EUROCODE 1 : Basis of design
and actions on structures

Part 3 : Traffic loads on bridges

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

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Foreword

Objectives of the Eurocodes

(1) The Structural Eurocodes comprise a group of standards for the structural and geotechnical design of buildings and civil engineering works.

(2) They cover execution and control only to the extent that is necessary to indicate the quality of the construction products, and the standard of the workmanship, needed to comply with the assumptions of the design rules.

(3) Until the necessary set of harmonised technical specifications for products and for methods of testing their performance is available, some of the Structural Eurocodes cover some of these aspects in informative annexes.

Background to the Eurocode programme

(4) The Commission of the European Communities (CEC) initiated the work of establishing a set of harmonized technical rules for the design of building works and civil engineering works which would initially serve as an alternative to the different rules in force in the various Member States and would ultimately replace them. These technical rules became known as the 'Structural Eurocodes'.

(5) In 1990, after consulting their respective Member States, the CEC transferred the work of further development, issue and updating of the Structural Eurocodes to CEN, and the EFTA Secretariat agreed to support the CEN work.

(6) CEN Technical Committee CEN/TC 250 is responsible for all Structural Eurocodes.

Eurocode programme

(7) Work is in hand on the following Structural Eurocodes, each generally consisting of a number of Parts:

- EN 1991 Eurocode 1 Basis of design and 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 alloy structures

(8) A separate sub-committee has been formed by CEN/TC250 for each of Eurocodes listed above.
(9) This Part of ENV 1991, which has benefited from preliminary studies made by CEC and UIC (Union Internationale des Chemins de Fer), and has been finalised in accordance with a mandate issued by CEC, is being published as a European Prestandard with an initial life of three years.

(10) This Prestandard is intended for experimental application.

(11) After approximately two years CEN members will be invited to submit formal comments on this Prestandard to be taken into account in determining future action.

(12) Meanwhile feedback and comments on this Prestandard should be sent to the Secretariat of Sub-committee CEN/TC250/SC1 at the following address:

- until end May 1995: SNV / SIA Selnaustrasse 16 CH - 8039 ZURICH SWITZERLAND
- from June 1995: SIS / BST Box 5630 S - 11486 STOCKHOLM SWEDEN

or to your National Standards organisation.

**National Application Documents**

(13) In view of the responsibilities of authorities in member countries for safety, health and other matters covered by the essential requirements of the Construction Products Directive (CPD), certain safety elements in this ENV have been assigned indicative values which are identified by \[ \] or \[ \] ("boxed values"). The authorities in each member country are expected to review the "boxed values" and may substitute alternative definitive values for these safety elements for use in national application.

(14) Bridges are essentially public works, for which:

- the European Directive 89/440/CEC on contracts for public works is particularly relevant, and

- public authorities have responsibilities as owners.

In addition, public authorities also have responsibilities for the issue of regulations on authorised traffic (especially on vehicle loads) and for delivery and control dispensations when relevant, eg. for special vehicles. In this respect, it is assumed that the authorities having these responsibilities will cooperate closely with those responsible for the design and reassessment of bridges (see the clauses and Notes dealing with the basis and conditions of numerical validity of this Prestandard).
Within this context this Prestandard has been established with two main objectives:

- to be sufficiently precise and comprehensive for contractual use,

- to be sufficiently flexible to allow the relevant authorities and their designers fully to exert their technical responsibilities.

(15) Because of the responsibilities of public authorities for bridges, it has been anticipated that, for the application of this Part, it will be supplemented by:

- general complementary rules and options to be provided by National Application Documents (NAD - see (16) below) and

- complementary and/or modifying specifications for particular projects.

Wherever this Prestandard mentions "unless otherwise specified", it is intended that the relevant authorities (to be identified, if relevant, in the particular NADs) will remain free to intervene at either of the two levels above. It is the same where this Prestandard refers to the "client", if the client is not the relevant authority itself.

Information supplementing the Notes given in this Prestandard is given below to assist the preparation of the NADs.

(16) Some of the necessary supporting European or International Standards may not be available by the time this Prestandard is issued. It is therefore anticipated that a National Application Document (NAD) giving any mandatory values to be substituted for "boxed" values, referencing compatible supporting Standards and providing guidance on the national application of this Prestandard, will be issued by each member country or its Standards Organization.

(17) It is intended that this Prestandard will be used in conjunction with the particular NAD valid in the country in which the bridges are located.

**Matters specific to this Prestandard**

(18) The scope of Eurocode 1 is defined in clause 1.1.1 and the scope of this Part of Eurocode 1 is defined in clause 1.1.2. Additional Parts of Eurocode 1 which are planned are indicated in clause 1.1.3.

(19) This Prestandard is divided into six sections:

- three general sections 1 to 3 of common clauses
- three sections 4 to 6 dealing with road traffic loads, pedestrian and cycle loads, and railway traffic loads, respectively, and also with other loads specifically for road bridges, footbridges and railway bridges, respectively.

The limits of validity of the contents of these sections are defined. Beyond these limits, rules shall be given by NAD or specifically for particular projects.
Boxed values for partial load factors and $\psi$ factors are given in annexes C, D and G.

(20) The bases for combinations of traffic loads with non-traffic loads are introduced in section 3, and developed in annexes C, D and G. They are intended to be applied in conjunction with other Parts of ENV 1991 and with the Parts of ENV 1992 to 1995 which are relevant for bridges.

If necessary, the NADs may make complementary reference to other documents.

When traffic loads need to be considered which are not codified in this Prestandard (e.g. site loads, military loads, tramway loads) and which are not sufficiently treated in the NADs, complementary rules may be specified for particular projects.

Complementary rules may also be specified for bridges intended for both road and rail traffic.

Complementary rules will also often be necessary for accidental actions to be considered in design, see the notes in 2.3.

(21) Actions due to road traffic are represented in section 4 by a series of load models which represent different traffic and different components (e.g. horizontal forces) of traffic action. Specific models are given for verification relating to fatigue.

(a) Load Models 1 and 2, defined in 4.3, are considered (with adjustment factors $\alpha$ and $\beta$ equal to 1) to represent the most severe traffic met or expected in practice 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 Prestandard and the associated design codes ENV 1992 to 1995.

It is therefore recommended to the national authorities that values of the adjustment factors $\alpha$ be chosen for bridge design corresponding possibly to several classes of routes on which the bridges are located. Information on the numerical bases of Load Models 1 and 2 has already been issued and it is intended that further information will be provided in background documents.

It is recommended that the adjustment factors chosen are as few and simple as possible based on consideration of the national traffic regulations and the efficiency of the associated control. For the minimum of $\alpha_{Q1}$, it is also recommended that the boxed value $0.8$ specified in 4.3.2(7) is not reduced without a precise justification for the relevant country.

(b) Load Model 3 (special vehicles) is intended in this Prestandard to be taken into account only where and as far as specified by the relevant
authority. These decisions shall be supplemented, when relevant, by also specifying the associated traffic conditions, as mentioned in notes, and the degree of supervision provided by the police. In order to reduce as much as possible the diversity of such models in Europe, it is suggested that, in cases in which the relevant authority is selecting special vehicles for particular bridge designs, priority be given to special vehicles 900/150, 1800/200 and 3000/240 defined in annex A to section 4.

(c) Load Model 4 (crowd loading on road bridges) is also intended in this Prestandard to be taken into account only where specified by the relevant authority, especially for some bridges located in dense urban areas. It has been developed from observations during special events, eg. at the inauguration of important bridges.

(d) For verifications regarding fatigue, a series of alternative models is provided to be used depending on the verification level selected from the relevant design codes. Except in the simplest case where reference is made to Fatigue Load Model 1, the relevant authorities may, depending on the case and the expected traffic, have to:

- confirm or amend some numerical values given in this Prestandard and/or

- specify or approve complementary data for the use of the models, including traffic records.

(22) Actions due to pedestrian and cycle traffic are defined in section 5. Other actions, variable or accidental, specifically for footbridges are also defined. For these other actions, complementary data are required from the relevant authorities and decisions are needed by them, for a part to be specified in the NAD, and, for the remainder, for the particular projects.

In the few cases in which a dynamic analysis should be performed, appropriate load models should be taken.

(23) Actions due to rail traffic are defined in section 6 by reference to two Load Models 71 and SW relating to the two main types of traffic. Associated actions including dynamic effects, braking and traction forces, centrifugal forces, nosing force, and certain specific requirements are covered by means of factors, equations, diagrams or tables. Load spectra are given for the purpose of carrying out fatigue checks.

(a) Load Model 71, defined in 6.3.2, represents the static effect of standard rail traffic operating over the standard-gauge or wide-gauge European mainline-network.

(b) Load Models SW, defined in 6.3.3, represent the static effect of heavy rail traffic. Two load classifications, SW/0 and SW/2, are considered. The relevant authority is required to specify the lines, or sections of lines, over which such loads shall be taken into account.
(c) 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 $\alpha$, to be specified by the relevant authority, for lines carrying rail traffic which is heavier or lighter than the standard (see 6.3.2(3)P).

(d) 6.4 gives detailed rules for the assessment of dynamic effects on bridges created by rail traffic. Generally, such effects may be adequately covered by the use of a dynamic amplification factor. In some cases, however, where there is the possibility of resonance or excessive vibrations of the deck, a specific check will be required. This is more likely for very high speed traffic.

Note: For such specific check see annex H.

(e) For the consideration of centrifugal forces, it is necessary to make provision in the rules for the fact that heavy traffic does not operate at high speeds whereas high speed passenger trains have light axle loading. Centrifugal forces depend on the loaded length of the bridge and on the maximum permissible speed. These variables are taken into account by multiplying Load Model 71 by a factor $f$, for which values and specific application rules are given in 6.5.1.

(f) Fatigue Models for steel bridges are based on specified load spectra for which results are presented in terms of a reference loading (Load Model 71) which is multiplied by a factor $\lambda$ to take into account the effect of the load spectra passing over influence lines of various lengths. This factor is defined in terms of the span length of the structural member being considered, the tonnage of traffic crossing the bridge and the specified life of the structure.

Two main traffic combinations, based on the twelve reference service trains identified, are specified in annex F. Values of the factor $\lambda$ have been defined for a range of spans and will be included in ENVs 1992 to 1994.

(g) Unless the track over the bridge is separated at each end by means of an adjustment switch, the interaction between the track and the bridge will produce additional forces. Requirements for limiting these forces and taking them into account are given in 6.5.4.

(h) For railway bridges, the deformations and vibrations caused by the passage of rail traffic have to be limited for safety considerations and passenger comfort. Principles and application rules dealing with these requirements are given in annex G.

