



BSI Standards Publication

Eurocode 1 — Actions on structures

Part 2: Traffic loads on bridges and other civil engineering works

National foreword

This British Standard is the UK implementation of EN 1991-2:2023. It supersedes BS EN 1991-2:2003, which will be withdrawn on 30 March 2028.

The UK participation in its preparation was entrusted to Technical Committee B/525/10, Bridges.

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

National choice is allowed in this standard where explicitly stated within notes. The National Annex to this standard contains the national choices to be used for buildings and civil engineering works constructed in the UK.

The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010. This document forms part of the second generation of EN Eurocodes.

The second generation of EN Eurocodes is expected to be published between 2023 and 2026. These documents are being published as soon as they are available. This is being done to enable users to prepare for the transition from the first generation to second generation of EN Eurocodes.

UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028. Until that date, the first generation documents should be considered as the applicable standards for buildings and civil engineering works constructed in the UK unless otherwise specified by the relevant authority or in the specification for a particular project.

This standard is intended to be used with its National Annex and other referenced documents, including other second generation Eurocodes, as an interdependent suite of documents.

While the use of provisions in this standard in conjunction with first generation Eurocodes is not precluded, it should be undertaken with care and should only be done when users are satisfied that it will not result in a lower level of reliability than the minimum level set in the first generation Eurocodes and associated UK National Annexes.

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Date

Text affected

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Eurocode 1 - Actions sur les structures - Partie 2:
Actions dues au trafic sur les ponts et autres ouvrages
du génie civil

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

This European Standard was approved by CEN on 23 July 2023.

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European foreword

This document (EN 1991-2:2023) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

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 2027, and conflicting national standards shall be withdrawn at the latest by March 2028.

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

This document supersedes EN 1991-2:2003.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations 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, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

Introduction

0.1 Introduction to the Eurocodes

The structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990, *Eurocode — Basis of structural and geotechnical 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*
- New parts are under development, e.g. Eurocode for design of structural glass.

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to the EN 1991 (all parts)

EN 1991 specifies actions for the structural and geotechnical design of buildings, bridges and other civil engineering works, or parts thereof, including temporary structures, in conjunction with EN 1990 and the other Eurocodes.

EN 1991 does not cover the specific requirements of actions for seismic regions. Provisions related to such requirements are given in EN 1998 (all parts), which complement and are consistent with EN 1991.

EN 1991 is also applicable to existing structures for:

- structural assessment,
- strengthening or repair,
- changes of use.

NOTE 1 In these cases, additional or amended provisions can be necessary.

EN 1991 is also applicable for the design of structures where materials or actions outside the scope of the other Eurocodes are involved.

NOTE 2 In this case additional or amended provisions can be necessary.

EN 1991 is subdivided in various parts:

- EN 1991-1-1, Eurocode 1 — Actions on structures — Part 1-1: Specific weight of materials, self-weight of construction works and imposed loads for buildings
- EN 1991-1-2, Eurocode 1 — Actions on structures — Part 1-2: Actions on structures exposed to fire
- EN 1991-1-3, Eurocode 1 — Actions on structures — Part 1-3: Snow Loads
- EN 1991-1-4, Eurocode 1 — Actions on structures — Part 1-4: Wind Actions
- EN 1991-1-5, Eurocode 1 — Actions on structures — Part 1-5: Thermal Actions
- EN 1991-1-6, Eurocode 1 — Actions on structures — Part 1-6: Actions during execution
- EN 1991-1-7, Eurocode 1 — Actions on structures — Part 1-7: Accidental actions
- EN 1991-1-8, Eurocode 1 — Actions on structures — Part 1-8: Actions from waves and currents on coastal structures
- EN 1991-1-9, Eurocode 1 — Actions on structures — Part 1-9: Atmospheric icing
- EN 1991-2, Eurocode 1 — Actions on structures — Part 2: Traffic loads on bridges and other civil engineering works
- EN 1991-3, Eurocode 1 — Actions on structures — Part 3: Actions induced by cranes and machines
- EN 1991-4, Eurocode 1 — Actions on structures — Part 4: Silos and tanks

0.3 Introduction to EN 1991-2

EN 1991-2 gives design guidance and actions due to road, pedestrian and railway traffic on bridges and civil engineering works together with all relevant Eurocodes.

EN 1991-2 is addressed to all parties involved in construction activities (e.g. public authorities, clients, designers, contractors, producers, consultants, committees drafting standards for structural design and related product, testing and execution standards, etc.).

EN 1991-2 is intended to be used with EN 1990, the other parts of the EN 1991 series and the EN 1992 series to EN 1999 series for the design of structures.

0.4 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 the Eurocodes.

The basis for combinations of traffic loads with non-traffic loads are given in EN 1990:2023, A.2.

For road bridges, Load Models 1 and 2, defined in 6.3.2 and 6.3.3, 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 could be substantially lighter, or better controlled.

For railway bridges, Load Model 71 (together with Load Model SW/0 for continuous structural elements and decks), defined in 8.3.2, represent the static effect of standard rail traffic operating over the standard track gauge or wider than the standard track gauge European railway network. Load Model SW/2, defined in 8.3.3, represents the static effect of heavy rail traffic.

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.

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

- load model “unloaded train” for checking the lateral stability of 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.

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

0.5 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.6 National Annex for EN 1991-2

National choice is allowed in this document where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1991-2 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this document is to be used.

When no national choice is made and no default is given in this document, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by relevant parties.

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

4.3(1)	5.2(4)	6.1(1)	6.1(2)
6.2.1(1)	6.2.1(2)	6.2.3(1)	6.3.2(4)
6.3.2(9)	6.3.3(1)	6.3.3(4)	6.3.4(1)
6.3.5(1)	6.4.1(2)	6.4.1(4)	6.4.2(5)
6.5.1 – 2 choices	6.5.3(1)	6.6.1(2) – 2 choices	6.6.2(2)

6.6.4(1)	6.6.4(2)	6.6.7(4)	6.6.8(2)
6.6.8(4)	6.6.8(5)	6.6.9(1)	6.7.1(2)
6.7.3.3(2)	6.7.3.3(3)	6.7.3.3(5) – 2 choices	6.7.3.3(6)
6.7.3.4(1)	6.8(2)	6.8(3)	6.8(5)
6.8(6)	6.9.1(1)	6.9.2(1) – 4 choices	6.9.3(1) – 2 choices
7.3.2(1)	7.3.3(1)	7.3.4(4)	7.4(1)
7.6.3(1)	8.1(3)	8.1(7) – 2 choices	8.3.2(4)
8.3.3(4)	8.3.6.4(5)	8.3.7(4)	8.4.4(1)
8.4.5.2(1)	8.4.5.4(1)	8.4.5.4(2) – 2 choices	8.4.6.1.1(2)
8.4.6.1.1(4)	8.4.6.1.1(5)	8.4.6.1.1(7)	8.4.6.1.2(3)
8.4.6.2(1)	8.4.6.2(2)	8.4.6.2(7)	8.4.6.2(8)
8.4.6.2(9)	8.4.6.3.1(3)	8.4.6.3.2(2)	8.4.6.3.3(4)
8.4.6.3.3(5)	8.4.6.5(4)	8.4.6.6(4)	8.4.6.6(6)
8.5.1(2)	8.5.1(8)	8.5.1(13)	8.5.3(6)
8.5.3(10)	8.5.3(11)	8.5.3(14)	8.5.4.1(5)
8.5.4.3(1)	8.5.4.3(2) – 2 choices	8.5.4.4(3)	8.5.4.4(6)
8.5.4.5	8.5.4.5.1(2)	8.5.4.5.1(3)	8.5.4.6.1(1)
8.5.4.6.3(1)	8.5.4.6.3(4)	8.6.1(4)	8.6.1(6)
8.7.2(2)	8.7.2(7)	8.7.2(8)	8.7.4(2)
8.8.1(1)	8.8.1(2)	8.8.1(7)	8.8.2(3)
8.8.3.1(1)	8.8.3.2(1)	8.8.4(1)	8.9(2)
8.9(3)	8.9(4)	8.10.1(1)	8.10.1(7)
8.10.2(1) – 3 choices	8.10.3(1) – 2 choices	8.10.3(2)	C.3(2) – 2 choices
D.4(2)	D.5(1)		

National choice is allowed in EN 1991-2 on the application of the following informative annexes:

Annex A	Annex B	Annex E	Annex F
Annex G			

The National annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

(1) This document 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) The imposed loads defined in this document are applicable for the design of new bridges, including decks, piers, abutments and associated walls (e.g. upstand walls, wing walls and flank walls) and their foundations. These imposed loads can also be used for the design of other structures subject to traffic loads (e.g. road tunnel floor slabs, noise barriers and their foundations). Where appropriate, the loads can also be considered as a basis for assessment or modification of existing structures in combination with complementary conditions if necessary.

