (1) The locations of notional lanes should not be necessarily related to their numbering.
- (2) For each individual verification (*e.g.* for a verification of the ultimate limit state of resistance of a cross-section to bending), the number of lanes to be taken into account as loaded, their location on the carriageway and their numbering should be so chosen that the effects from the load models are the most adverse.
- (3) For fatigue representative values and models, the location and the numbering of the lanes should be selected depending on the traffic to be expected in normal conditions.

(4) The lane giving the most unfavourable effect is numbered Lane Number 1, the lane giving the second most unfavourable effect is numbered Lane Number 2, etc. (see Figure 4.1).



Key

- w Carriageway width
- w_1 Notional lane width
- 1 Notional Lane Nr. 1
- 2 Notional Lane Nr. 2
- 3 Notional Lane Nr. 3
- 4 Remaining area

Figure 4.1 - Example of the Lane Numbering in the most general case

(5) Where the carriageway consists of two separate parts on the same deck, only one numbering should be used for the whole carriageway.

NOTE Hence, even if the carriageway is divided into two separate parts, there is only one Lane Number 1, which can $\boxed{AC_1}$ be considered alternatively $\langle AC_1 \rangle$ on the two parts.

(6) Where the carriageway consists of two separate parts on two independent decks, each part should be considered as a carriageway. Separate numbering should then be used for the design of each deck. If the two decks are supported by the same piers and/or abutments, there should be one numbering for the two parts together for the design of the piers and/or the abutments.

4.2.5 Application of the load models on the individual lanes

(1) For each individual verification, the load models, on each notional lane, should be applied on such a length and so longitudinally located that the most adverse effect is obtained, as far as this is compatible with the conditions of application defined below for each particular model.

(2) On the remaining area, the associated load model should be applied on such lengths and widths in order to obtain the most adverse effect, as far as this is compatible with particular conditions specified in 4.3.

(3) When relevant, the various load models should be combined together (see 4.5) and with models for pedestrian or cycle loads.

4.3 Vertical loads - Characteristic values

4.3.1 General and associated design situations

(1) Characteristic loads are intended for the determination of road traffic effects associated with ultimate limit state verifications and with particular serviceability verifications (see EN 1990 to EN 1999).

(2) The load models for vertical loads represent the following traffic effects :

a) Load Model 1 (LM1) : Concentrated and uniformly distributed loads, which cover most of the effects of the traffic of lorries and cars. This model should be used for general and local verifications.

b) Load Model 2 (LM2) : A single axle load applied on specific tyre contact areas which covers the dynamic effects of the normal traffic on short structural members.

NOTE 1 As an order of magnitude, LM2 can be predominant in the range of loaded lengths up to 3m to 7m.

NOTE 2 The use of LM2 may be further defined in the National Annex.

c) Load Model 3 (LM3) : A set of assemblies of axle loads representing special vehicles (*e.g.* for industrial transport) which can travel on routes permitted for abnormal loads. It is intended for general and local verifications.

d) Load Model 4 (LM4) : A crowd loading, intended only for general verifications.

NOTE This crowd loading is particularly relevant for bridges located in or near towns if its effects are not covered by Load Model 1.

(3) Load Models 1, 2 and 3, where relevant, should be taken into account for any type of design situation (*e.g.* for transient situations during repair works).

(4) Load Model 4 should be used only for some transient design situations.

4.3.2 Load Model 1

(1) Load Model 1 consists of two partial systems :

(a) Double-axle concentrated loads (tandem system : TS), each axle having the following weight :

$$\alpha_Q Q_k \quad (4.1)$$

where :

α_Q are adjustment factors.

- No more than one tandem system should be taken into account per notional lane.
- Only complete tandem systems should be taken into account.

- For the assessment of general effects, each tandem system should be assumed to travel centrally along the axes of notional lanes (see (5) below for local verifications and Figure 4.2b).
- Each axle of the tandem system should be taken into account with two identical wheels, the load per wheel being therefore equal to $0,5\alpha_Q Q_k$.
- The contact surface of each wheel should be taken as square and of side 0,40 m (see Figure 4.2b).