Note: See also annex H.
Section 1  General

1.1 Scope

1.1.1 Scope of ENV 1991 - Eurocode 1

(1) ENV 1991 provides general principles and actions for the structural design of building and civil engineering works including some geotechnical aspects and shall be used in conjunction with ENV 1992-1999.

(2) It may also be used as a basis for the design of structures not covered in ENV 1992-1999 and where other materials or other structural design actions are involved.

(3) ENV 1991 also covers structural design for construction conditions and structural design for temporary structures. It relates to all circumstances in which a structure is required to give adequate performance.

(4) ENV 1991 is not directly intended for the structural appraisal of existing construction, in developing the design of repairs and alterations, or for assessing changes of use, but may be so used where applicable.

(5) ENV 1991 does not completely cover special design situations which require unusual reliability considerations such as nuclear structures for which other specified design procedures should be used.

1.1.2 Scope of ENV 1991-3 - Traffic loads on bridges

(1) Part 3 of ENV 1991 specifies imposed loads (models and representative values) associated with road traffic, pedestrian actions and rail traffic which include, when relevant, dynamic effects and centrifugal, braking, acceleration and accidental forces.

(2) Section 1 defines common definitions and notation.

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

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

(5) Section 4 specifies:

- Imposed loads (models and representative values) due to the 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.
(6) Section 5 specifies:

- Imposed loads (models and representative values) associated with pedestrian and cycle actions on road bridges, footbridges and railway bridges.

- Other actions specifically for the design of footbridges.

(7) Sections 4 and 5 also specify loads on parapets.

(8) Section 6 specifies:

- Imposed actions due to rail traffic on bridges;

- Other specific actions which railway bridges shall be designed to sustain.

1.1.3 Further Parts of ENV 1991

(1) Further Parts of ENV 1991 which, at present, are being prepared or planned are given in 1.2.

1.2 Normative references

This European Prestandard incorporates by dated or undated reference, provisions from other standards. These normative references are cited at the appropriate places in the text and publications listed hereafter.

ISO 3898 1987  Basis of design for structures
Notations. General symbols.

Note: The following European prestandards which are published or in preparation are cited at the appropriate places in the text and publications listed hereafter.

ENV 1991-1  Eurocode 1 : Basis of design and actions on structures
Part 1 : Basis of Design

ENV 1991-2-1  Eurocode 1 : Basis of design and actions on structures
Part 2.1 : Densities, self-weight and imposed loads

ENV 1991-2-2  Eurocode 1 : Basis of design and actions on structures
Part 2.2 : Actions on structures exposed to fire

ENV 1991-2-3  Eurocode 1 : Basis of design and actions on structures
Part 2.3 : Snow loads

ENV 1991-2-4  Eurocode 1 : Basis of design and actions on structures
Part 2.4 : Wind loads

ENV 1991-2-5  Eurocode 1 : Basis of design and actions on structures
Part 2.5 : Thermal actions

ENV 1991-2-6  Eurocode 1 : Basis of design and actions on structures
Part 2.6 : Loads and deformations imposed during execution
1.3 Distinction between principles and application rules

(1) Depending on the character of the individual clauses, distinction is made in this Part 3 of ENV 1991 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.

(4) The application rules are generally recognised rules which follow the principles and satisfy their requirements.

(5) It is permissible to use alternative rules different from the application rules given in this Eurocode, provided it is shown that the alternative rules accord with the relevant principles and have at least the same reliability.

(6) In this Part 3 of ENV 1991 the application rules are identified by a number in brackets, e.g. as this clause.
1.4 Definitions

For the purposes of this prestandard, a basic list of definitions is provided in ENV 1991-1, “Basis of design” and the additional definitions given below are specific to this Part.

1.4.1 Harmonized terms and common definitions

1.4.1.1 Deck (tablier, Überbau) : The parts of a bridge over piers, abutments and other walls, pylons being excluded.

1.4.1.2 Road restraint systems (dispositifs de retenue, Leiteinrichtungen):

Note: These terms may be revised at a later stage depending on the final versions, in three languages, of Standards in progress in CEN/TC 226.

(i) Road restraint systems are all systems intended to retain road vehicles and/or pedestrians on roads, bridges or other construction works.

(ii) Road vehicle restraint systems are systems installed to provide a level of containment for an errant vehicle and may be used to limit damage or injury to users of the road and others in the vicinity.

(iii) Road vehicle 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).

1.4.1.3 Safety barrier (barrière ou glissière, Absturzsicherung) : Safety barriers are road vehicle restraint systems installed alongside, or on the central reservation, of a road or a bridge (or other construction works).

1.4.1.4 Parapets (garde-corps, Geländer) : Parapets are road restraint systems intended to retain pedestrians on bridges or other construction works.

1.4.1.5 Noise barrier (écran anti-bruit, Lärmschutzwand) : A noise barrier is a screen to reduce transmission of noise.

1.4.1.6 Inspection gangway (passerelle fixe de visite, Besichtigungssteg): An inspection gangway is a permanent access for inspection, not open for public traffic.
1.4.1.7 Movable inspection platform (plateforme mobile de visite, Besichtigungswagen): Part of a vehicle, distinct from the bridge, used for inspection.

1.4.1.8 Footbridge (passerelle, Fussgängerbrücke): A footbridge is a bridge intended mainly to carry pedestrian and/or cycle-track loads, and on which neither normal road traffic loads nor any railway load are permitted.

1.4.2 Terms and definitions specifically for road bridges

1.4.2.1 Carriageway (chaussée, Fahrbahn): The carriageway is, for application of sections 4 and 5, defined as the part of the road surface, supported by a single structure (deck, pier,...), which includes all physical traffic lanes (ie. as may be marked on the road surface), hard shoulders, hard strips and marker strips. Its width, \( w \), is measured between kerbs, if the height of the kerbs is greater than 100 mm, or between the inner limits of safety barriers in all other cases. Unless otherwise specified for a particular project, the carriageway width does not include the distance between fixed safety barriers or kerbs of a central reservation nor the widths of these barriers.

1.4.2.2 Hard shoulder (bande d'arrêt, Standstreifen): A hard shoulder is a strip, at least 2 m wide, located alongside a physical traffic lane at the outside part of the carriageway, for use in emergency.

1.4.2.3 Hard strip (bande dérasée, Bankette): A hard strip is a strip, less than 2 m wide, located alongside a physical traffic lane, and between this traffic lane and a safety barrier.

1.4.2.4 Central reservation (terre-plein central, Mittelstreifen): 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 lanes (voies, Fahrstreifen): A notional lane is a 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 (aire résiduelle, Restfläche): The remaining area is, if relevant, the difference 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 (tandem, Doppelachslast): A tandem system is an assembly of two consecutive axles considered to be simultaneously loaded.
1.4.3 Terms and definitions specifically for railway bridges

1.4.3.1 Tracks (voies, Gleise): The 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 Footpaths (passages de service, Dienstwege): Footpaths are strips located alongside the tracks, between the tracks and the parapets.

1.5 Notation

For the purpose of this Prestandard, the following notation applies.

Note: The notation used is based on ISO 3898:1987

1.5.1 Common notation

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

*Latin upper case letters*

- \(A_{\text{ref}}\): reference area for the determination of wind effects.
- \(F_W\): wind force.
- \(F_{Wk}\): characteristic wind force.
- \(F_{Wn}\): nominal wind force.
- \(L_s\): in general, length of a span.
- \(L_{sj}\): length of span number \(j\).
- \(r\): horizontal radius of a carriageway or track centre-line, distance between wheel loads (6.3.1(3)P).
- \(S_n\) (or \(S\)): snow load.
- \(T\): thermal climatic action.
- \(T_k\): a group of thermal components, which for many bridges is limited to uniform and gradient components (characteristic value). In other cases more complex groups have to be distinguished (eg. for railway bridges with continuous welded rails and for bridges with stays).

*Latin lower case letters*

- \(g_{ri}\): group of loads, \(i\) is number (\(i = 1\) to \(n\))
Greek lower case letters

\( \gamma_G \) partial factor for permanent actions

\( \gamma_Q \) partial factor for variable actions

\( \psi_0 \) reduction factor for combination values of loads.

\( \psi'_1 \) reduction factor for infrequent loads (see 2.2(2)).

\( \psi_1 \) reduction factor for frequent loads.

\( \psi_2 \) reduction factor for quasi-permanent loads.

1.5.2 Notation specifically for sections 4 and 5

Latin upper case letters

\( F_W^* \) wind force compatible with road traffic.

\( Q_{ak} \) characteristic value of a single axle load (Load Model 2) for a road bridge (see 4.3.3).

\( Q_{fk} \) characteristic horizontal force on a footbridge.

\( Q_{fwk} \) characteristic value of the concentrated load (wheel load) on a footbridge (see 5.3.2).

\( Q_{lk} \) magnitude of characteristic axle load (Load Model 1) on notional lane number \( i \) (\( i=1,2,... \)) of a road bridge.

\( Q_{lk} \) magnitude of the characteristic longitudinal forces (braking and acceleration forces) on a road bridge.

\( Q_{tik} \) magnitude of the characteristic transverse or centrifugal forces on road bridges.

TS tandem system for Load Model 1.

UDL uniformly distributed load for Load Model 1.

Latin lower case letters

\( n_l \) 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 $i$ ($i=1,2...$) 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 1.4.2).

$w_l$ 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(7)).

**Greek lower case letters**

$\alpha_{Qi}, \alpha_{qi}$ adjustment factors of some load models on lanes $i$ ($i=1,2...$), defined in 4.3.2.

$\alpha_{qr}$ adjustment factor of load models on the remaining area, defined in 4.3.2.

$\beta_Q$ adjustment factor of Load Model 2 defined in 4.3.3.

$\phi_{fat}$ dynamic amplification factor for fatigue (see annex B to section 4).

### 1.5.3 Notation specifically for section 6 (see Figure 1.1)

![Figure 1.1](image-url)

**Figure 1.1** : Notation and dimensions specifically for railways

**Latin upper case letters**

$A$ area of rail cross-section.
$F_T$ interaction force due to temperature.

$F_W$ wind force compatible with railway traffic.

$F_D$ interaction force transferred to the bearings (general).

$F_{la}$ interaction force due to traction (acceleration).

$F_{lb}$ interaction force due to braking.

$F_δ$ interaction force due to deflection.

$G$ self-weight (general).

$L$ length (general).

$L_T$ expansion length.

$L_i$ influence length.

$L_Φ$ "determinant" length (length associated with $Φ$).

$Q$ rail traffic action (general).

$Q_h$ horizontal force (general).

$Q_{la}$ traction (acceleration) force

$Q_{lb}$ braking force

$Q_r$ resulting action (general).

$Q_S$ nosing force.