(3) The load models and values given in this document are also applicable for the design of retaining walls adjacent to roads and railway lines and the design of earthworks subject to road or rail traffic actions. This document also provides applicability conditions for specific load models.

(4) This document is intended to be used with EN 1990, the other parts of the EN 1991 series and the EN 1992 series to EN 1999 series for the design of structures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. in 'should' clauses), permissions ('may' clauses), possibilities ('can' clauses), and in notes.

EN 1990:2023, *Eurocode — Basis of structural and geotechnical design*

EN 1992 (all parts), *Eurocode 2 — Design of concrete structures*

EN 1993 (all parts), *Eurocode 3 — Design of steel structures*

EN 1994 (all parts), *Eurocode 4 — Design of composite steel and concrete structures*

EN 1995-1-1:—¹, *Eurocode 5 — Design of timber structures - Part 1-1: General - Common rules and rules for buildings*

EN 1997-1:—², *Eurocode 7 — Geotechnical design - Part 1: General rules*

EN 1999 (all parts), *Eurocode 9 — Design of aluminium structures*

EN 15663, *Railway applications — Vehicle reference masses*

¹ Under preparation. Stage at the time of publication: prEN 1995-1-1:2023.

² Under preparation. Stage at the time of publication: prEN 1997-1:2022.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1990 and the following apply.

3.1 Terms and definitions

3.1.1 Harmonized terms and common definitions

3.1.1.1

deck

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

3.1.1.2

road restraint system

vehicle restraint system and pedestrian restraint system used on the road

Note 1 to entry: Road restraint systems can 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).

[SOURCE: EN 1317-1:2010, modified – Note 1 to entry has been added.]

3.1.1.3

safety barrier

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

[SOURCE: EN 1317-1:2010, 4.3]

3.1.1.4

vehicle parapet

safety barrier installed on the side of a bridge or on a retaining wall or similar structure where there is a vertical drop and which can include additional protection and restraint for pedestrians and other road users (combined vehicle/pedestrian parapet)

[SOURCE: EN 1317-1:2010, 4.6]

3.1.1.5

pedestrian restraint system

system installed to provide restraint for pedestrians

[SOURCE: EN 1317-1:2010, 4.8]

3.1.1.6

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

3.1.1.7**noise barrier**

screen to reduce transmission of noise

3.1.1.8**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

3.1.1.9**civil engineering work**

comprising a structure, such as a bridge, road, railway, runway, utilities, or sewerage system, or the result of operations such as earthworks and geotechnical processes, but excluding a building and its associated site works

3.1.1.10**geotechnical structure**

structure that includes ground or a structural member that relies on the ground for resistance

3.1.2 Terms and definitions specifically for road bridges**3.1.2.1****carriageway**

area on the superstructure, that is located between the lesser of the width between kerbs or the inner limits of the vehicle restraint systems

3.1.2.2**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

3.1.2.3**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

3.1.2.4**central reservation**

area separating the physical traffic lanes of a dual-carriageway road

Note 1 to entry: It generally includes a median strip and lateral hard strips separated from the median strip by safety barriers.

3.1.2.5**notional lane**

strip of the carriageway, parallel to an edge of the carriageway, which in Clause 6 is deemed to carry a line of cars and/or lorries

3.1.2.6**remaining area**

difference, where relevant, between the total area of the carriageway and the sum of the areas of the notional lanes

Note 1 to entry: See Figure 6.1.

3.1.2.7

tandem system

assembly of two consecutive axles considered to be simultaneously loaded

3.1.2.8

abnormal load

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

3.1.2.9

kerb

for application of Clauses 6 and 7, a separation line of stone, concrete or another material forming an edge between the carriageway and the adjacent areas (shoulders, islands, cycle ways or footways)

Note 1 to entry: Kerbs can be of upstand type to provide a barrier and discourage vehicles from leaving the carriageway, or be of lower or mountable type which do not provide such barrier

3.1.3 Terms and definitions specifically for railway bridges

3.1.3.1

track

includes rails and sleepers, laid on a ballast bed, or directly fastened to the decks of bridges

Note 1 to entry: 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 or for the maintenance of tracks.

3.1.3.2

resonant speed

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

3.1.3.3

frequent operating speed

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

3.1.3.4

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)

3.1.3.5

maximum permitted vehicle speed

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

3.1.3.6

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

3.1.3.7

maximum design speed

generally $1,2 \times$ Maximum Nominal Speed

3.1.3.8**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

Note 1 to entry: The speed generally exceeds the Maximum Permitted Vehicle Speed and the appropriate requirements are to be specified for the individual project.

3.1.3.9**classified vertical load**

rail traffic loads multiplied by the factor α

3.2 Symbols and abbreviations**3.2.1 General**

For the purposes of this document, the following symbols apply.

3.2.2 Symbols specifically for Clauses 6 and 7

Latin upper case letters

L	In general, loaded length
N_{obs}	Number of heavy vehicles
P_j	Component of the force due to a single jogger
P_w	Component of the force due to a single pedestrian
Q_{ak}	Characteristic value of a single axle load (Load Model 2) for a road bridge (see 6.3.3)
Q_{ek}	Load model of a single concentrated load corresponding to traffic on road surface (see 6.9.2)
Q_{flk}	Characteristic horizontal force on a footbridge
Q_{fwk}	Characteristic value of the concentrated load (wheel load) on a footbridge (see 7.3.3)
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 (see 7.3.4)
$Q_{\text{sv1}}, Q_{\text{sv2}}$	Characteristic value of the axle load group of a service vehicle (see 7.6.3)
Q_{tk}	Magnitude of the characteristic transverse or centrifugal forces on road bridges
Q_{trk}	Transverse braking force on road bridges
S	Area of loaded surface
TC	Pedestrian traffic class
TS	Tandem system for Load Model 1
UDL	Uniformly distributed load for Load Model 1

Latin lower case letters

d	Density of pedestrians
f_s	Step frequency
g_{ri}	Group of loads, i is a number ($i = 1$ to n)
N	Number of pedestrians on the loaded surface S
n'	Equivalent number of pedestrians on the loaded surface S
n_0	reference spatial frequency [0,1 cycle/m]
n_1	Number of notional lanes for a road bridge
$p_w(t)$	Uniformly distributed harmonic load for pedestrian stream
q_{ek}	Load model of a uniformly distributed load corresponding to traffic on road surface (see 6.9.2)
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)
r	Horizontal radius of a carriageway or track centreline, Transverse distance between wheel loads
v_j	Velocity of jogger
v_w	Velocity of walking pedestrian
w	Carriageway width for a road bridge, including hard shoulders, hard strips and marker strips (see 6.2.3(1))
w_l	Width of a notional lane for a road bridge