(b) Uniformly distributed loads (UDL system), having the following weight per square metre of notional lane :

$$\alpha_q q_k \quad (4.2)$$

where :

α_q are adjustment factors.

The uniformly distributed loads should be applied only in the unfavourable parts of the influence surface, longitudinally and transversally.

NOTE LM1 is intended to cover flowing, congested or traffic jam situations with a high percentage of heavy lorries. In general, when used with the basic values, it covers the effects of a special vehicle of 600 kN as defined in annex A.

(2) Load Model 1 should be applied on each notional lane and on the remaining areas. On notional lane Number i , the load magnitudes are referred to as $\alpha_{Qi} Q_{ik}$ and $\alpha_{qi} q_{ik}$ (see Table 4.2). On the remaining areas, the load magnitude is referred to as $\alpha_{qr} q_{rk}$.

(3) The values of adjustment factors α_{Qi} , α_{qi} and α_{qr} should be selected depending on the expected traffic and possibly on different classes of routes. In the absence of specification these factors should be taken equal to unity.

NOTE 1 The values of α_{Qi} , α_{qi} and α_{qr} factors are given in the National Annex. In all cases, for bridges without road signs restricting vehicle weights, the following minimum values are recommended :

$$\alpha_{Qi} \geq 0,8 \quad \text{and} \quad (4.3)$$

$$\text{for : } i \geq 2, \alpha_{qi} \geq 1 ; \text{ this restriction being not applicable to } \alpha_{qr}. \quad (4.4)$$

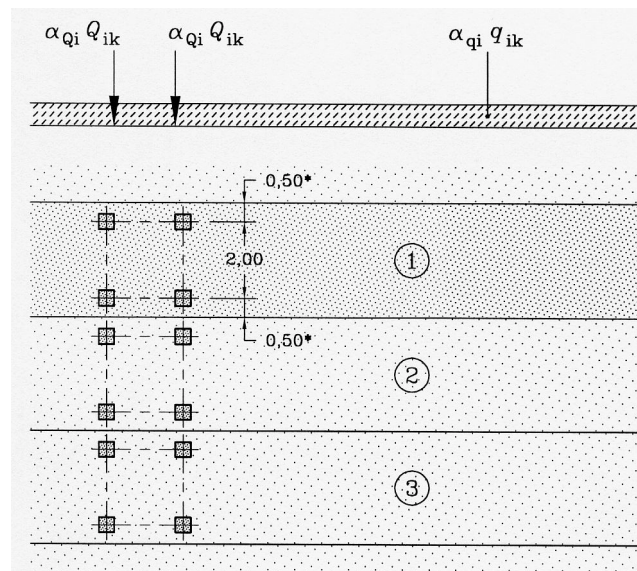
NOTE 2 Values of α factors may correspond, in the National Annex, to classes of traffic. When they are taken equal to 1, they correspond to a traffic for which a heavy industrial international traffic is expected, representing a large part of the total traffic of heavy vehicles. For more common traffic compositions (highways or motorways), a moderate reduction of α factors applied to tandems systems and the uniformly distributed loads on Lane 1 may be applied (10 to 20%).

(4) The characteristic values of Q_{ik} and q_{ik} , dynamic amplification included, should be taken from Table 4.2.

Table 4.2 - Load model 1 : characteristic values

Location	Tandem system <i>TS</i>	<i>UDL</i> system
	Axle loads Q_{ik} (kN)	$\alpha_{q1} q_{ik}$ (or q_{rk}) (kN/m ²) α_{q1}
Lane Number 1	300	9
Lane Number 2	200	2,5
Lane Number 3	100	2,5
Other lanes	0	2,5
Remaining area (q_{rk})	0	2,5

The details of Load Model 1 are illustrated in Figure 4.2a.