$Q_t$ centrifugal force.

$Q_V$ vertical axle load.

$Q_{vi}$ wheel load.

$V$ speed in km/h.

$V_R$ resistance of the rail to longitudinal displacement.

*Latin lower case letters*
a  distance between rail supports, length of distributed loads (Load Models SW).

\( a_g \)  horizontal distance to the track centre.

\( b \)  length of the longitudinal distribution of a load by sleeper and ballast.

\( c \)  space between distributed loads (Load Models SW).

\( c_p \)  aerodynamic coefficient.

\( d \)  regular spacing of axles.

\( e \)  eccentricity of vertical loads, eccentricity of resulting action (on reference plane).

\( f \)  reduction factor, force, centrifugal force.

\( g \)  acceleration due to gravity.

\( h \)  height (general).

\( h_g \)  vertical distance from rail level to the underside of a structure.

\( k_1 \)  train shape coefficient.

\( k_2 \)  specific factor for slipstream effects on vertical surfaces parallel to the tracks.

\( k_3 \)  reduction factor for slipstream effects on simple horizontal surfaces adjacent to the track.

\( k_4 \)  increasing factor of slipstream effects on surfaces enclosing the tracks (horizontal actions).

\( k_5 \)  increasing factor of slipstream effects on surfaces enclosing the tracks (vertical actions).

\( n_0 \)  natural frequency of the unloaded bridge.

\( q_{Ai} \)  accidental line load.

\( q_f \)  footpath loading.

\( q_i \)  equivalent distributed loads from slipstream effects.

\( q_N \)  vertical distributed load.
\(s\) gauge.

\(t\) twist (changing of cant over 3m).

\(u\) cant.

\(v\) speed in m/sec.

**Greek upper case letters**

\(\Theta\) end rotation of structure (general).

\(\Phi(\Phi_2,\Phi_3)\) dynamic factor for railway loads.

**Greek lower case letters**

\(\alpha\) load classification factor ; coefficient for speed.

\(\delta\) deformation (general) ; vertical deflection.

\(\delta_h\) horizontal displacement.

\(\rho\) density.

\(\sigma\) stress.

\(\varphi,\phi',\phi''\) dynamic impact components for actual trains.
Section 2 Classification of actions

2.1 General

(1) The relevant traffic actions and other specific actions on bridges are classified below in accordance with ENV 1991-1 "Basis of design", section 4 (4.1).

(2) Traffic actions on road bridges, footbridges and railway bridges consist of variable and accidental actions, which are represented by various models.

(3) All traffic actions are classified as free actions (see ENV 1991-1, 1.5.1(4) and 4.1(2)P-ii), within limits specified in sections 4 to 6.

(4) Traffic actions are multi-component actions (see ENV 1991-1, 4.1(7) and 4.8(15)).

2.2 Variable actions

(1) For normal conditions of use (ie. 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, ie. corresponding to a limited probability of being exceeded on a bridge during its normal design working life, or nominal, see ENV 1991-1 clause 4.2(7);

- infrequent values;

- frequent values;

- quasi-permanent values.

Note : Infrequent values are intended to correspond approximately to a mean return period of one year. Frequent values are intended to correspond approximately to a mean return period of one week.

(3) For verification with regard to fatigue, 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 Accidental actions

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

Note : A protection cannot be considered to be appropriate if the conditions specified by the relevant authority are not satisfied.
(2) Accidental actions described in this Part refer to the common situations. They are represented by various load models defining design values (i.e. to be used with $\gamma_A = 1.0$) in the form of static loads. The load models and values given in this Part are intended for bridges, and, unless otherwise specified, for retaining walls adjacent to roads and railway lines.

Note: For some models only, applicability conditions are defined in this Part. Complementary conditions, where applicable, should be specified by the relevant authorities, for a particular project or in a more general manner.

(3) Collision forces due to road vehicles under road and railway bridges are defined in 4.7.2 (see 5.6.2 for footbridges).

(4) Collision forces due to boats, ships or airplanes, for road and railway bridges (e.g. over canals and navigable water), are not covered by this Part.

Note: These forces should be taken into account, when relevant, as specified or agreed by the relevant authority.

(5) Accidental actions due to road vehicles on road bridges and footbridges are defined in 4.7.3 and 5.6.3 respectively.

(6) Accidental actions due to trains or rail traffic equipment are defined in 6.7.
Section 3  Design situations

(1)P The general format given in ENV 1991-1 for design procedures is applicable.

Note: This does not mean that clauses and values specified for buildings in ENV 1991-1 may be applied to bridges.

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

(3) Generally, the various traffic loads to be considered as simultaneous are represented by groups of loads (combinations of action components, as given in the following sections); each of which is to be considered in design calculations, where relevant, (see ENV 1991-1, 4.2(15) and annexes C, D and G).

(4)P The combination rules depend on the verification under consideration and shall be identified in accordance with ENV 1991-1 "Basis of design" and in accordance with annexes C, D and G.

(5) Specific rules for the simultaneity with other actions for road bridges, footbridges, and railway bridges are given in annexes C, D and G.

(6)P For bridges intended for both road and rail traffic, the simultaneity of actions and the particular required verifications shall be specified or agreed by the client.

(7) For seismic combinations for bridges and associated rules, see ENV1998-2.
Section 4  Road traffic actions and other actions specifically for road bridges

4.1 Field of application

(1) Unless otherwise specified, this section should be applied only for the design of road bridges with:

- Individual span lengths less than 200 m, and with
- Carriageway widths not greater than 42 m.

For bridges having larger dimensions, traffic loads should be defined or agreed by the client.

Note: For span lengths exceeding 200 m, the main models for characteristic values are considered to be conservative.

(2) The models and associated rules are intended to cover all normally foreseeable design 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).

For bridges equipped with appropriate road signs intended to strictly limit the weight of any vehicle (e.g. for local, agricultural or private roads), specific models may be used.

Load models on embankments are defined separately (see 4.9).

Note: The specific models mentioned above should be defined or agreed by the relevant authority.

(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.

(2) The load models defined in this section do not describe actual loads. They have been selected so that their effects (with dynamic amplification included unless otherwise specified) represent the effects of the actual traffic. Where traffic outside the scope of the load models specified in this section needs to be considered, then complementary load models, with associated combination rules, should be defined or agreed by the client.
Note 1 : The dynamic amplification factor included in the models (fatigue excepted), although established for a medium roughness of the pavement (see annex B to section 4) and normal vehicle suspension, depends on various parameters. In the most unfavourable cases it may reach 1.7. However still more unfavourable values might be reached for poorer pavement roughnesses, or if there is a risk of resonance. These cases should be avoided by appropriate quality and design measures. Therefore, it is only in exceptional cases, for particular verifications (see 4.6.1.(7)) or for particular projects that an adjustment of the included amplification should be made.

Note 2 : For military convoys, the routes and verification rules for road bridges located on these routes are defined by the relevant authority.

(3) Separate models are defined below for vertical, horizontal, accidental and fatigue loads.

(4) For the sake of simplicity, the load models defined for embankments adjacent to road bridges are intended for the design and verification of abutments. They are deduced from the road traffic models without any correction for dynamic effects (see 4.9).

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 justify the use of load models suited to the location of a bridge. Some classifications are defined in this section (e.g. classes of special vehicles introduced in 4.3.4). Others are only suggested for further decision (e.g. choice of adjustment factors $\alpha$ and $\beta$ defined in 4.3.2(7) for the main model and in 4.3.3 for the single axle model) and may be presented as loading classes (or traffic classes).

Note : However, because of the variety of parameters, having very different consequences depending on the location of individual bridges (e.g. in urban, rural or industrial areas), a unique set of such classes associated with all aspects should not be decided without a detailed examination of all consequences.

4.2.3 Divisions of the carriageway into notional lanes

(1) The widths $w_l$ of notional lanes on a carriageway and the greatest possible whole (integer) number $n_l$ of such lanes on this carriageway are shown in Table 4.1.
Table 4.1 : Number and width of lanes

<table>
<thead>
<tr>
<th>Carriageway width &quot;w&quot;</th>
<th>Number of notional lanes</th>
<th>Width of a notional lane</th>
<th>Width of the remaining area</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w &lt; 5.4 \text{ m} )</td>
<td>( n_l = 1 )</td>
<td>3 m</td>
<td>( w - 3 \text{ m} )</td>
</tr>
<tr>
<td>( 5.4 \text{ m} \leq w &lt; 6 \text{ m} )</td>
<td>( n_l = 2 )</td>
<td>( \frac{w}{2} )</td>
<td>0</td>
</tr>
<tr>
<td>( 6 \text{ m} \leq w )</td>
<td>( n_l = \text{Int}\left(\frac{w}{3}\right) )</td>
<td>3 m</td>
<td>( w - 3 \times n_l )</td>
</tr>
</tbody>
</table>

Note : For example, for a carriageway width of 11 m, \( n_l = \text{Int}\left(\frac{11}{3}\right) = 3 \), and the width of the remaining area is \( 11 - 3 \times 3 = 2 \text{ m} \).

(2) For variable carriageway widths, the number of notional lanes is defined in accordance with the principles used for Table 4.1. The number of notional lanes will be:

- 1 where \( w < 5.4 \text{ m} \)
- 2 where \( 5.4 \text{ m} \leq w < 9 \text{ m} \)
- 3 where \( 9 \text{ m} \leq w < 12 \text{ m} \)

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

(a) each part, including all hard shoulders or strips, is separately divided into notional lanes if the parts are separated by a fixed safety barrier;

(b) the whole carriageway, central reservation included, is divided into notional lanes if the parts are separated by demountable safety barriers or another road restraint system.

NOTE : A departure from these rules may be justified depending on envisaged future modifications of the traffic lanes on the deck.

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 are not necessarily related to their numbering.

(2) For each individual verification (e.g. for a verification of the ultimate limit states 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; see however clause 4.3.4(3a).
(3) However, for infrequent, frequent and fatigue representative values and models, the location and the numbering of the lanes may be specified for particular projects to correspond to the traffic conditions normally expected. For characteristic values, departures of location and numbering from (2) above may only be specified for particular projects where it can be shown that they result in effects approximating to the most adverse, or by the client.

(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, et cetera (see Figure 4.1).

![Example of the Lane Numbering in the most general case.](image)

(5) Where the carriageway consists of two separate parts on the same deck, only one numbering is used for the whole carriageway. Hence, even if the carriageway is divided into two separate parts, there is only one Lane Number 1, which can be alternatively on the two parts.

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

[[NOTE: This rule provides conservative results, especially for frequent values and for fatigue verifications based on Fatigue Load Model 1.]]