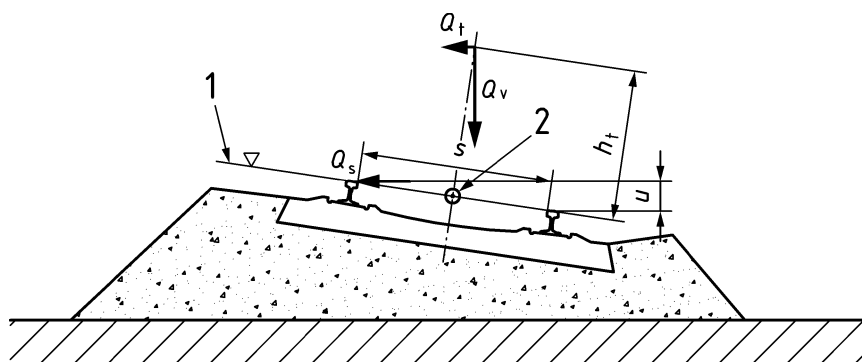
Greek upper case letters

$\Delta\varphi_{fat}$	Additional dynamic amplification factor for fatigue near expansion joints (see 6.6.2)
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Greek lower case letters

α_{Qi}, α_{qi}	adjustment factors of Load Model 1 on lanes i ($i = 1, 2, \dots$), defined in 6.3.2
α_{qr}	Adjustment factor of Load Model 1 on the remaining area, defined in 6.3.2
β_Q	Adjustment factor of Load Model 2 defined in 6.3.3
φ_{fat}	Dynamic amplification factor for fatigue (see Annex B)
ξ	Structural damping ratio
ψ_j	Reduction coefficient taking into account the probability that the footfall frequency (jogging) approaches the critical range of natural frequencies under consideration
ψ_w	Reduction coefficient taking into account the probability that the footfall frequency (walking) approaches the critical range of natural frequencies under consideration

3.2.3 Symbols specifically for Clause 8



Key

- 1 Running surface
- 2 Longitudinal forces Q_{Ia} and Q_{Ib} acting along the centreline of the track

Figure 3.1 — Notation and dimensions specifically for railways

Latin upper case letters

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 bearing due to deformation of the deck
F_{Tk}	Characteristic longitudinal force on a fixed bearing due to the combined response of track and structure to temperature
F_{li}	Individual longitudinal support reaction corresponding to the action i
K	Total longitudinal support stiffness
L	Length (general)
L_T	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 equal point forces
P	Point force (individual axle load)
P_k	Axle load of the k -th axle
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
Q_{lak}	Characteristic value of traction force
Q_{lbk}	Characteristic value of braking force
Q_r	Resultant of actions due to rail traffic (general, e.g. resultant of vertical loads and horizontal loads such as 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_D	range of uniform temperature component of the deck
ΔT_N	range of uniform temperature component
ΔT_R	range of uniform temperature component of the rail
V	Speed in km/h Maximum Line Speed at the Site in km/h
Y	Horizontal distance in metres between the track centreline and the surface

Latin lower case letters

a	Distance between rail supports, length of distributed loads (Load Models SW/0 and SW/2)
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 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
i	Number of axles of a subset of the train, up to the total number of axles
f	Reduction factor for centrifugal force first natural frequency of the wall system [Hz]
f_{ck}	Concrete compressive cylinder 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 Height of wall above rail top [m]
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
k	Longitudinal plastic shear resistance of the track [kN/m]
k_1	Train shape coefficient
k_2	Multiplication factor for slipstream actions on vertical surfaces parallel to the tracks
k_3	Multiplication 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)
n_0	First natural bending frequency of the structure
n_T	First natural torsional frequency of the structure
q_{1k}	Characteristic value of equivalent distributed aerodynamic action
q_{A1d} , q_{A2d}	Distributed loading for derailment loading
q_{DS}	quasi-static load for the air pressure wave due to a passing train at an elevation z above rail top considering the influence length, wall height and dynamic effects in kN/m ²
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	Horizontal radius of a carriageway or track centre-line Transverse distance between wheel loads
s	Track gauge
s_{DS}	horizontal spacing between the two relevant load model positions of the air pressure wave for maximum structural reactions, in m
u	Cant, relative vertical distance between the uppermost surface of the two rails at a particular location along the track
v	Maximum Nominal Speed [m/s] Maximum Permitted Vehicle Speed [m/s] Speed [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
x_k	Distance between the first axle and the k-th axle
z	elevation above rail top in m, where the quasi-static equivalent load shall be calculated. For elevations $z < 0$ it is assumed that $z = 0$

Greek upper case letters

θ	End rotation of structure (general)
Φ (Φ_2 , Φ_3)	Dynamic factor for railway Load Models 71, SW/0 and SW/2
Φ_{nb}	Dynamic factor for noise barriers

Greek lower case letters

α	Load classification factor
α_v	Coefficient for speed (Annex C)
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 factor — considering dynamic effects
φ'_{dyn}	Dynamic enhancement of static loading for a Real Train determined from a dynamic analysis
φ_L, φ_H	dynamic length and height factor for noise barriers
κ	Coefficient relating to the stiffness of an abutment relative to the piers

κ_t	relation between natural and applied frequency
λ	Damage equivalent factor for fatigue Excitation wavelength
ρ	Density
σ	Stress
$\sigma_A, \sigma_B, \sigma_M$	Pressure on the upper surface of the deck from rail traffic actions
$\Delta\sigma_{71}$	Stress range due to the Load Model 71 (and where required SW/0)
$\Delta\sigma_C$	Reference value of fatigue strength
ζ	Lower limit of percentage of critical damping (%), or ratio of critical damping

4 Classification of actions

4.1 General

(1) The relevant traffic actions and other specific actions on bridges should be classified in accordance with EN 1990:2023, 6.1.1.

NOTE 1 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.

NOTE 2 Traffic actions are multi component actions.

(2) All traffic actions should be classified as free actions within the limits specified in Clauses 6 to 8.

4.2 Variable actions

(1) For normal conditions of use (i.e. excluding any accidental situation), the traffic loads (dynamic amplification included where relevant) should be considered as variable actions with their representative values.

NOTE 1 The representative values of a variable action are defined according to EN 1990 as:

- characteristic values;
- frequent values;
- quasi-permanent values.

NOTE 2 In Table 4.1 (NDP), information is given on the basis of calibration of the main Load Models (fatigue excluded) presented in this document for road bridges, footbridges and railway bridges for characteristic, frequent and quasi-permanent values. Rail loading and the associated γ and ψ factors have been based on nominal values.

NOTE 3 For the calculation of fatigue lives, separate models, associated values and (where relevant) specific requirements are given in 6.6 for road bridges, in 8.9 for railway bridges and in the relevant annexes.

Table 4.1 (NDP) — Bases for the calibration of the main Load Models (fatigue excluded) presented in this document

Traffic Load Models	Characteristic values	Frequent values	Quasi-permanent values
Road Traffic			
LM1 (6.3.2)	1000 years 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 6.3.2).	1 week return period for traffic on the main roads in Europe (α factors equal to 1, see 6.3.2).	Calibration in accordance with definition given in EN 1990.
LM2 (6.3.3)	1000 years 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 6.3.3).	1 week return period for traffic on the main roads in Europe (β factor equal to 1, see 6.3.3).	a
LM3 (6.3.4)	Set of nominal values. Basic values defined in Annex A are derived from a synthesis based on various national regulations.	a	a
LM4 (6.3.5)	Nominal value deemed to represent the effects of a crowd. Defined with reference to existing national standards.	a	a
Pedestrian Traffic			
Uniformly distributed load (7.3.2)	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 (7.3.3)	Nominal value. Defined with reference to existing national standards.	a	a
Service vehicle (7.3.4)	Nominal value. As specified or given in 7.6.3.	a	a
Railway Traffic			
LM71 (8.3.2)	Nominal values deemed to represent the static effect of vertical loading due to normal rail traffic.	a	a

Traffic Load Models	Characteristic values	Frequent values	Quasi-permanent values
SW/0 and SW/2 (8.3.3)	Nominal values deemed to represent the static effect of vertical loading due to normal rail traffic on continuous structural elements and decks (SW/0), and heavy rail traffic (SW/2).	a	a
HSLM (8.4.6.1.1)	Nominal values obtained as envelope of dynamic resonant load effects of selected high-speed trains.	a	a
^a To adjust the values to the specific return period see EN 1990:2023, A.2.			