Key

- (1) Lane Nr. 1 : $Q_{1k} = 300$ kN ; $q_{1k} = 9$ kN/m²
- (2) Lane Nr. 2 : $Q_{2k} = 200$ kN ; $q_{2k} = 2,5$ kN/m²
- (3) Lane Nr. 3 : $Q_{3k} = 100$ kN ; $q_{3k} = 2,5$ kN/m²

α_{q1} Tandem axle spacing = 1,2 m α_{q1}

* For $w_l = 3,00$ m

Figure 4.2a - Application of load Model 1

NOTE The application of 4.2.4-(2) and 4.3.2-(1) to (4) practically consists, for this model, of choosing the locations of the numbered lanes and the locations of the tandem systems (in most cases in the same cross-section). The length and width to be loaded by UDL are those of the relevant adverse parts of the influence surfaces.

(5) For local verifications, a tandem system should be applied at the most unfavourable location. Where two tandem systems on adjacent notional lanes are taken into account, they may be brought closer, with a distance between wheel axles not below 0,50 m (see Figure 4.2b).

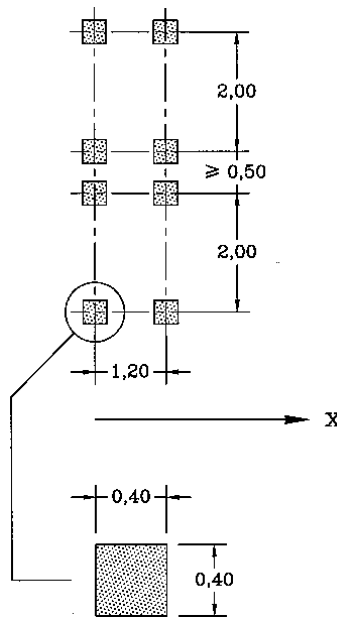


Figure 4.2b - Application of tandem systems for local verifications

(6) Where general and local effects can be calculated separately, the general effects may be calculated by using the following simplified alternative rules :

NOTE The National Annex may define the conditions of use of these alternative rules.

- a) the second and third tandem systems are replaced by a second tandem system with axle weight equal to :

$$(200 \alpha_{Q2} + 100 \alpha_{Q3}) \text{ kN, or} \quad (4.5)$$

- b) for span lengths greater than 10 m, each tandem system are replaced in each lane by a one-axle concentrated load of weight equal to the total weight of the two axles.

NOTE In that case, the single axle weight is :

- 600 α_{Q1} kN on Lane Number 1
- 400 α_{Q2} kN on Lane Number 2
- 200 α_{Q3} kN on Lane Number 3

4.3.3 Load Model 2

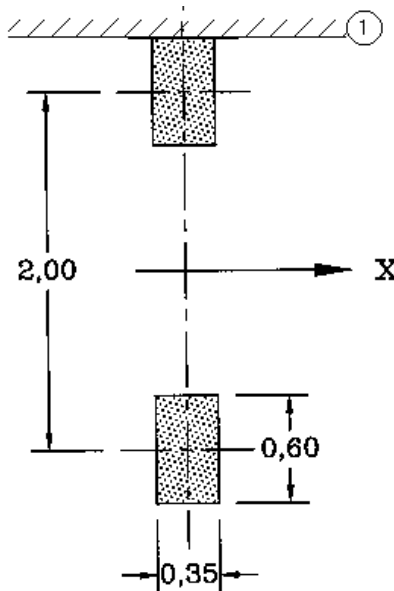
(1) Load Model 2 consists of a single axle load $\beta_Q Q_{ak}$ with Q_{ak} equal to 400 kN, dynamic amplification included, which should be applied at any location on the carriageway. However, when relevant, only one wheel of 200 β_Q (kN) may be taken into account.

(2) The value of β_Q should be specified.

NOTE The National Annex may give the value of β_Q . It is recommended that $\beta_Q = \alpha_{Q1}$.

(3) In the vicinity of expansion joints, an additional dynamic amplification factor equal to the value defined in 4.6.1(6) should be applied.