On the remaining area, the associated load model is applied on such lengths and widths such that the most adverse effect is obtained, as far as this is compatible with particular conditions specified below.

[[NOTE: When relevant, the various loading 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 ENV 1991-1, 9.4.2 and 9.5.2, and ENV 1992 to 1995).

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

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

(b) Load Model 2: A single axle load applied on specific tyre contact areas which covers the dynamic effects of the normal traffic on very short structural elements. This model should be separately considered and is only intended for local verifications.

(c) Load Model 3: A set of assemblies of axle loads representing special vehicles (eg. for industrial transport) which may travel on routes permitted for abnormal loads. This model is intended to be used only when and as far as required by the client, for general and local verifications.

(d) Load Model 4: A crowd loading. This model should be considered only when required by the client. It is intended only for general verifications.

NOTE: This crowd loading may be usefully specified by the relevant authority for bridges located in or near towns if its effects are not obviously covered by Load Model 1.

(3) Load Models 1 and 2 are defined numerically for persistent situations and are to be considered for any type of design situation (e.g. for transient situations during repair works).

(4) Load Models 3 and 4 are defined only for some transient design situations.

Note: See annex C. Design situations are specified as far as necessary in design Eurocodes and/or in particular projects, in accordance with definitions and principles given in ENV 1991-1. Combinations for persistent and transient situations may be numerically different.

4.3.2 Main loading system (Load Model 1)

(1) The main loading system consists of two partial systems:

(a) Double-axle Concentrated Loads (tandem system: TS), each axle having a weight:

\[ \alpha_Q Q_k \]  

where:

\[ \alpha_Q \] are adjustment factors (see (2) and (7)).
No more than one tandem system should be considered per lane; only complete tandem systems shall be considered. Each tandem system should be located in the most adverse position in its lane (see however (4) below and Figure 4.2). Each axle of the tandem model has two identical wheels, the load per wheel being therefore equal to $0,5\alpha Q_k$. The contact surface of each wheel is to be taken as square and of side 0,40 m (see Figure 4.2).

(b) Uniformly Distributed Loads (UDL system), having a weight density per square metre:

$$\alpha q_k$$  

where:

$\alpha q$ are adjustment factors (see (2) and (7)).

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

(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 $\alpha Q_i Q_k$ and $\alpha q_i q_k$ (see Table 4.2). On the remaining areas, the load magnitude is referred to as $\alpha q r q_{rk}$.

(3) Unless otherwise specified, the dynamic amplification is included in the values for $Q_{lk}$ and $q_{lk}$.

(4) For the assessment of general effects, the tandem systems may be assumed to travel along the axes of the notional lanes.

(5) The values of $Q_{lk}$ and $q_{lk}$ are given in Table 4.2.

<table>
<thead>
<tr>
<th>Location</th>
<th>Tandem system</th>
<th>UDL system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Axle loads $Q_{lk}$ (kN)</td>
<td>$q_{lk}$ (or $q_{rk}$) (kN/m$^2$)</td>
</tr>
<tr>
<td>Lane Number 1</td>
<td>300</td>
<td>9</td>
</tr>
<tr>
<td>Lane Number 2</td>
<td>200</td>
<td>2,5</td>
</tr>
<tr>
<td>Lane Number 3</td>
<td>100</td>
<td>2,5</td>
</tr>
<tr>
<td>Other lanes</td>
<td>0</td>
<td>2,5</td>
</tr>
<tr>
<td>Remaining area</td>
<td>0</td>
<td>2,5</td>
</tr>
</tbody>
</table>

The details of Load Model 1 are illustrated in Figure 4.2.
Figure 4.2 : 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 location of Lane 1 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.

(6) Where general and local effects can be calculated separately, and unless otherwise specified by the client, the general effects may be calculated:

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

\[(200 \alpha Q_2 + 100 \alpha Q_3) \text{ kN, or} \]

(4.3)

Note: The relevant authorities may restrict the application of this simplification.

b) for span lengths greater than \(10 \text{ m}\), by replacing each tandem system in each lane by a one-axle concentrated load of weight equal to the total weight of the two axles.

NOTE: The relevant authorities may restrict the application of this simplification. The single axle weight is:

- \(600 \alpha Q_1 \text{ kN on Lane Number 1}\)
- \(400 \alpha Q_2 \text{ kN on Lane Number 2}\)
- \(200 \alpha Q_3 \text{ kN on Lane Number 3}\)
(7) The values of the factors $\alpha_{Q1}$, $\alpha_{qi}$, and $\alpha_{qr}$ (adjustment factors) may be different for different classes of route or of expected traffic. In the absence of specification these factors are taken equal to one. In all classes, for bridges without road signs restricting vehicle weights,

$$\alpha_{Q1} \geq 0.8$$

and

$$\alpha_{qi} \geq 1$$

for $i \geq 2$; this restriction is not applicable to $\alpha_{qr}$.

Note: $\alpha_{Q1}$, $\alpha_{qi}$, and $\alpha_{qr}$ factors other than one should be used only if they are chosen or agreed by the relevant authority.

### 4.3.3 Single axle model (Load Model 2)

(1) This model consists of a single axle load $\beta Q \cdot Q_{ak}$ 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 $200 \beta Q$ (kN) may be considered. Unless otherwise specified, $\beta Q$ is equal to $\alpha_{Q1}$.

(2) Unless it is specified to adopt for the wheels the same contact surface as for Load Model 1, the contact surface of each wheel is a rectangle of sides 0.35 m and 0.60 m as shown in Figure 4.3.

![Figure 4.3: Load Model 2](image)

### 4.3.4 Set of models of special vehicles (Load Model 3)

(1) When one or more of the standardized models of this set is required by the client to be taken into account, the load values and dimensions should be as described in annex A.

Note 1: For $\alpha_{Q1}$ and $\alpha_{qi}$ factors all equal to one, the effects of the 600/150 standardized model are covered by the effects of the main loading system and do not need to be considered.

Note 2: The client may also specify particular models, especially to cover the effects of exceptional loads with a gross weight exceeding 3600 kN.
(2) The characteristic loads associated with the special vehicles should be taken as nominal values and should be considered as associated solely with transient design situations.

(3) Unless otherwise specified:

(a) Each standardized model is applicable on one notional traffic lane as defined in 1.4.2 and 4.2.3 (considered as Lane Number 1) for the models composed of 150 or 200 kN axles, or on two adjacent notional lanes (considered as Lane Numbers 1 and 2 - see Figure 4.4) for models composed of heavier axles. The lanes are located as unfavourably as possible in the carriageway. For this case, the carriageway width may be defined as excluding hard shoulders, hard strips and marker strips.

(b) Special vehicles simulated by the models are assumed to move at low speed (not more than 5 km/h); only vertical loads without dynamic amplification have therefore to be considered.

(c) Each notional lane and the remaining area of the bridge deck are loaded by the main loading system with its frequent values defined in 4.5 and in annex C. On the lane(s) occupied by the standardized vehicle, this system should not be applied at less than 25 metres from the outer axles of the vehicle under consideration (see Figure 4.5).
Figure 4.5: Simultaneity of Load Models 1 and 3

Note: Only the relevant authority may choose a more favourable transverse position for some special vehicles and restrict the simultaneous presence of general traffic. The authority may authorize vehicle speeds greater than 5 km/h if the associated dynamic amplification and horizontal forces are specified.

4.3.5 Crowd loading (Load Model 4)

Crowd loading, if relevant, is represented by a nominal load (which includes dynamic amplification) which is the characteristic load specified in 5.3.2-(1). Unless otherwise specified, it 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, is associated solely with a transient situation.

4.3.6 Dispersal of concentrated loads

(1) The various concentrated loads to be considered for local verifications, associated with Load Models 1, 2 and 3, are assumed to be uniformly distributed on their whole contact area.

(2) The dispersal through the pavement and concrete slabs is taken at a spread-to-depth ratio of 1 horizontally to 1 vertically down to the level of the centroid of the structural flange below (Figure 4.6).

Figure 4.6: Dispersal of concentrated loads through pavement and slabs

Note: In the case of dispersal through backfill or earth, see the Note in 4.9.1.
(3) The dispersal through the pavement and orthotropic decks is 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 below (Figure 4.7).

![Figure 4.7: Dispersal of concentrated loads through pavement and orthotropic decks](image)

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

4.4 Horizontal forces - characteristic values

Note: Unless required by the relevant authority, it is not necessary to consider lateral forces from skew braking or skidding. A minimum lateral loading results from the effects of the wind and of collision on kerbs. The horizontal forces to be taken into account, defined below, are horizontal braking and acceleration forces, considered longitudinal, and, when relevant, centrifugal transverse forces.

4.4.1 Braking and acceleration forces

(1) A braking force, denoted by $Q_{lk}$, shall be taken as a longitudinal force acting at the finished carriageway level.

(2) The characteristic value of $Q_{lk}$, limited to 800 kN for the total width of the bridge, should be calculated as a fraction of the total maximum vertical loads corresponding to the main loading system likely to be applied on Lane Number 1, as follows:

$$Q_{lk} = 0.6 \alpha Q_1 (2Q_{1k}) + 0.10 \alpha_q q_{1k} w_l L$$

$$180 \alpha Q_1 \text{kN} \leq Q_{lk} \leq 800 \text{kN} \quad (4.6)$$

where:

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

Note: For example, $Q_{lk} = 360 + 2.7L$ (≤ 800 kN) for a 3m wide lane and for a loaded length $L > 1.2$ m, if $\alpha$ factors are equal to one.

(3) 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 axis of carriageway. It may be considered as uniformly distributed over the loaded length.
(4) Unless otherwise specified, acceleration forces should be taken into account with the same magnitude as braking forces, but in the opposite direction.

Note: Practically this means that $Q_{tk}$ may be negative as well as positive.

### 4.4.2 Centrifugal forces

(1) The centrifugal force, denoted by $Q_{tk}$, 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, is defined in Table 4.3.

**Table 4.3: Characteristic values of centrifugal forces**

<table>
<thead>
<tr>
<th>$Q_{tk}$</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.2Q_v$ (kN)</td>
<td>if $r &lt; 200$ m</td>
</tr>
<tr>
<td>$40Q_v / r$ (kN)</td>
<td>if $200 \leq r \leq 1500$ m</td>
</tr>
<tr>
<td>0</td>
<td>if $r &gt; 1500$ m</td>
</tr>
</tbody>
</table>

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 the main loading system, i.e. $\sum \alpha_i (2Q_{ik})$ (see Table 4.2).

(3) Unless otherwise specified for the particular project, $Q_{tk}$ should be assumed to act as a point load at any cross-section.