4.3 Accidental actions

(1) If appropriate protection is not provided, actions due to collision, or the accidental presence or location of road vehicles and trains, shall be considered for the structural design.

NOTE The term “appropriate protection” can be defined in the National Annex.

(2) For common situations, the accidental actions described in this document should be used.

NOTE 1 They are represented by various load models defining design values in the form of static equivalent loads.

NOTE 2 For collision forces due to vehicles under road bridges, footbridges and railway bridges, see 6.7.2, 7.6.2 and 8.7.3.

NOTE 3 For actions due to vehicles on road bridges and footbridges, see 6.7.3 and 7.6.3 respectively.

NOTE 4 For actions due to derailment, see 8.7.

(3) 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 1 Values for boat and ship impacts are given in EN 1991-1-7.

NOTE 2 Additional requirements can be specified for a special project.

5 Design situations

5.1 General

(1) Relevant design situations shall be selected and critical load cases identified.

(2) For each critical load case, the design values of the effects of actions in combination shall be determined.

5.2 Simultaneity of traffic loads

(1) When using groups of loads, the various traffic loads acting simultaneously in combinations of action components should be considered in design calculations, where relevant.

NOTE For combinations of traffic actions, see Clauses 6, 7 and 8.

(2) 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.

(3) Specific rules for the simultaneity with other actions for road bridges, footbridges, and railway bridges are given in EN 1990:2023, A.2.

(4) 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 can be defined in the National Annex.

6 Road traffic actions and other actions specifically for road bridges

6.1 Field of application

(1) Load models defined in Clause 6 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 6.3.2). 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 can be defined in the National Annex.

(2) The load models and associated rules provided in this clause 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.

NOTE 1 Specific load models can be defined in the National Annex.

NOTE 2 Load models for geotechnical structures are defined in 6.9.

(3) The load models and associated rules provided in this clause do not cover the effects of loads on road construction sites or of loads specifically for inspection and tests which should be separately specified, where relevant by the relevant authority or where not specified agreed for a specific project by the relevant parties.

(4) The load models and associated rules provided in this clause include dynamic amplification effect (fatigue excluded).

NOTE The dynamic amplification included in the models, was established for a medium pavement quality (see Annex B) and pneumatic vehicle suspension. However, it 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 can 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.

(5) An additional dynamic amplification should be taken into account for particular calculations (see 6.3.3(2) and 6.6.2(2)) or when agreed for a specific project by the relevant parties.

NOTE This can be particularly relevant for local verification of a bridge deck, bearings and for supports under expansion joints.

6.2 Representation of actions

6.2.1 Models of road traffic loads

(1) Imposed loads due to the road traffic, consisting of cars, lorries and special vehicles (e.g. for industrial transport) should be taken into account as relevant.

NOTE 1 These loads give rise to vertical and horizontal, static and dynamic forces defined in Clause 6.

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

(2) Where vehicles (including military or other special vehicles) which do not comply with national regulations are to be considered, they shall be defined.

NOTE The National Annex can define these models for special vehicles not compliant with the national regulations. Guidance on standard models for special vehicles and their application is given in Annex A. See 6.3.4.

6.2.2 Loading classes

(1) The actual loads on road bridges resulting from various categories of vehicles and from pedestrians shall be calculated.

(2) The differences between bridges in terms of:

- Vehicle traffic composition (e.g. percentages of lorries),
- density (e.g. average number of vehicles per year),
- conditions (e.g. jam frequency),
- extreme likely weights of vehicles and their axle loads, and, if relevant,
- in the influence of road signs restricting carrying capacity,

should be taken into account through the use of load models suited on relevant locations of a bridge and where appropriate, through the choice of adjustment factors α and β defined in 6.3.2 for Load Model 1 and in 6.3.3 for Load Model 2 respectively.

6.2.3 Divisions of the carriageway into notional lanes

(1) The carriageway width, w , should be measured between the lesser of:

- the width between kerbs (where they have sufficient height)
- the anchored vehicle restraint system
- the pedestrian parapet

The width, w , 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 minimum value of the height of the kerbs to be taken into account is 100 mm unless the National Annex gives a different value.

(2) If the height of the kerb exceeds a minimum value, it should be taken into account for the determination of the carriageway width w .

(3) 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 should be taken from Table 6.1.

Table 6.1 — 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
$w < 5,4 \text{ m}$	$n_l = 1$	3 m	$w - 3 \text{ m}$
$5,4 \text{ m} \leq w < 6 \text{ m}$	$n_l = 2$	$\frac{w}{2}$	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 11 m, $n_l = \text{Int}\left(\frac{w}{3}\right) = 3$, and the width of the remaining area is $11 - 3 \times 3 = 2 \text{ m}$.			

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

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

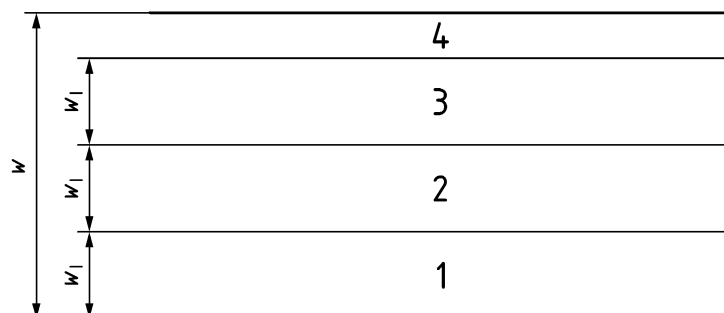
(5) The rules given in 6.2.3(4) may be as agreed for a specific project by the relevant parties to allow for envisaged future modifications of the traffic lanes on the deck, e.g. for repair.

6.2.4 Location and numbering of the lanes for design

(1) For each individual verification, 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.

(2) 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.

(3) The lane giving the most unfavourable effect should be numbered Lane Number 1, the lane giving the second most unfavourable effect Lane Number 2, etc. (see Figure 6.1).

**Key**

- w Carriageway width
- w_l Notional lane width
- 1 Notional Lane No. 1
- 2 Notional Lane No. 2
- 3 Notional Lane No. 3
- 4 Remaining area

Figure 6.1 — Example of the Lane Numbering in the most general case

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

(5) Where the carriageway consists of two separate parts on two independent decks, each part shall be considered as a carriageway. Separate numbering system shall then be used for the design of each deck.

(6) Where the carriageway consists of two separate parts on two independent decks, 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.

6.2.5 Application of the load models on the individual lanes

(1) For each individual verification, the load models shall be applied on each notional lane 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 shall 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 6.3.

6.3 Vertical loads — Characteristic values

6.3.1 General

(1) The load models for vertical loads should represent the following road 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 global and local verifications.
- b) Load Model 2 (LM2): A single axle load applied on specific tyre contact areas which cover the dynamic effects of the normal traffic on short structural members.

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

- 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 global and local verifications.
- d) Load Model 4 (LM4): A crowd loading intended only for global verifications.

6.3.2 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:

$$\alpha_Q \times Q_k \quad (6.1)$$

where

α_Q is adjustment factor;

Q_k is the characteristic value of the axle load.

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

$$\alpha_q \times q_k \quad (6.2)$$

where

α_q are adjustment factors;

q_k is the characteristic value of the uniformly distributed load.

(2) Load Model 1 should be applied on each notional lane and on the remaining areas.

NOTE On notional lane Number i , the load magnitudes are referred to as $\alpha_{Qi} \times Q_{ik}$ and $\alpha_{qi} \times q_{ik}$ (see Table 6.2). On the remaining areas, the load magnitude is referred to as $\alpha_{qr} \times q_{rk}$.

(3) The characteristic values of Q_{ik} and q_{ik} should be taken from Table 6.2 (dynamic amplification included) based on their location on the bridge.