(4) The contact surface of each wheel should be taken into account as a rectangle of sides 0,35 m and 0,60 m (see Figure 4.3).



Key

X Bridge longitudinal axis direction

1 Kerb

Figure 4.3 - Load Model 2

NOTE 1 The contact areas of Load Models 1 and 2 are different, and correspond to different tyre models, arrangements and pressure distributions. The contact areas of Load Model 2, corresponding to twin tyres, are normally relevant for orthotropic decks.

NOTE 2 For simplicity, the National Annex may adopt the same square contact surface for the wheels of Load Models 1 and 2.

4.3.4 Load Model 3 (special vehicles)

(1) Where relevant, models of special vehicles should be defined and taken into account.

NOTE The National Annex may define Load Model 3 and its conditions of use. Annex A gives guidance on standard models and their conditions of application.

4.3.5 Load Model 4 (crowd loading)

(1) Crowd loading, if relevant, should be represented by a Load Model consisting of a uniformly distributed load (which includes dynamic amplification) equal to 5 kN/m².

NOTE The application of LM4 may be defined for the individual project.

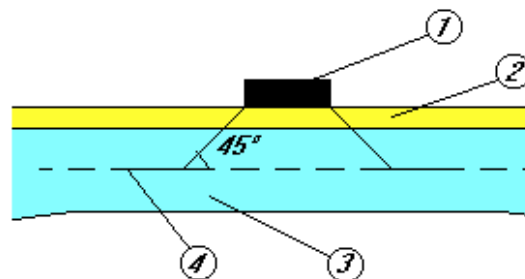
(2) Load Model 4 should be applied on the relevant parts of the length and width of the road bridge deck, the central reservation being included where relevant. This loading system, intended for general verifications, should be associated only with a transient design situation.

4.3.6 Dispersal of concentrated loads

(1) The various concentrated loads to be considered for local verifications, associated with Load Models 1 and 2, should be taken as uniformly distributed on their whole contact area.

(2) The dispersal through the pavement and concrete slabs should be taken at a spread-to-depth ratio of 1 horizontally to 1 vertically down to the level of the centroid of the slab (Figure 4.4).

NOTE In the case of dispersal through backfill or earth, see the NOTES in 4.9.1.



- Key**
- 1 Wheel contact pressure
 - 2 Pavement
 - 3 Concrete slab
 - 4 Middle surface of concrete slab

Figure 4.4 - Dispersal of concentrated loads through pavement and a concrete slab

(3) The dispersal through the pavement and orthotropic decks should be taken at a spread-to-depth ratio of 1 horizontally to 1 vertically down to the level of the middle plane of the structural top plate (Figure 4.5).

NOTE The transverse distribution of the load among the ribs of the orthotropic deck is not considered here.

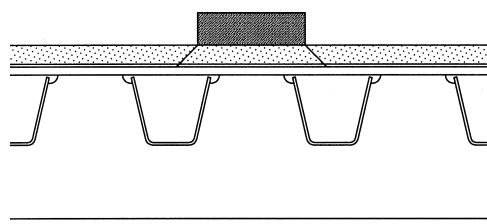


Figure 4.5 - Dispersal of concentrated loads through pavement and orthotropic decks

4.4 Horizontal forces - Characteristic values

4.4.1 Braking and acceleration forces

(1)P A braking force, Q_{lk} , shall be taken as a longitudinal force acting at the surfacing level of the carriageway.

(2) The characteristic value of Q_{lk} , limited to 900 kN for the total width of the bridge, should be calculated as a fraction of the total maximum vertical loads corresponding to the Load Model 1 likely to be applied on Lane Number 1, as follows :

$$Q_{lk} = 0,6\alpha_{Q1}(2Q_{1k}) + 0,10\alpha_{q1}q_{1k}w_1L$$

$$180\alpha_{Q1} (kN) \leq Q_{lk} \leq 900 (kN) \quad (4.6)$$

where :

L is the length of the deck or of the part of it under consideration.