### 4.5 Groups of traffic loads on road bridges

#### 4.5.1 Characteristic values of the multi-component action

(1) Unless otherwise specified, the simultaneity of the loading systems defined in 4.3.2 (Load Model 1), 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 is taken into account by considering the groups of loads defined in Table 4.4. Each of these groups of loads, which are mutually exclusive, should be considered as defining a characteristic action for combination with non-traffic loads. The single axle defined in 4.3.3 should not be considered simultaneously with any other model.
Table 4.4 : Assessment of groups of traffic loads
(characteristic values of the multi-component action)

<table>
<thead>
<tr>
<th>Load type</th>
<th>CARRIAGEWAY</th>
<th>FOOTWAYS AND CYCLE TRACKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.3.2</td>
<td>4.3.4</td>
</tr>
<tr>
<td></td>
<td>4.3.5</td>
<td>4.4.1</td>
</tr>
<tr>
<td></td>
<td>4.4.2</td>
<td>5.3.2-(1)</td>
</tr>
<tr>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main loading system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special vehicles</td>
<td></td>
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<tr>
<td>Crowd loading</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Braking and acceleration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centrifugal forces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniformly distributed load</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>gr1</td>
<td>Characteristic values</td>
<td>Reduced value (**)</td>
</tr>
<tr>
<td>gr2</td>
<td>Frequent values(*)</td>
<td>Characteristic value</td>
</tr>
<tr>
<td>gr3 (***)</td>
<td>Characteristic value</td>
<td></td>
</tr>
<tr>
<td>gr4</td>
<td>See 4.3.4</td>
<td>Characteristic value</td>
</tr>
<tr>
<td>gr5</td>
<td>Characteristic value</td>
<td></td>
</tr>
</tbody>
</table>

Dominant component action (designated as component associated with the group).

(*) Unless otherwise specified in design codes or other standards
(****) See 5.3.2.1-(3). One footway only should be considered to be loaded if the effect is more unfavourable than the effect of two loaded footways.
(****) This group is irrelevant if gr4 is considered.

4.5.2 Other representative values of the multi-component action

Note : For the individual components of the traffic action, these representative values are defined in annexes C and D.

4.5.2.1 Infrequent values of the multi-component action

(1) The same rule as in 4.5.1 is applicable by replacing all characteristic values in Table 4.4 by infrequent values defined in annex C, without modifying the other values mentioned in the Table.

Note : It has been considered that the infrequent group gr2 is practically irrelevant for road bridges.

4.5.2.2 Frequent values of the multi-component action

(1) Unless otherwise specified, the frequent action consist only of, either the frequent values of the main loading system or the frequent value of the single axle model, or the frequent values of loads on footways or cycle-tracks (taking the more unfavourable), without any accompanying component.

Note : For quasi-permanent values (generally equal to zero), see annex C.

4.5.3 Groups of loads in transient situations
(1) The rules given in 4.5.1 and 4.5.2 are applicable with the following modifications.

(2) Unless otherwise specified, for verifications in transient situations the characteristic values $\alpha Q_i Q_k$ (tandem system) are taken equal to the infrequent values defined in annex C, and all other characteristic, infrequent, frequent and quasi-permanent values and the horizontal forces are as specified for persistent situations without any modification (i.e. they are not reduced proportionally to the weight of the tandems).

Note: In transient situations due to road or bridge maintenance, the traffic is commonly concentrated on smaller areas without significant reduction, and long lasting traffic jams are frequent. However, more reductions may be applied if agreed by the relevant authority, in the cases where the heaviest lorries are diverted by appropriate road signs.

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. Horizontal forces usually need not be considered.

Note 1: Centrifugal forces may occasionally need to be considered in conjunction with the vertical loads.

Note 2: The use of the various Fatigue Load Models is defined in the relevant ENV 1992 to 1994.

(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 ENV 1992 to 1994.

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.

(b) 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. 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.

Fatigue Load Models 3, 4 and 5 are intended to be used for fatigue life assessment by reference to fatigue strength curves defined in design Eurocodes. 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 $\lambda_E$.

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 agreed by the relevant authority.

Fatigue Load Model 5 is the most general model, using actual traffic data.

c) For fatigue verifications, the required design working life of bridges as indicated in ENV 1991-1 (100 years) is applicable, unless otherwise specified for certain categories of bridges.

(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: The relevant authority may modify values of Fatigue Load Models 1 and 2 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.

(4) A traffic category on a bridge should be defined, for fatigue verifications, at least, by:
- the number of slow lanes,
- the number of lorries per year per slow lane, observed or estimated, \( N_{\text{obs}} \).

Unless otherwise specified, the numerical values of \( N_{\text{obs}} \) given in Table 4.5, corresponding to a slow lane, should be adopted for using Fatigue Load Models 3 and 4.

### Table 4.5: Number of lorries expected per year and for a slow lane

<table>
<thead>
<tr>
<th>Traffic categories</th>
<th>( N_{\text{obs}} ) per year and per slow lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 : Roads and motorways with 2 or more lanes per direction with high flow rates of lorries</td>
<td>( 2,0 \times 10^6 )</td>
</tr>
<tr>
<td>2 : Roads and motorways with medium flow rates of lorries</td>
<td>( 0,5 \times 10^6 )</td>
</tr>
<tr>
<td>3 : Main roads with low flow rates of lorries</td>
<td>( 0,125 \times 10^6 )</td>
</tr>
<tr>
<td>4 : Local roads with low flow rates of lorries</td>
<td>( 0,05 \times 10^6 )</td>
</tr>
</tbody>
</table>

On each fast lane, additionally, 10% of \( N_{\text{obs}} \) should be considered.
Note 1: Table 4.5 is not sufficient to characterize the traffic for fatigue verifications. Other parameters to be considered may be:
- 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 2: There is no general relation between traffic categories for fatigue verifications, and the loading classes and associated $\alpha$ factors mentioned in 4.2.2 and 4.3.2.

Note 3: Intermediate values of $N_{obs}$ are not excluded, but are unlikely to have very significant influence on the fatigue life.

(5) 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.

(6) For the assessment of local action effects (e.g. in slabs or orthotropic decks) the models should be centered on notional lanes assumed to be located anywhere on the carriageway. However, when the transverse location of the vehicles for Fatigue Load Models 3, 4 and 5 is significant for the studied effects, a statistical distribution of this transverse location should be considered, unless otherwise specified, in accordance with Figure 4.8.

![Figure 4.8 - Frequency distribution of transverse location of centre line of vehicle](image)

(7) Fatigue Load Models 1 to 4 include dynamic load amplification appropriate for pavements of good quality (see annex B). An additional amplification factor $\Delta\varphi_{fat}$ should be considered near expansion joints, as shown in Figure 4.9, to be applied to all loads as a function of the distance of the considered cross-section from the expansion joint.
Note: A conservative, often acceptable, simplification may consist of adopting $\Delta \varphi_{fat} = 1.3$ for any cross-section within 6m from the expansion joint.

4.6.2 Fatigue Load Model 1 (similar to main loading system)

(1) Fatigue Load Model 1 has the configuration of the main loading system (characteristic Load Model 1 defined in 4.3.2) with the values of the axle loads equal to $0.7 Q_k$ and the values of the uniformly distributed loads equal to $0.3 q_k$ and (unless otherwise specified) $0.3 q_{rk}$.

Note: The load values for Fatigue Load Model 1 are similar to those defined for the Frequent Load Model. However adopting the Frequent Load Model without adjustment would have been excessively conservative by comparison with the other models, especially for large loaded areas. For particular projects, $q_{rk}$ may be neglected.

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

4.6.3 Fatigue Load Model 2 (set of "frequent" lorries)

(1) Fatigue Load Model 2 consists of a set of idealised lorries, called "frequent" lorries, to be used as defined in (3) below.

(2) Each frequent lorry is defined by:
   - the number of axles and the axle spacing (Table 4.6, columns 1+2),
   - the frequent load of each axle (Table 4.6, column 3),
   - the wheel contact areas and the transverse distance between wheels (column 4 of Table 4.6 and Table 4.8).

(3) The maximum and minimum stresses should be determined from the most severe effects of different lorries, separately considered, travelling alone along the appropriate lane.

Note: When some of these lorries are obviously the most critical, the others may be disregarded.
Table 4.6 : Set of "frequent" lorries

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>LORRY SILHOUETTE</td>
<td>Axle spacing (m)</td>
<td>Frequent axle loads (kN)</td>
<td>Wheel type (see table 4.8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frequent axle loads (kN)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>190</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>140</td>
<td>B</td>
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<tr>
<td></td>
<td></td>
<td>140</td>
<td>B</td>
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<td></td>
<td></td>
<td>90</td>
<td>A</td>
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<tr>
<td></td>
<td></td>
<td>180</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>190</td>
<td>B</td>
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<tr>
<td></td>
<td></td>
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<td>C</td>
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<td>B</td>
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<td></td>
<td></td>
<td>120</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>C</td>
</tr>
</tbody>
</table>

4.6.4 Fatigue Load Model 3 (single vehicle model)

(1) This model consists of four axles, each of them having two identical wheels. The geometry is shown in Figure 4.10. The weight of each axle is equal to 120 kN, and the contact surface of each wheel is a square of side 0.40 m.

![Figure 4.10 : Fatigue Load Model 3](image)
(2) The maximum and minimum stresses and the stress ranges, ie. their algebraic difference, resulting from the transit of the model along the bridge should be calculated.

4.6.5 Fatigue Load Model 4 (set of "standard" lorries)

(1) Fatigue Load Model 4 consists of sets of standard lorries which together produce effects equivalent to those of typical traffic on European roads. Unless otherwise specified, a set of lorries appropriate to the traffic mixes predicted for the route as defined in Tables 4.7 and 4.8 should be considered.

Note : This model, 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 4.5.
It is up to the relevant authority, if necessary, to specify or agree other standard lorries.

(2) Each standard lorry is defined by :

- The number of axles and the axle spacing (Table 4.7, columns 1+2),
- The equivalent load of each axle (Table 4.7, column 3)
- The wheel contact areas and the transverse distances between wheels, in accordance with column 7 of Table 4.7. and Table 4.8.

(3) Unless otherwise specified :

- The percentage of each standard lorry in the traffic flow should be selected from Table 4.7. columns 4, 5 or 6 as relevant.
- The total number of vehicles per annum to be considered for the whole carriageway $\Sigma N_{obs}$ is obtained from 4.5.1-(4).
- Each standard lorry is considered to cross the bridge in the absence of any other vehicle.

(4) The stress range spectrum and the corresponding number of cycles due to the successive passage of individual lorries across the bridge should be used with the Rainflow or the Reservoir counting method to determine the fatigue damage rate.