Table 6.2 — Load Model 1: characteristic values

Location	Tandem system TS Axle loads Q_{ik} kN	UDL system q_{ik} (or q_{rk}) kN/m ²
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

(4) 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 all cases, for bridges without road signs restricting vehicle weights, the following should be taken as minimum values for the adjustment factors:

$$\alpha_{Q1} \geq 0,8 \text{ and} \quad (6.3)$$

$$\text{for: } i \geq 2, \alpha_{q1} \geq 1; \text{ this restriction being not applicable to } \alpha_{qr}. \quad (6.4)$$

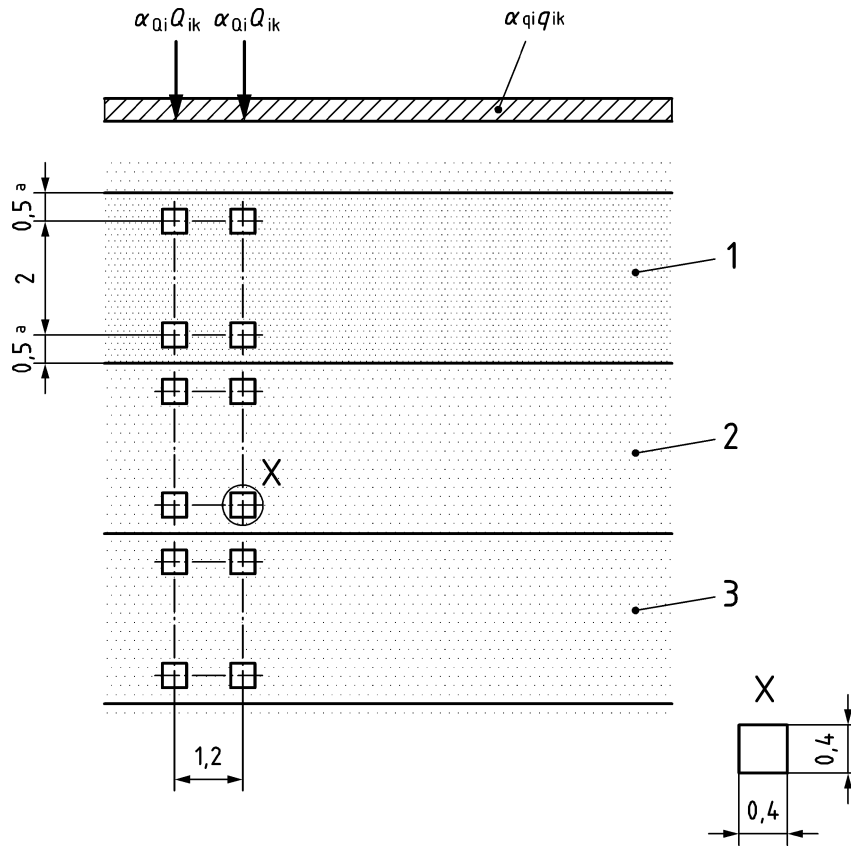
NOTE In the absence of specification, the values of α_{Q1} , α_{qi} and α_{qr} factors are equal to 1 unless the National Annex gives different values. Values of adjustment factors equal to 1 correspond to heavy industrial international traffic, representing a large part of the total traffic of heavy vehicles.

(5) The following rules should be followed for the application of the tandem system:

- No more than one tandem system should be taken into account per notional lane.
- Only complete tandem systems should be taken into account.
- Each axle of the tandem system should be taken into account with two identical wheels, the load per wheel being therefore equal to $0,5 \alpha_Q \times Q_k$.
- The contact surface of each wheel should be taken as square and of side 0,40 m (see Figure 6.2).

(6) The uniformly distributed loads q_k should be applied only to unfavourable parts of the influence surface, longitudinally and transversally.

(7) The application of Load Model 1 is illustrated in Figure 6.2.

**Key**

- 1 Lane No. 1: $Q_{1k} = 300 \text{ kN}$; $q_{1k} = 9 \text{ kN/m}^2$
- 2 Lane No. 2: $Q_{2k} = 200 \text{ kN}$; $q_{2k} = 2,5 \text{ kN/m}^2$
- 3 Lane No. 3: $Q_{3k} = 100 \text{ kN}$; $q_{3k} = 2,5 \text{ kN/m}^2$
- Tandem axle spacing = 1,2 m
- a For $w_1 = 3,00 \text{ m}$

Figure 6.2 — Application of Load Model 1

(8) For global verifications, each tandem system should be assumed to travel centrally along the axes of notional lanes (see Figure 6.2).

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

NOTE Alternative rules on the application of tandem systems for local verifications can be set in the National Annex.

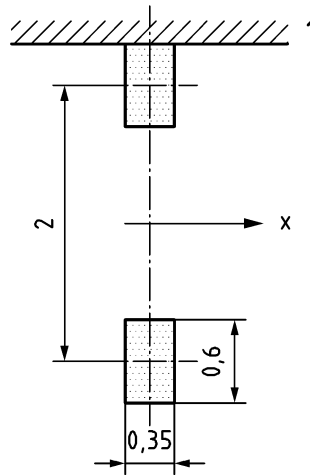
6.3.3 Load Model 2

(1) Load Model 2 should be represented by a single axle load $\beta_Q \times Q_{ak}$ with Q_{ak} equal to 400 kN (dynamic amplification included). However, when relevant, only one wheel of $200 \beta_Q$ (kN) may be taken into account.

NOTE The value of β_Q is equal to α_{Qi} unless the National Annex gives a different value.

- (2) In the vicinity of expansion joints, an additional dynamic amplification factor equal to the value defined in 6.6.2 should be applied.
- (3) Load Model 2 shall be applied at any location on the carriageway.
- (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 6.3).

Dimensions in metres



Key

- x Bridge lane direction
- 1 Kerb

Figure 6.3 — Application of 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 same square contact surface for the wheels of Load Models 1 and 2 can be set in the National Annex.

6.3.4 Load Model 3 (special vehicles)

- (1) Where relevant, models of special vehicles (Load Model 3) should be defined and taken into account.

NOTE The definition of Load Model 3 and its conditions of use can be set by the National Annex. Annex A gives guidance on standard models and their conditions of application.

6.3.5 Load Model 4 (crowd loading)

- (1) Where relevant, a crowd loading (Load Model 4), represented by a uniformly distributed load should be defined and taken into account.

NOTE The magnitude of LM 4 is 5 kN/m² (dynamic amplification included), unless the National Annex gives a different value.

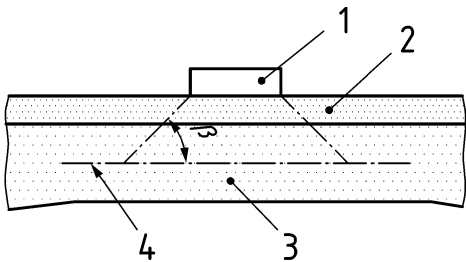
(2) Load Model 4 should be applied on the relevant parts of the length and width of the road bridge deck, the central reservation being included where relevant.

NOTE The loading system LM4 is intended for global verifications.

6.3.6 Dispersal of concentrated loads

(1) If the various concentrated loads associated with Load Models 1 and 2 are applied as patch loads, they should be taken as uniformly distributed on their whole contact area.

(2) The dispersal through the pavement and concrete deck plates may be taken at a spread-to-depth ratio of 1 horizontally to 1 vertically down to the level of the centroid of the concrete deck plate (Figure 6.4).



- Key**
- 1 Wheel contact pressure
 - 2 Pavement
 - 3 Concrete deck plate
 - 4 centroid of concrete deck plate
 - β angle β see Table 6.3

Figure 6.4 — Dispersal of concentrated loads through pavement and deck plate

Table 6.3 — Dispersion angle β of concentrated loads for various materials

Pavement	45°
Boards and planks	45°
Concrete deck plates	45°
Laminated timber deck plates:	
— in the direction of the grain	45°
— perpendicular to the grain	75°
Plywood and cross-laminated deck plates	45°

(3) The dispersal through the pavement and orthotropic decks may 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 6.5).