NOTE 1 For example, $Q_{lk} = 360 + 2,7L (\leq 900 \text{ kN})$ for a 3m wide lane and for a loaded length $L > 1,2 \text{ m}$, if α factors are equal to unity.

NOTE 2 The upper limit (900 kN) may be adjusted in the National Annex. The value 900 kN is normally intended to cover the maximum braking force of military vehicles according to STANAG⁶.

(3) Horizontal forces associated with Load Model 3 should be defined where appropriate.

NOTE The National Annex may define horizontal forces associated with Load Model 3.

(4) This force should be taken into account as located along the axis of any lane. However, if the eccentricity effects are not significant, the force may be considered to be applied only along the carriageway axis, and uniformly distributed over the loaded length.

(5) Acceleration forces should be taken into account with the same magnitude as braking forces, but in the opposite direction.

NOTE Practically this means that Q_{lk} may be negative as well as positive.

(6) The horizontal force transmitted by expansion joints or applied to structural members that can be loaded by only one axle should be defined.

NOTE The National Annex may define the value for Q_{lk} . The recommended value is :

$$Q_{lk} = 0,6\alpha_{Q1}Q_{1k} \quad (4.6a)$$

⁶ STANAG : Military STANdardization AGreements (STANAG 2021)

4.4.2 Centrifugal and other transverse forces

- (1) The centrifugal force Q_{tk} should be taken as a transverse force acting at the finished carriageway level and radially to the axis of the carriageway.
- (2) The characteristic value of Q_{tk} , in which dynamic effects are included, should be taken from Table 4.3.

Table 4.3 - Characteristic values of centrifugal forces

$Q_{tk} = 0,2Q_v$ (kN)	if $r < 200$ m
$Q_{tk} = 40Q_v / r$ (kN)	if $200 \leq r \leq 1500$ m
$Q_{tk} = 0$	if $r > 1500$ m

where :

r is the horizontal radius of the carriageway centreline [m]

Q_v is the total maximum weight of vertical concentrated loads of the tandem systems of LM1, i.e. $\sum_i \alpha_{Qi}(2Q_{ik})$ (see Table 4.2).

- (3) Q_{tk} should be assumed to act as a point load at any deck cross-section.
- (4) Where relevant, lateral forces from skew braking or skidding should be taken into account. A transverse braking force, Q_{trk} , equal to 25% of the longitudinal braking or acceleration force Q_{lk} , should be considered to act simultaneously with Q_{lk} at the finished carriageway level.

NOTE The National Annex may define a minimum transverse loading. In most cases, forces resulting from wind effects and collisions on kerbs provide a sufficient transverse loading.

4.5 Groups of traffic loads on road bridges

4.5.1 Characteristic values of the multi-component action

- (1) The simultaneity of the loading systems defined in 4.3.2 (Load Model 1), 4.3.3 (Load Model 2), 4.3.4 (Load Model 3), 4.3.5 (Load Model 4), 4.4 (horizontal forces) and the loads defined in section 5 for footways should be taken into account by considering the groups of loads defined in Table 4.4a. Each of these groups of loads, which are mutually exclusive, should be considered as defining a characteristic action for combination with non-traffic loads.

Table 4.4a - Assessment of groups of traffic loads (characteristic values of the multi-component action)