Table 4.7 : Set of equivalent lorries

<table>
<thead>
<tr>
<th>VEHICLE TYPE</th>
<th>TRAFFIC TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LORRY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VEHICLE TYPE</td>
</tr>
<tr>
<td></td>
<td>TRAFFIC TYPE</td>
</tr>
<tr>
<td></td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td></td>
<td>Axle spacing (m)</td>
</tr>
</tbody>
</table>

Note: Table 4.7 provides the set of equivalent lorries for different vehicle types and traffic types.
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<thead>
<tr>
<th></th>
<th>4,5</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
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<table>
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<th></th>
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<th>70</th>
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<td></td>
<td>5,0</td>
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</tbody>
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Note: For the selection of a traffic type, it may broadly be considered that:
- "Long distance" means hundreds of kilometres,
- "Medium distance" means 50 to 100 km,
- "Local traffic" means distances less than 50 km.
In reality, mixture of traffic types may occur.
Table 4.8 : Definition of wheels and axles

<table>
<thead>
<tr>
<th>WHEEL/ AXLE TYPE</th>
<th>GEOMETRICAL DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>![Diagram A]</td>
</tr>
<tr>
<td>B</td>
<td>![Diagram B]</td>
</tr>
<tr>
<td>C</td>
<td>![Diagram C]</td>
</tr>
</tbody>
</table>

4.6.6 Fatigue Load Model 5 (based on recorded road traffic)

(1) Fatigue Load Model 5 consists of the direct application of recorded traffic data, supplemented, if relevant, by appropriate statistical and projected extrapolations. Guidance for a complete specification and the application of such a model is given in annex B.

Note: This model should be used only if specified or agreed by the relevant authority.

4.7 Accidental actions

4.7.1 General

(1) Accidental loads due to road vehicles are defined in 4.7.2 for road and railway bridges, and in 4.7.3 for road bridges only. They shall be considered, where relevant, during accidental situations as follows:

- vehicle collision with bridge piers or decks,
- heavy wheels on footways (effects of heavy wheels on footways shall be considered for all road bridges where footways are not protected by a rigid safety barrier),
- vehicle collision with kerbs, safety barriers and structural struts (effects of vehicle collision with safety barriers shall be considered for all road bridges where such restraint systems are provided on the bridge deck; effects of vehicle collision with kerbs shall be considered in all cases).

4.7.2 Collision forces from vehicles under the bridge
4.7.2.1 Collision forces on piers and other supporting members

(1) In the absence of an appropriate risk analysis, the force due to the collision of road vehicles with piers or with the supporting members of a portal bridge should be taken as 1000 kN in the direction of vehicle travel or 500 kN perpendicular to that direction, acting 1.25 m above the level of the adjacent ground surface.

Note: A risk analysis can be considered to be appropriate only if it satisfies the relevant authority. The design load to be taken into account may be differentiated depending on the volume of the traffic expected under the bridge, the presence of protection between carriageway and piers and other particular circumstances. When additional protective measures between carriageway and piers are provided, they should be specified or agreed by the relevant authority.

4.7.2.2 Collision with decks

(1) If relevant the vehicle collision force should be specified for the particular project or, in relation to vertical clearance and other forms of protection, by a more general rule.

Note: This force should be defined or agreed by the relevant authority. Collision loads on bridge decks and other structural components over roads may vary widely depending on structural and non-structural parameters, and their conditions of applicability. The possibility of collision by vehicles having an illegal height should be envisaged, as well as a crane swinging up while a vehicle is moving. Protective measures may be introduced as an alternative to designing for collision forces.

4.7.3 Actions from vehicles on the bridge

4.7.3.1 Vehicle on footways and cycle tracks on road bridges

(1) If a rigid safety barrier of an appropriate class is provided, consideration of the axle load beyond this protection is unnecessary.

Note: A deformable safety barrier (cable, guard-rail) is insufficient. In particular cases (e.g. bridges on rural roads or urban streets), a kerb of 0.25 m or more height can make consideration of the axle load unnecessary, if specified or agreed by the relevant authority.

(2) Where the protection mentioned in (1) is provided, one accidental axle load corresponding to \( \alpha Q_2 Q_{2k} \) (see 4.3.2) should be taken into account. It should be so placed and oriented in the carriageway as to give the most adverse effect adjacent to the barrier as shown in Figure 4.11. This axle load does not act simultaneously with any other variable load on the carriageway. A single wheel alone is taken into account if geometrical constraints make a two-wheel arrangement impossible.

Beyond the barrier, the characteristic variable concentrated load defined in clause 5.3.2(4) is applicable, if relevant, separately from the accidental load.
(3) In the absence of the protection mentioned in (1), the rules given in (2) are applicable up to 1m beyond a deformable safety barrier if it is provided, or up to the edge of the deck in the absence of a safety barrier.

4.7.3.2 Collision forces on kerbs

(1) The action from vehicle collision with kerbs is a lateral force equal to 100 kN acting at a depth of 0.05 m below the top of the kerb.

This force is considered as acting on a line 0.5 m long and is transmitted by the kerbs to the structural members supporting them. In rigid structural members, the load is assumed to have an angle of dispersal of 45°. When unfavourable, the vertical traffic load acting simultaneously with the collision force is equal to $0.75 \alpha Q_1 Q_{1k}$ (see Figure 4.12).

4.7.3.3 Collision forces on safety barriers

Note: See also, when available, technical approvals or standards established by CEN/TC 226.
(1) For structural design, an horizontal vehicle collision force transferred to the bridge deck by rigid safety barriers is \(100\) kN acting transversely and horizontally 100mm below the top of the barrier or 1,0 m above the level of the carriageway or footway, whichever is the lower. As for kerbs, this force is considered as acting on a line 0,5m long. The vertical traffic load acting simultaneously with the collision force is equal to \(0,5\alpha_{Q1}Q_{1k}\).

For deformable safety barriers, the collision force is taken from results obtained for the technical approval of the barriers.

The structure supporting the safety barrier should also be designed to sustain locally an accidental load effect corresponding to \(1,25\) times the characteristic local resistance of the barrier (e.g. resistance of the connection of the barrier to the structure) exclusive of any variable load.

### 4.7.3.4 Collision forces on structural members

(1) The vehicle collision forces on unprotected vertical structural end members above carriageway levels are the same as specified in 4.7.2.1-(1), acting 1,25 m above the carriageway level. However, when additional protective measures between the carriageway and these members are provided, this force may be reduced.

Note: Such a reduction should be agreed by the relevant authority.

(2) Unless otherwise specified, these forces are not considered to act simultaneously with any variable load.

Note: For some intermediate members damage to one of which would not cause collapse (e.g. hangers or stays), smaller forces may be specified by the relevant authority.

### 4.8 Actions on parapets

Note: This clause, which has no structural character, might be partially superseded by technical approvals or by standards established by CEN/TC 226.

#### 4.8.1 Definition of actions applicable to parapets

(1) Unless otherwise specified, the action to be considered is a line force of 1,0 kN/m acting, as a variable load, horizontally or vertically on the top of the parapet.

Note: A lower force should be specified only by the relevant authority.

(2) For service side paths, the line force may be reduced to 0,8 kN/m.

Note: Exceptional and accidental cases are not covered by these forces. It is up to the relevant authority to require such cases to be taken into account for the particular projects.

### 4.8.2 Consideration of the actions
(1) Parapets for footways on road bridges should be designed for the previously defined actions if they are adequately protected against vehicle collision. For the design of the supporting structure, the horizontal actions should be considered as simultaneous with the uniformly distributed actions defined in 5.2.2.(1), unless otherwise specified.

Note: Parapets can be considered as adequately protected only if the protection satisfies the specifications of the relevant authority.

Where they are not so protected, the supporting structure should also be designed to sustain an accidental load effect corresponding to $1.25 \times$ the characteristic resistance of the parapet, exclusive of any variable load.

4.9 Load models on embankments

4.9.1 Vertical loads

(1) Unless otherwise specified for the particular project, the carriageway located behind abutments, wing walls, side walls and other parts of the bridge in contact with earth, should be loaded with the same models as defined in 4.3, corresponding to characteristic loads on carriageways.

Note: Other more general specifications may also be issued by the relevant authority.

For the sake of simplification, the tandem system loads may be replaced by an equivalent uniformly distributed load, noted $q_{eq}$, spread over a rectangular surface of sides 1.0m x 2.0m.

Note: For the dispersal of the loads through the backfill or earth, see the NAD. In the absence of any other rule, if the backfill is properly consolidated, a dispersal at an angle of 30° from to the vertical may be assumed.

(2) Representative values of the load model other than the characteristic values are not to be considered.

4.9.2 Horizontal force

(1) Unless otherwise specified, no horizontal force should be considered at the coating level of the carriageway over the backfill.

(2) For the design of abutment upstand walls (see Figure 4.13), a longitudinal braking force should be considered. The characteristic value of this force is equal to $0.6\alpha Q_1 Q_{1k}$; it acts simultaneously with the $\alpha Q_1 Q_{1k}$ axle loading of Load Model Number 1 and with the earth pressure from the backfill. The embankment should be assumed not to be loaded simultaneously.
Figure 4.13 : Definition of loads on upstand walls
Section 5  Pedestrian, cycle actions and other actions specifically for footbridges

5.1 Field of application

(1) The effects of loads on construction sites are not covered by the load models.

(2) The uniformly distributed load $q_{\text{FK}}$ and the concentrated load $Q_{\text{IFW}}$ (see 5.3) are applicable to road and railway bridges as well as to footbridges, where relevant (see 4.5, 4.7.3 and 6.3.6.2(1)). However, for exceptionally wide footbridges (e.g. more than 6m between parapets) other values of these loads may be specified for the particular project, based on the considerations that have justified the choice of the width. All other variable and accidental loads defined in this section are intended only for footbridges.

(3) Models and representative values are given for verifications applicable to any limit state, with the exception of fatigue. Unless otherwise specified, no traffic represented in this section needs verification with regard to fatigue.

(4) For verifications relating to the vibration of pedestrian bridges and based on dynamic analysis, see 5.7. For all other verifications to be performed for any bridge type, the models and values given in this section include the dynamic amplification effects. The variable actions should be treated as static.

5.2 Representation of actions

5.2.1 Models of the loads

(1) The imposed loads defined in this section result from pedestrian and cycle traffic, minor common construction loads, some specific vehicles (e.g. for maintenance), and accidental situations. These loads give rise to vertical and horizontal, static and dynamic forces.

(2) The load models defined in this section do not describe actual loads. They have been selected so that their effects (with dynamic amplification generally included) represent the effects of actual traffic. When traffic outside the field of application of these load models needs to be considered, then complementary load models, with associated combination rules, should be defined or agreed by the client.

(3) Accidental loads due to collision are represented by static equivalent loads.