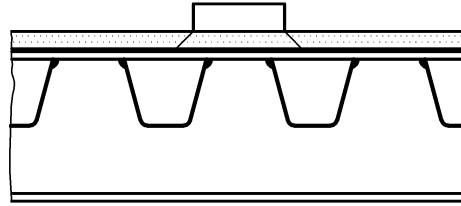


Figure 6.5 — Dispersal of concentrated loads through pavement and orthotropic decks

6.4 Horizontal forces — characteristic values

6.4.1 Braking and acceleration forces

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

(2) The characteristic value of the braking force Q_{Lk} 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 indicated in Formula (6.5):

$$Q_{Lk} = 0,6 \times \alpha_{Q1} (2 \times Q_{1k}) + 0,10 \alpha_{q1} q_{1k} w_l L$$

$$180 \times \alpha_{Q1} [\text{kN}] \leq Q_{Lk} \leq 900 \text{ kN} \quad (6.5)$$

where

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

NOTE 1 The upper limit $Q_{Lk, \max}$ is equal to 900 kN unless the National Annex gives a different value. $Q_{Lk, \max}$ is normally intended to cover the maximum braking force of military vehicles according to STANAG.

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

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

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

NOTE Horizontal forces associated with other Load Models than LM1 can be defined in the National Annex.

(5) This force should be taken into account as located along the axis of any possible 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.

(6) The horizontal force transmitted by expansion joints or applied to structural members that can be loaded by only one axle shall be Q_{Lk} defined in Formula (6.6):

$$Q_{Lk} = 0,6 \alpha_{Q1} Q_{1k} \quad (6.6)$$

6.4.2 Centrifugal and other transverse forces

(1) The centrifugal force Q_{tk} shall 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 the centrifugal force Q_{tk} , should be taken from Table 6.4 (dynamic effects included).

Table 6.4 — Characteristic values of centrifugal forces

$Q_{tk} = 0,2 Q_v$ (kN)	if $r < 200$ m
$Q_{tk} = 40 Q_v / r$ (kN)	if $200 \leq r \leq 1\,500$ m
$Q_{tk} = 0$	if $r > 1\,500$ m
where r is the horizontal radius of the carriageway centreline [m]; Q_v is the total vertical load of the tandem systems of LM1.	

(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 shall be taken into account.

(5) If lateral forces from skew braking or skidding are taken into account, transverse braking force, Q_{trk} , equal to 25 % of the longitudinal braking or acceleration force Q_{1k} , should be considered to act simultaneously with Q_{1k} at the finished carriageway level.

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

6.5 Groups of traffic loads on road bridges (multi component actions)

6.5.1 Characteristic values in persistent design situations

(1) The simultaneity of the loading systems defined in 6.3 and 6.4 and the loads defined in Clause 7 for footways should be taken into account by considering the groups of traffic loads defined in Table 6.5 (NDP), each group defining a single variable characteristic action for combination with non-traffic loads.

NOTE The group of loads indicated in Table 6.5 (NDP) are mutually exclusive.

Table 6.5 (NDP) — Assessment of groups of traffic loads (characteristic values of the multi-component action in persistent design situations)

		Carriageway					Footways and cycle ways
Load type		Vertical forces			Horizontal forces		Vertical forces only
Reference		6.3.2	6.3.3	6.3.4	6.3.5	6.4.1	6.4.2
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
Groups of Loads	gr1a	Characteristic values					
	gr1b		Characteristic value				
	gr2	Frequent values				Characteristic value	Characteristic value
	gr3d						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 These can be defined in the National Annex (for the cases mentioned).					
		b This value is equal to 3 kN/m ² unless the National Annex gives a different value.					
		c See 7.3.2. 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.					

6.5.2 Other representative values

(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 6.6.

NOTE 1 For the individual components of the traffic action, these representative values are defined in EN 1990:2023, A.2.

NOTE 2 For transient design situations see 6.5.3.

Table 6.6 — Assessment of groups of traffic loads (frequent values of the multi-component action in persistent design situations)

		Carriageway		Footways and cycle ways
Load type		Vertical forces		
Reference		6.3.2	6.3.3	7.3.2
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.

(2) The quasi-permanent values should be derived in accordance with EN 1990:2023, A.2.

NOTE Quasi-permanent values are generally equal to zero.

6.5.3 Groups of loads in transient design situations

(1) In transient design situations the characteristic values of vertical loads from tandem system in LM1 may be reduced to $0,8 \alpha_{Qi} \times Q_{ik}$. Other loads, including horizontal loads should not be reduced.

NOTE The National Annex can define alternative characteristic values associated with the tandem system or other load models for instance associated with LM 3 (special vehicles).

6.6 Fatigue load models

6.6.1 General

(1) Traffic running on bridges produces a stress spectrum which could 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 6.6.5 to 6.6.9.

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

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 the EN 1992 series to EN 1999 series.

- 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 can be considered as unlimited when a constant stress amplitude fatigue limit is given. Therefore, they are appropriate for steel constructions and can 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.

NOTE 2 The National Annex can set 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 the EN 1992 series to EN 1999 series. They are not intended to 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 can 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 6.7 (NDP)).

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

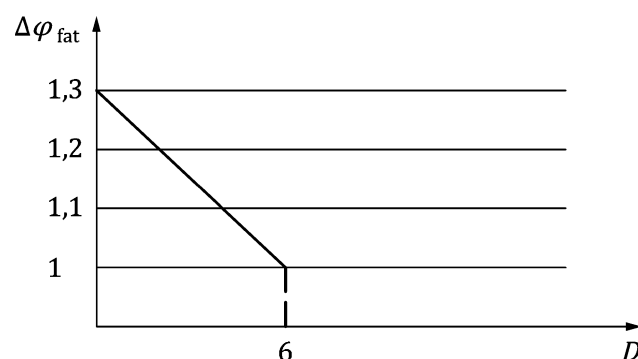
6.6.2 Dynamic amplification factor

- (1) Fatigue Load Models 1 to 4 include dynamic load amplification appropriate for pavements of good quality (see Annex B).
- (2) An additional amplification factor $\Delta\phi_{\text{fat}}$ given by Formula (6.7) should be taken into account near expansion joints and applied to all loads:

$$\Delta\phi_{\text{fat}} = 1,0 + 0,3 \left(1 - \frac{D}{6} \right); \quad \Delta\phi_{\text{fat}} \geq 1 \quad (6.7)$$

where

D is the distance [m] of the cross-section under consideration from the expansion joint. See Figure 6.6.

**Key**

$\Delta\varphi_{fat}$ Additional amplification factor

D Distance of the cross-section under consideration from the expansion joint [m]

Figure 6.6 — Representation of the additional amplification factor

NOTE The dynamic additional amplification factor $\Delta\varphi_{fat}$ can be set in the National Annex.

6.6.3 Fatigue Load Models location for global and local effects

(1) For the assessment of global 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 6.2.4(1) and (2). The slow lanes (i.e. traffic lanes used predominantly by lorries) should be identified in the design.

(2) For the assessment of local action effects (e.g. in slabs) the models should be centred 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 6.7.

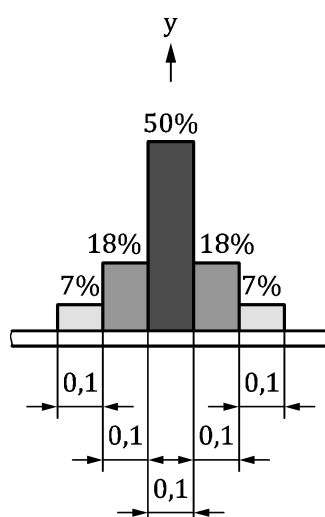


Figure 6.7 — Frequency distribution of transverse location of centre line of vehicle

(3) When the probability that traffic loading is located in the most adverse position is significantly less than 100 %, the spectra of effects of actions due to that traffic loading may be derived by considering less adverse (but nevertheless realistic) locations as specified by the relevant authority or, where not specified, agreed for a specific project by the relevant parties.

6.6.4 Traffic category on the bridge

(1) For fatigue verifications, the traffic category on the bridge should be defined by considering, as a minimum:

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

NOTE The traffic categories can be defined in the National Annex.