AC ₁		CARRIAGEWAY						FOOTWAYS AND CYCLE TRACKS
Load type		Vertical forces				Horizontal forces		Vertical forces only
Reference		4.3.2	4.3.3	4.3.4	4.3.5	4.4.1	4.4.2	5.3.2-(1)
Load system		LM1 (TS and UDL systems)	LM2 (Single axle)	LM3 (Special vehicles)	LM4 (Crowd loading)	Braking and acceleration forces ^a	Centrifugal and transverse forces ^a	Uniformly Distributed load
Groups of Loads	gr1a	Characteristic values						Combination value ^b
	gr1b		Characteristic value					
	gr2	Frequent values				Characteristic value	Characteristic value	
	gr3 ^d							Characteristic value ^c
	gr4				Characteristic value			Characteristic value
	gr5	See annex A		Characteristic value				
		Dominant component action (designated as component associated with the group)						
^a May be defined in the National Annex (for the cases mentioned).								
^b May be defined in the National Annex. The recommended value is 3 kN/m ² .								
^c See 5.3.2.1-(2). One footway only should be considered to be loaded if the effect is more unfavourable than the effect of two loaded footways.								
^d This group is irrelevant if gr4 is considered.								

AC₁

4.5.2 Other representative values of the multi-component action

(1) The frequent action should consist only of either the frequent values of LM1 or the frequent value of LM2, or the frequent values of loads on footways or cycle-tracks (taking the more unfavourable), without any accompanying component, as defined in Table 4.4b.

NOTE 1 For the individual components of the traffic action, these representative values are defined in EN 1990, A2.

NOTE 2 For quasi-permanent values (generally equal to zero), see EN 1990, A2.

NOTE 3 Where the National Annex refers to infrequent values of variable actions, the same rule as in 4.5.1 may be applied by replacing all characteristic values in Table 4.4 by infrequent values defined in EN 1990, A2, without modifying the other values mentioned in the Table. But the infrequent group gr2 is practically irrelevant for road bridges.

Table 4.4b - Assessment of groups of traffic loads (frequent values of the multi-component action)

		CARRIAGEWAY		FOOTWAYS AND CYCLE TRACKS
Load type		Vertical forces		
Reference		4.3.2	4.3.3	5.3.2(1)
Load system		LM1 (TS and UDL systems)	LM2 (single axle)	Uniformly distributed load
Groups of loads	gr1a	Frequent values		
	gr1b		Frequent value	
	gr3			Frequent value ^a
^a One footway only should be considered to be loaded if the effect is more unfavourable than the effect of two loaded footways.				

4.5.3 Groups of loads in transient design situations

(1) The rules given in 4.5.1 and 4.5.2 are applicable with the following modifications given in 4.5.3(2).

(2) For verifications in transient design situations, the characteristic values associated with the tandem system should be taken equal to $0,8\alpha_{Qi}Q_{ik}$, and all other characteristic, frequent and quasi-permanent values and the horizontal forces are as specified for persistent design situations without any modification (*i.e.* they are not reduced proportionally to the weight of the tandems).

NOTE In transient design situations due to road or bridge maintenance, the traffic is commonly concentrated on smaller areas without being significantly reduced, and long lasting traffic jams are frequent. However, more reductions may be applied in cases where the heaviest lorries are diverted by appropriate measures.

4.6 Fatigue load models

4.6.1 General

(1) Traffic running on bridges produces a stress spectrum which may cause fatigue. The stress spectrum depends on the geometry of the vehicles, the axle loads, the vehicle spacing, the composition of the traffic and its dynamic effects.

(2) In the following, five fatigue load models of vertical forces are defined and given in 4.6.2 to 4.6.6.

NOTE 1 Horizontal forces may have to be taken into account simultaneously with vertical forces for the individual project : for example, centrifugal forces may occasionally need to be considered together with the vertical loads.

NOTE 2 The use of the various Fatigue Load Models is defined in EN 1992 to EN 1999 and further information is given as below :