5.2.2 Loading classes

Loads on footbridges may differ depending on their location and on the possible traffic flow of some vehicles. These factors are mutually independent and are envisaged in various clauses given below. No general classification of these bridges is therefore to be defined.
5.2.3 Application of the load models

(1) The same models should be used for pedestrian and cycle traffic on footbridges, on the areas of the deck of road bridges limited by parapets and not included in the carriageway as defined in 1.4.2 (denominated footways in this Part) and on the footpaths of railway bridges.

(2) Unless otherwise specified, other models should be used for inspection gangways within the structures of bridges and for platforms on railway bridges.

(3) In each individual application, the models of vertical loads should be applied anywhere within the relevant areas so that the most adverse effect is obtained.

Note: In other terms, these actions are considered to be fully free (see ENV-1991-1, 1.5.3.8 and 4.1-2(P)-(ii)).

5.3 Vertical loads - characteristic values

5.3.1 General

(1) Characteristic loads are intended for the determination of pedestrian or cycle-track load effects associated with ultimate limit-states verifications and particular serviceability verifications (see ENV-1991-1, 9.4.2 and 9.5.2, and ENV 1992 to 1995).

(2) Three models, mutually exclusive, should be considered, as relevant. They consist of a uniformly distributed load, a concentrated load and loads representing service vehicles.

(3) Unless otherwise specified for a particular project, the characteristic values given below should be used for both persistent and transient design situations.

5.3.2 Load Models

5.3.2.1 Uniformly distributed load

(1) The density of the uniformly distributed load is:

\[ q_{fk} = 5 \text{ kN/m}^2 \quad (5.1) \]

(2) However, for footbridges, unless otherwise specified, the following values should be taken for individual spans exceeding 10 m:

\[ 2,5 \text{ kN/m}^2 \leq q_{fk} = 2,0 + \frac{120}{L_{sj} + 30} \leq 5,0 \text{ kN/m}^2 \quad (5.2) \]

where:

\[ L_{sj} \] is the individual span length in [m].
Figure 5.1: Uniformly distributed load in relation to the span length

Note 1: For special types of footbridges, e.g. footbridges with inclined supporting members, the span length $L_{sj}$ should be defined for the particular project. The span length may be substituted by the loaded length.

Note 2: Other values of $q_{fk}$ may be specified if they are defined or agreed by the relevant authority.

(3) For road bridges supporting footways or cycle tracks, only the 5 kN/m$^2$ value should be considered (Figure 5.2). A reduced combination value equal to 2.5 kN/m$^2$ may also have to be considered in accordance with 4.5.1.

Figure 5.2

5.3.2.2 Concentrated load

(1) The concentrated load $Q_{fwk}$ is equal to 10 kN acting on a square surface of sides 0.10 m. Where, in a verification, general and local effects can be distinguished, it is taken into account only for local effects. If, for a footbridge, a service vehicle, as mentioned in c) below is specified, $Q_{fwk}$ should not be considered.

5.3.2.3 Service vehicle
In the case of footbridges, when specified by the client, one service vehicle (or several, mutually exclusive) shall be taken into account.

Note: This vehicle may be a vehicle for maintenance, emergencies (e.g. ambulance, fire) or other services. It is the responsibility of the client (or of the relevant authority) to define the characteristics of this vehicle (axle weight and spacing, contact area of wheels), the dynamic amplification and all other appropriate loading rules. If no information is available and if no permanent obstacle prevents a vehicle being driven onto the bridge deck, it is suggested the vehicle defined in 5.6.3(3) be defined as the service vehicle (characteristic load); in this case, there will be no need to apply 5.6.3, i.e. to consider the same vehicle as accidental.

5.4 Horizontal forces - characteristic values

(1) For footbridges only, the characteristic value of the horizontal force \( Q_{flk} \) acts along the bridge deck axis at the pavement level and is equal to the greater of the following two values:
- \( \frac{10}{10} \) per cent of the total load corresponding to the uniformly distributed load (5.3.2.1-(1) and (2)),
- \( \frac{60}{60} \) per cent of the total weight of the service vehicle, if relevant (5.3.2.3-(1)P).

(2) The horizontal force is considered as acting simultaneously with the corresponding vertical load, and in no case with the concentrated load \( Q_{fwk} \).

Note: This force is normally sufficient to ensure the horizontal longitudinal stability of footbridges. It does not ensure horizontal transverse stability, which should be ensured by considering other actions or by appropriate design measures.

5.5 Assessment of traffic loads on footbridges

(1) The assessment of traffic loads on footbridges is to be undertaken, for characteristic values, in accordance with 5.3.1 and 5.4, and, for the other representative values, in accordance with annex D.

Note: For the individual components of the traffic action, the other representative values are defined in annex D.

5.6 Accidental actions for footbridges

5.6.1 General

(1) Such actions are due to:
- road traffic under the bridge (i.e. collision) or
- the accidental presence of a lorry on the bridge.

Note: Other collision forces (see 2.3) should be taken into account, when relevant, as specified or agreed by the relevant authority.

5.6.2 Collision forces from road vehicles under the bridge
Note 1: Footbridges (piers and decks) are generally much more sensitive to collision forces than road bridges. Designing them for the same collision load may be unrealistic. The most effective way to take collision into account generally consists of protecting the footbridges:

- by establishing safety barriers at appropriate distances before piers,
- by giving the bridges a higher clearance than for neighbouring road or railway bridges over the same road in the absence of intermediate access to the road.

The measures to be adopted should be defined or agreed by the relevant authority.

Note 2: See annex D, D.2.1.2.

5.6.2.1 Collision forces on piers

(1) Unless otherwise specified, and as for road bridges, in the absence of an appropriate risk analysis, the collision force on piers or on the supporting members of a portal bridge from road vehicles passing under the bridge is 1000 kN in the direction of vehicle travel or 500 kN perpendicular to that direction, acting 1.25 m above the level of the adjacent ground surface. Additional or substitute protective measures between carriageway and piers should be specified if required.

5.6.2.2 Collision forces on decks

(1) An adequate vertical clearance between the ground surface and the soffit of the deck above should be ensured in the design, when relevant. Consideration should also be given to providing protection of the deck from collision or designing for a collision force.

Note: The possibility of collision by vehicles having an illegal height should be envisaged.

5.6.3 Accidental presence of vehicles on the bridge

(1) If no permanent obstacle prevents a vehicle from being driven onto the bridge deck, an accidental loading shall be taken into account.

(2) Unless otherwise specified, no variable action should be assumed to act simultaneously with the accidental action defined hereafter.

(3) Unless otherwise specified, the accidental loading to be used consists of a two-axle load group of 80 and 40 kN, separated by a wheel base of 3 m as shown in Figure 5.3, with a track (wheel-centre to wheel-centre) of 1.3 m and square contact areas of side 0.2 m at pavement level. The braking force associated with the load group is 50% of the vertical load.
Figure 5.3: Accidental loading

Note 1: See the note in 5.3.2.3-(1)P.

Note 2: If relevant, other characteristics of the accidental loading should be defined or agreed by the relevant authority.

5.7 Dynamic models of pedestrian loads

(1) These models are those to be used, where relevant, for the design of buildings.

Note: Footbridges can be excited into vibration by users. Appropriate models should be selected for various situations (walking, running and jumping pedestrians). It has been envisaged to define models in ENV 1991-1 and ENV 1991-2. In the meantime they may be taken from national rules or from the literature.

5.8 Actions on parapets

Note: See the note in 4.8.

(1)P For footbridges, parapets shall be designed for the line load defined in 4.8.1(1).

5.9 Load model on embankments

(1) Unless otherwise specified for the particular project, the area external to a carriageway and located behind abutments, wing walls, side walls and other parts of the bridge in contact with earth, is loaded with a uniformly distributed vertical load whose magnitude is equal to 5 kN/m².

Note: This load does not cover the effects of heavy site vehicles and other lorries commonly used for the placing of the backfill.
Models of special vehicles for road bridges

Note: The consideration of special vehicles for bridge design is intended to be limited to particular cases.

(1) The special vehicles defined here are intended to produce load effects such as are caused by vehicles which do not comply with the national regulations concerning limits of weights and, possibly, dimensions of normal vehicles.

(2) The following conventional classes of special vehicles, corresponding to usual abnormal loads, are defined in Table A.1.

Table A.1 : Classes of special vehicles

<table>
<thead>
<tr>
<th>Total weight</th>
<th>Composition</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 kN</td>
<td>4 axle-lines of 150 kN</td>
<td>600/150</td>
</tr>
<tr>
<td>900 kN</td>
<td>6 axle-lines of 150 kN</td>
<td>900/150</td>
</tr>
<tr>
<td>1200 kN</td>
<td>8 axle-lines of 150 kN</td>
<td>1200/150</td>
</tr>
<tr>
<td></td>
<td>or 6 axle-lines of 200 kN</td>
<td>1200/200</td>
</tr>
<tr>
<td>1500 kN</td>
<td>10 axle-lines of 150 kN</td>
<td>1500/150</td>
</tr>
<tr>
<td></td>
<td>or 7 axle-lines of 200 kN + 1 axle line of 100 kN</td>
<td>1500/200</td>
</tr>
<tr>
<td>1800 kN</td>
<td>12 axle-lines of 150 kN</td>
<td>1800/150</td>
</tr>
<tr>
<td></td>
<td>or 9 axle-lines of 200 kN</td>
<td>1800/200</td>
</tr>
<tr>
<td>2400 kN</td>
<td>12 axle-lines of 200 kN</td>
<td>2400/200</td>
</tr>
<tr>
<td></td>
<td>or 10 axle-lines of 240 kN</td>
<td>2400/240</td>
</tr>
<tr>
<td></td>
<td>or 6 axle-lines of 200 kN (spacing 12m) + 6 axle-lines of 200 kN</td>
<td>2400/200/200</td>
</tr>
<tr>
<td>3000 kN</td>
<td>15 axle-lines of 200 kN</td>
<td>3000/200</td>
</tr>
<tr>
<td></td>
<td>or 12 axle-lines of 240 kN + 1 axle line of 120 kN</td>
<td>3000/240</td>
</tr>
<tr>
<td></td>
<td>or 8 axle-lines of 200 kN (spacing 12 m) + 7 axle-lines of 200 kN</td>
<td>3000/200/200</td>
</tr>
<tr>
<td>3600 kN</td>
<td>18 axle-lines of 200 kN</td>
<td>3600/200</td>
</tr>
<tr>
<td></td>
<td>or 15 axle-lines of 240 kN</td>
<td>3600/240</td>
</tr>
<tr>
<td></td>
<td>or 9 axle-lines of 200 kN (spacing 12 m) + 9 axle-lines of 200 kN</td>
<td>3600/200/200</td>
</tr>
</tbody>
</table>

(3) The definitions and axle arrangements are given in Table A.2, in which n gives the number of axles and the weight of each axle in each group, and e gives the axle spacing within and between each group.