(2) Indicative values for N_{obs} are given in Table 6.7 (NDP) 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} should be taken into account.

NOTE 1 The values of N_{obs} can be defined in the National Annex.

Table 6.7 (NDP) — Indicative number of heavy vehicles expected per year and per slow lane when using Fatigue Load Models 3 and 4

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 Other parameters that might have to be considered to characterize the traffic for fatigue verifications include:

- percentages of vehicle types (see, e.g. Table 6.9 (NDP)), which depend on the “traffic type”,
- parameters defining the distribution of the weight of vehicles or axles of each type.

6.6.5 Fatigue Load Model 1 (similar to LM1)

(1) Fatigue Load Model 1 should have the configuration of the characteristic Load Model 1 defined in 6.3.2, with the values of the axle loads equal to $0,7 Q_{ik}$ and the values of the uniformly distributed loads equal to $0,3 q_{ik}$ for the notional lanes and (unless otherwise specified) $0,3 q_{rk}$ for the remaining area of the carriageway

(2) The uniformly distributed loads q_{rk} may be neglected when agreed for a specific project by the relevant parties.

NOTE The load values for Fatigue Load Model 1 are similar to those defined for the Load Model 1 with its frequent values. However adopting the Frequent Load Model without adjustment would have been excessively conservative by comparison with the other models, especially for large loaded areas.

(3) The maximum and minimum stresses ($\sigma_{FLM,max}$ and $\sigma_{FLM,min}$) should be determined from the possible load arrangements of the model on the bridge.

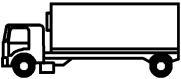
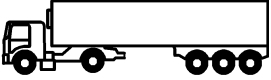
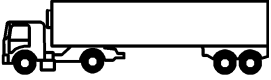
6.6.6 Fatigue Load Model 2 (set of “frequent” lorries)

(1) Fatigue Load Model 2 should be represented by a set of idealised lorries, called “frequent” lorries, (see Table 6.8).

(2) Each “frequent lorry” should be defined by:

- the number of axles and the axle spacing,
- the frequent load of each axle,
- the wheel contact areas and the transverse distance between wheels based on the wheel type as indicated in Table 6.10.

Table 6.8 — Set of “frequent” lorries

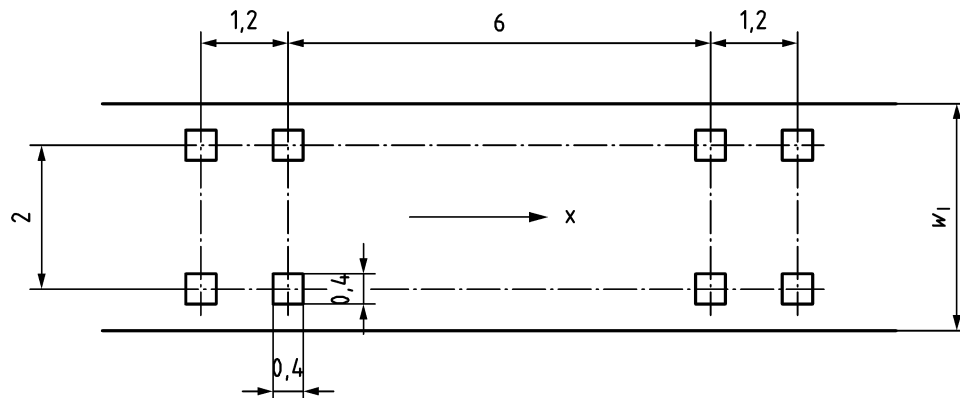
1	2	3	4
Lorry silhouette	Axle spacing m	Frequent axle loads kN	Wheel type (see Table 6.10)
	4,5	90	A
		190	B
	4,20 1,30	80	A
		140	B
		140	B
	3,20	90	A
	5,20	180	B
	1,30	120	C
	1,30	120	C
	1,30	120	C
	3,40	90	A
	6,00	190	B
	1,80	140	B
	1,80	140	B
	4,80	90	A
	3,60	180	B
	4,40	120	C
	1,30	110	C
	1,30	110	C

(3) The maximum and minimum stresses ($\sigma_{FLM, \max}$ and $\sigma_{FLM, \min}$) should be determined from the most severe effects of different lorries, separately considered, travelling alone along the appropriate lane. When some of these lorries are obviously the most critical, the others may be disregarded.

6.6.7 Fatigue Load Model 3 (single vehicle model)

- (1) The Fatigue Load Model 3 should be represented by four axles, each of them having two identical wheels (see Figure 6.8).
- (2) The weight of each axle should be equal to 120 kN, and the contact surface of each wheel as a square of side 0,40 m.

Dimensions in metres



Key

- w_l Lane width
 x Bridge lane direction

Figure 6.8 — Fatigue Load Model 3

- (3) The maximum and minimum stresses ($\sigma_{FLM, \max}$ and $\sigma_{FLM, \min}$) and the stress ranges for each cycle of stress fluctuation, i.e. their algebraic difference, resulting from the transit of the model along the bridge should be calculated.

- (4) Two vehicles representing Fatigue Load Model 3 may be taken into account in the same lane.

NOTE The conditions of application of this rule can be defined in the National Annex. Possible conditions are given hereafter:

- one vehicle is as defined in 6.6.7 (1) above;
- the geometry of the second vehicle is as defined in 6.6.7 (1) above and the weight of each axle is equal to 36 kN (instead of 120 kN);
- the distance between the two vehicles, measured from centre to centre of vehicles, is not less than 40 m.

6.6.8 Fatigue Load Model 4 (set of “standard” lorries)

- (1) Fatigue Load Model 4 should be represented by sets of standard lorries which together produce effects equivalent to those of typical traffic on European roads.

- (2) Each “standard” lorry should be defined by:

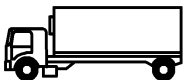
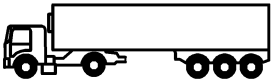
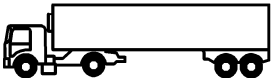
- the number of axles and the axle spacing,
- the equivalent load of each axle,

- the wheel contact areas and the transverse distances between wheels based on the wheel type as indicated in Table 6.10.

NOTE 1 The model shown in Table 6.9 (NDP), based on five standard lorries, simulates traffic which is deemed to produce fatigue damage equivalent to that due to actual traffic of the corresponding category defined in Table 6.7 (NDP).

NOTE 2 The National Annex can set other standard lorries and lorry percentages than those in Table 6.9.

Table 6.9 (NDP) — Set of equivalent lorries

Vehicle type			Traffic type			Wheel type
1	2	3	4	5	6	7
			Long distance*	Medium distance*	Local traffic*	
Lorry silhouette	Axle spacing m	Equivalent loads of each axle kN	Lorry percentage	Lorry percentage	Lorry percentage	
	4,5	70	20,0	40,0	80,0	A
		130				B
	4,20	70	5,0	10,0	5,0	A
	1,30	120				B
		120				B
	3,20	70	50,0	30,0	5,0	A
	5,20	150				B
	1,30	90				C
	1,30	90				C
		90				C
	3,40	70	15,0	15,0	5,0	A
	6,00	140				B
	1,80	90				B
		90				B
	4,80	70	10,0	5,0	5,0	A
	3,60	130				B
	4,40	90				C
	1,30	80				C
		80				C

Vehicle type			Traffic type			Wheel type
1	2	3	4	5	6	7
			Long distance*	Medium distance*	Local traffic*	
Lorry silhouette	Axle spacing m	Equivalent loads of each axle kN	Lorry percentage	Lorry percentage	Lorry percentage	
* For the selection of a traffic type, it can broadly be considered that: — “Long distance” means hundreds of kilometres, — “Medium distance” means 50 km to 100 km, — “Local traffic” means distances less than 50 km. In reality, mixture of traffic types can occur.						

Table 6.10 — Geometrical definition of wheels and axles

Dimensions in millimetres

Wheel/axle type	Geometrical definition
A	
B	
C	

(3) A set of standard lorries appropriate to the mixture of traffic types predicted for the route should be identified.