- a) Fatigue Load Models 1, 2 and 3 are intended to be used to determine the maximum and minimum stresses resulting from the possible load arrangements on the bridge of any of these models ; in many cases, only the algebraic difference between these stresses is used in EN1992 to EN1999.
- b) Fatigue Load Models 4 and 5 are intended to be used to determine stress range spectra resulting from the passage of lorries on the bridge.
- c) Fatigue Load Models 1 and 2 are intended to be used to check whether the fatigue life may be considered as unlimited when a constant stress amplitude fatigue limit is given. Therefore, they are appropriate for steel constructions and may be inappropriate for other materials. Fatigue Load Model 1 is generally conservative and covers multi-lane effects automatically. Fatigue Load Model 2 is more accurate than Fatigue Load Model 1 when the simultaneous presence of several lorries on the bridge can be neglected for fatigue verifications. If that is not the case, it should be used only if it is supplemented by additional data. The National Annex may give the conditions of use of fatigue load models 1 and 2.
- d) Fatigue Load Models 3, 4 and 5 are intended to be used for fatigue life assessment by reference to fatigue strength curves defined in EN1992 to EN1999. They should not be used to check whether fatigue life can be considered as unlimited. For this reason, they are not numerically comparable to Fatigue Load Models 1 and 2. Fatigue Load Model 3 may also be used for the direct verification of designs by simplified methods in which the influence of the annual traffic volume and of some bridge dimensions is taken into account by a material-dependent adjustment factor λ_e .
- e) Fatigue Load Model 4 is more accurate than Fatigue Load Model 3 for a variety of bridges and of the traffic when the simultaneous presence of several lorries on the bridge can be neglected. If that is not the case, it should be used only if it is supplemented by additional data, specified or as defined in the National Annex.
- f) Fatigue Load Model 5 is the most general model, using actual traffic data.

NOTE 3 The load values given for Fatigue Load Models 1 to 3 are appropriate for typical heavy traffic on European main roads or motorways (traffic category Number 1 as defined in Table 4.5).

NOTE 4 The values of Fatigue Load Models 1 and 2 may be modified for the individual project or by the National Annex when considering other categories of traffic. In this case, the modifications made to both models should be proportional. For Fatigue Load Model 3 a modification depends on the verification procedure.

(3) A traffic category on a bridge should be defined, for fatigue verifications, at least, by:

- the number of slow lanes,
- the number N_{obs} of heavy vehicles (maximum gross vehicle weight more than 100 kN), observed or estimated, per year and per slow lane (*i.e.* a traffic lane used predominantly by lorries).

NOTE 1 The traffic categories and values may be defined in the National Annex. Indicative values for N_{obs} are given in Table 4.5 for a slow lane when using Fatigue Load Models 3 and 4. On each fast lane (*i.e.* a traffic lane used predominantly by cars), additionally, 10% of N_{obs} may be taken into account.

Table 4.5(n) - Indicative number of heavy vehicles expected per year and per slow lane

Traffic categories		N_{obs} per year and per slow lane
1	Roads and motorways with 2 or more lanes per direction with high flow rates of lorries	$2,0 \times 10^6$
2	Roads and motorways with medium flow rates of lorries	$0,5 \times 10^6$
3	Main roads with low flow rates of lorries	$0,125 \times 10^6$
4	Local roads with low flow rates of lorries	$0,05 \times 10^6$

NOTE 2 Table 4.5 is not sufficient to characterise the traffic for fatigue verifications. Other parameters may have to be considered, for example :

- percentages of vehicle types (see, *e.g.*, Table 4.7), which depend on the "traffic type",
- parameters defining the distribution of the weight of vehicles or axles of each type.

NOTE 3 There is no general relation between traffic categories for fatigue verifications, and the loading classes and associated α factors mentioned in 4.2.2 and 4.3.2.

NOTE 4 Intermediate values of N_{obs} are not excluded, but are unlikely to have significant effect on the fatigue life.

(4) For the assessment of general action effects (*e.g.* in main girders) all fatigue load models should be placed centrally on the notional lanes defined in accordance with the principles and rules given in 4.2.4(2) and (3). The slow lanes should be identified in the design.

(5) For the assessment of local action effects (*e.g.* in slabs) the models should be centered on notional lanes assumed to be located anywhere on the carriageway. However, where the transverse location of the vehicles for Fatigue Load Models 3, 4 and 5 is significant for the studied effects (*e.g.* for orthotropic decks), a statistical distribution of this transverse location should be taken into account in accordance with Figure 4.6.