(4) The calculations should be based on the following procedure:

- the percentage of each standard lorry in the traffic flow should be selected from Table 6.9 (NDP) columns 4, 5 or 6 as relevant;
- the total number of vehicles per year to be considered for the whole carriageway ΣN_{obs} should be defined;

NOTE The total number of vehicles per year is given in Table 6.7 (NDP) for Fatigue Load Models 3 and 4, unless the National Annex gives different values.

— each standard lorry is considered to cross the bridge in the absence of any other vehicle.

(5) The stress range spectrum and the corresponding number of cycles from each fluctuation in stress during the passage of individual lorries on the bridge should be determined using the Rainflow or the Reservoir counting method (see EN 1990:2023, Annex F).

NOTE For verification rules, see EN 1992 series to EN 1999 series.

6.6.9 Fatigue Load Model 5 (based on recorded road traffic data)

(1) Fatigue Load Model 5 should be represented by the direct application of recorded traffic data, supplemented, if relevant, by appropriate statistical and projected extrapolations.

NOTE The use of Fatigue Load Model 5 can be set in the National Annex. Guidance for a complete specification and the application of Fatigue Load Model 5 is given in Annex B.

6.7 Collision and other actions for accidental design situations

6.7.1 General

(1) The following loads due to road vehicles in accidental design situations shall be taken into account where relevant:

- vehicle collision with bridge piers, soffit of bridge or decks (see 6.7.2),
- the presence of heavy wheels or vehicle on footways and cycle ways (see 6.7.3.1),
- vehicle collision with kerbs (see 6.7.3.2), vehicle restraint systems (see 6.7.3.3) and structural members (see 6.7.3.4).

(2) For bridges with weight limits indicated by road signs an accidental design situation should be considered with a load model corresponding to that representing the heaviest classes of vehicle permitted to use the bridge approach roads unless a physical obstacle prevents such vehicles from crossing the bridge.

NOTE Accidental loads corresponding to vehicles not respecting the load limits can be defined in the National Annex.

6.7.2 Collision forces from vehicles under the bridge

(1) Collision forces on piers, other supporting members, and on decks should be calculated in accordance with EN 1991-1-7.

6.7.3 Actions from vehicles on the bridge

6.7.3.1 Vehicle on footways and cycle ways on road bridges

(1) If footways and cycle ways are not protected by a vehicle restraint system with appropriate containment level, effects of heavy wheels or vehicle on footways shall be considered.

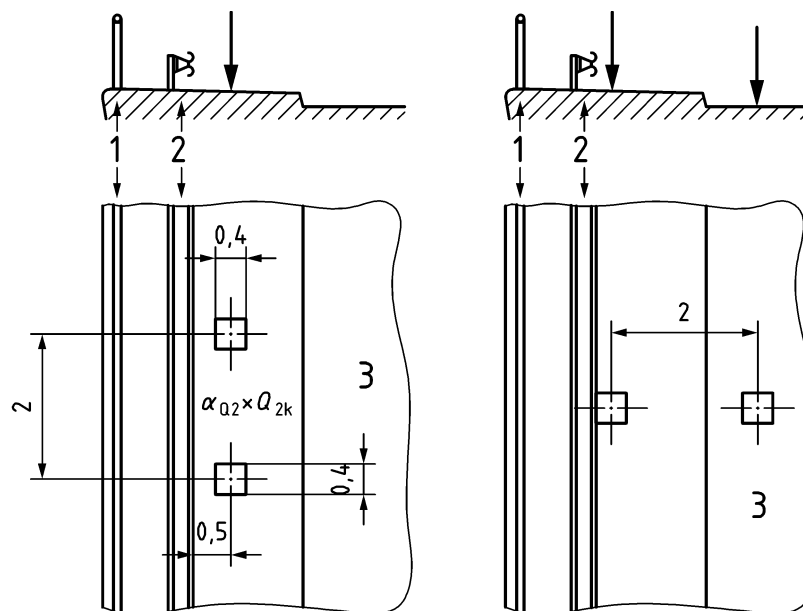
(2) If a safety barrier of an appropriate containment level is provided to protect footways and cycle ways on road bridges, the following should apply:

- Wheel or vehicle loading beyond this protection should not be taken into account.

- One accidental axle load corresponding to $\alpha_{Q2} Q_{2k}$ (see also 6.3.2) shall be placed and oriented on the unprotected parts of the deck to give the most adverse effect adjacent to the safety barrier (see for example Figure 6.9). The location of the axle load shall take into account the expected deformability of the restraint system.
- The accidental axle load should not be taken into account simultaneously with any other variable load on the deck; see also EN 1990:2023, A.2.
- If geometrical constraints make a two-wheel arrangement impossible, a single wheel alone should be taken into account.
- Beyond the vehicle restraint system, the characteristic variable concentrated load defined in 7.3.3 should be applied, if relevant, separately from the accidental load.

NOTE Containment levels for safety barriers are defined in EN 1317-2.

Dimensions in metres



Key

- 1 Pedestrian parapet (or vehicle parapet if a safety barrier is not provided)
- 2 Safety barrier
- 3 Carriageway

Figure 6.9 — Examples showing locations of loads from vehicles on footways and cycle ways of road bridges

(3) If a safety barrier of an appropriate containment level is not provided, the rules given in (2) are applicable up to the edge of the deck where a vehicle parapet is provided.

6.7.3.2 Collision forces on kerbs

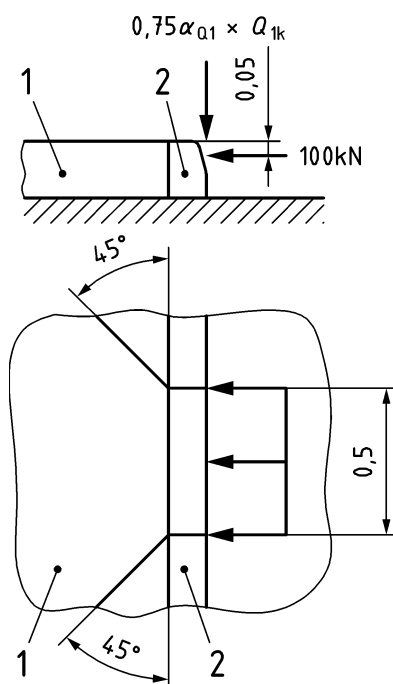
- (1) Effects of vehicle collision with kerbs shall be considered in all cases.
- (2) The action from vehicle collision with kerbs or pavement upstands should be taken as a lateral force equal to 100 kN acting at a depth of 0,05 m below the top of the kerb and on a line 0,5 m long (see

Figure 6.10). This force should be considered to be transmitted by the kerbs to the structural members supporting them.

(3) In rigid structural members, the load should be assumed to have an angle of dispersal of 45° (see Figure 6.10).

(4) When unfavourable, a vertical traffic load acting simultaneously with the collision force equal to $0,75 \alpha_{Q1} \times Q_{1k}$ (see Figure 6.10) should be taken into account.

Dimensions in metres



Key

- 1 Footway
- 2 Kerb

Figure 6.10 — Definition of vehicle collision forces on kerbs

6.7.3.3 Collision forces on vehicle restraint systems

(1) If vehicle parapets and safety barriers are provided on the bridge deck, effects of vehicle collision with such road restraints systems shall be considered.

NOTE The aim of the clauses in this chapter is to ensure adequate strength and robustness of anchorages, edge beams and bridge decks (cantilevered slabs) in order to prevent disproportionate damage caused by collision of road restraint systems that could require extensive repair and could cause unacceptable disturbance of the traffic operations.

(2) For local design, the structure supporting the vehicle parapet should be designed to sustain locally an accidental load effect arising from horizontal loading related to the characteristic local resistance of vehicle parapet (e.g. resistance of the connection of the parapet to the structure) and should not be combined with any other variable load.

NOTE Classes of characteristic capacities of restraint systems can be defined in the National Annex.