(4) Vehicle widths of 3,00 m for the 150 and 200 kN axle-lines, and of 4,50 m for the 240 kN axle-lines are assumed.
Table A.2 : Description of special vehicles

<table>
<thead>
<tr>
<th>Load (kN)</th>
<th>Axle-lines of 150 kN</th>
<th>Axle-lines of 200 kN</th>
<th>Axle-lines of 240 kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 kN</td>
<td>( n = 4 \times 150 ) ( e = 1.50 \text{ m} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>900 kN</td>
<td>( n = 6 \times 150 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 6 \times 200 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 6 \times 200 ) ( e = 1.50 \text{ m} )</td>
</tr>
<tr>
<td>1200 kN</td>
<td>( n = 8 \times 150 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 1 \times 100 + 7 \times 200 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 9 \times 200 ) ( e = 1.50 \text{ m} )</td>
</tr>
<tr>
<td>1500 kN</td>
<td>( n = 10 \times 150 ) ( e = 1.50 \text{ m} )</td>
<td></td>
<td>( n = 10 \times 240 ) ( e = 1.50 \text{ m} )</td>
</tr>
<tr>
<td>1800 kN</td>
<td>( n = 12 \times 150 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 12 \times 200 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 1 \times 120 + 12 \times 240 ) ( e = 1.50 \text{ m} )</td>
</tr>
<tr>
<td>2400 kN</td>
<td>( n = 12 \times 200 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 6 \times 200 + 6 \times 200 ) ( e = 5 \times 1.5 + 12 + 5 \times 1.5 )</td>
<td>( n = 15 \times 240 ) ( e = 1.50 \text{ m} )</td>
</tr>
<tr>
<td>3000 kN</td>
<td>( n = 15 \times 200 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 8 \times 200 + 7 \times 200 ) ( e = 7 \times 1.5 + 12 + 6 \times 1.5 )</td>
<td>( n = 8 \times 240 + 7 \times 240 ) ( e = 7 \times 1.5 + 12 + 6 \times 1.5 )</td>
</tr>
<tr>
<td>3600 kN</td>
<td>( n = 18 \times 200 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 15 \times 240 ) ( e = 1.50 \text{ m} )</td>
<td>( n = 15 \times 240 ) ( e = 1.50 \text{ m} )</td>
</tr>
</tbody>
</table>

(5) For local verifications, loads from each axle-line are assumed to be distributed as follows:

- For axle-lines of 150 and 200 kN, on two rectangular surfaces of sides 1.20 m x 0.15 m arranged as shown in Figure A.1-a)  

- For axle-lines of 240 kN, on three rectangular surfaces of sides 1.20 m x 0.15 m arranged as shown in Figure A.1-b)
Fatigue life assessment - assessment method based on recorded traffic

(1) A stress history is obtained by analysis using data recorded under representative real traffic provided or agreed by the client, multiplied by a dynamic amplification factor $\phi_{\text{fat}}$. This dynamic factor should take into account the dynamic behaviour of the bridge and depends on the expected roughness of the road surface and on any dynamic amplification already included in the records. The recorded axle loads should be multiplied by:

$\phi_{\text{fat}} = 1.2$ for surface of good roughness

$\phi_{\text{fat}} = 1.4$ for surface of medium roughness.

In addition, when considering a section within a distance of 6.00 m from an expansion joint, the load should be multiplied by the additional dynamic amplification factor $\Delta\phi_{\text{fat}}$ derived from Figure 4.9, but not exceeding the value $\frac{1.6}{\phi_{\text{fat}}}$.

Note: The classification of roadway roughnesses may be taken in accordance with a proposal from ISO/TC 108. The definition of roughness is given in terms of the power spectral density $\Phi$ of the roughness profile as a function of the cyclic frequency of path $\Omega$. The limit values of the different classes are given in Table B.1.

<table>
<thead>
<tr>
<th>Quality of pavement $\Phi(\Omega_0)$ [cm$^3$] for $\Omega_0 = 1$ [m$^{-1}$]</th>
<th>Lower limit</th>
<th>Mean value</th>
<th>Upper limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>0.5</td>
<td>1</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>Good</td>
<td>2</td>
<td>4</td>
<td>&lt; 8</td>
</tr>
<tr>
<td>Medium</td>
<td>8</td>
<td>16</td>
<td>&lt; 32</td>
</tr>
<tr>
<td>Poor</td>
<td>32</td>
<td>64</td>
<td>&lt; 128</td>
</tr>
<tr>
<td>Very poor</td>
<td>128</td>
<td>256</td>
<td>&lt; 516</td>
</tr>
</tbody>
</table>

Table B.1

The spectral density $\Phi(\Omega)$ is given by:

$$\Phi(\Omega) = \Phi(\Omega_0) \left(\frac{\Omega}{\Omega_0}\right)^2$$  \hspace{1cm} (B.1)

For a rough and quick estimation of the roughness quality, the following guidance is given:

- actual roadway layers, such as, for example, asphalt or concrete layers, can be assumed to have a good or even a very good roughness quality;

- old roadway layers which are not maintained may be classified as having a medium roughness;

- roadway layers consisting of cobblestones or similar material may be classified as medium ("average") or bad ("poor", "very poor").
(2) Unless otherwise specified, the wheel contact areas and the transverse distances between wheels are assumed as described in 4.6.5, if relevant.

(3) If the data are recorded on one lane only, assumptions should be made concerning the traffic on other lanes. These assumptions may be based on records made at other locations for a similar type of traffic.

(4) The stress history should take into account the simultaneous presence of vehicles recorded on the bridge in any lane. A procedure should be developed to allow for this when records of individual vehicle loadings are used as a basis.

(5) The numbers of cycles should be counted using the rainflow method or the reservoir method, so that the stress range histogram can be obtained.

(6) If the duration of recordings is less than a full week, the records and the assessment of the fatigue damage rates may be adjusted taking into account observed variations of traffic flows and mixes during a typical week. An adjustment factor should also be applied to take into account any future changes on the traffic

    Note: The adjustment factor should be specified or agreed by the relevant authority.

(7) The cumulative fatigue damage calculated by use of records should be multiplied by the ratio between the design working life and the duration considered on the histogram.
Annex C  (normative)

Basis of design - supplementary clauses to ENV 1991-1 for road bridges

Note : This annex is intended, at a later stage, to be incorporated into ENV 1991-1 "Basis of design".

C1 - General

(1) This annex gives rules on partial factors on actions (γ-factors), and on combinations of traffic loads on road bridges with permanent actions, quasi-static wind, snow and temperature actions, and the relevant ψ-factors. If other actions need to be considered (e.g. mining subsidence, instability due to wind, water, floating debris and ice pressure for some verifications relating to foundations), the combinations should be supplemented to take them into account. It should also be supplemented and adapted for the erection phases (see the relevant design Eurocodes) and for some particular categories of road bridges (eg. moving bridges and roofed bridges).

C2 - Ultimate limit states (fatigue excluded)

C2.1 Simultaneity of load models with other actions

C.2.1.1 Models of variable actions

(1)P When relevant, the road traffic, pedestrian (or cycle) and crowd actions shall be considered as groups of loads as given in 4.5. These groups differ depending on the representative values and on the design situations being considered.

For any combination of traffic loads together with actions specified in other parts of ENV 1991, any such group shall be considered as one action.

(2) The characteristic wind action on road bridges may be assessed in ENV 1991-2-4 either as characteristic force $F_{Wk}$ or as nominal force $F_{Wn}$.

Note : The choice of a sufficiently high value for $F_{Wn}$ (boxed in ENV 1991-2-4) may make it possible to simplify calculations by considering significant wind action and traffic action as not simultaneous.

When considering combinations of road traffic actions with wind action, the maximum wind force compatible with road traffic should also be considered. This force $F_{W*}$ is associated with a wind speed equal to $23$ m/s at the level of the deck.

(3) For combinations of wind and traffic actions, the reference area $A_{ref,x}$ defined in ENV 1991-2-4 should be increased by adding $2.00$ m to the deck thickness from the level of the carriageway, without adding it with the additional depth of parapets, safety barriers, noise barriers etc., defined in ENV 1991-2-4. The wind pressure on vehicles should be considered on the unfavourable length independently of the length of application of vertical loads.
(4) The forces and constrained deformations resulting from relevant permanent and variable actions on bridges specified in other Parts of ENV 1991 shall be considered in combinations of actions simultaneously with the traffic loads where relevant.

(5) Unless otherwise specified, Load Model 2 (defined in 4.3.3.) and the concentrated load $Q_{f wk}$ on footways (defined in 5.3.2.(4)) should not be combined with any other variable non-traffic load.

(6) Unless otherwise specified, and with the exception of roofed bridges, neither snow nor wind should be combined with:
- special vehicles (Load Model 3, see 4.3.4) or the associated group of loads gr 5 (see 4.5.1),
- crowd loading on road bridges (Load Model 4, defined in 4.3.5) or the associated group of loads gr4 (see 4.5.1),
- braking and acceleration forces on road bridges (see 4.4.1) or the centrifugal forces (see 4.4.2) or the associated group of loads gr2 (see 4.5.1),
- loads on footways and cycle tracks or with the associated group of loads gr3 (see 4.5.1)

(7) Snow loads should not be combined with the main loading system (Load Model 1) or with the associated group of loads gr1.

Note: Snow load is therefore not mentioned in the following Tables. It may however have to be considered during some transient situations.

(8) No wind action greater than the smaller of $F^*_{W}$ and $\psi_0 F_{Wk}$ (or $\psi_0 F_{Wn}$) should be combined with the main loading system (Load Model 1) nor with the associated group of loads gr1.

(9) Unless otherwise specified, for road bridges, wind and thermal actions should not be taken into account as simultaneous actions.

C2.1.2 Models including accidental actions

(1) Where an accidental action is to be considered, no other accidental action nor wind nor snow actions should be considered to occur simultaneously.

(2) The simultaneity of accidental actions with variable traffic actions is defined below where the relevant individual accidental actions are defined.

(3) When collisions due to traffic running under the bridge are considered (forces defined in 4.7.2, 5.6.2 and 6.7.1.3(1)P), the frequent loads due to the traffic running on the bridges should be introduced as accompanying actions in the combinations, unless otherwise specified.

(4) When accidental actions due to traffic running on the bridge are considered (loads defined in 4.7.3 and 5.6.3), all accompanying road traffic actions should be neglected, unless otherwise specified.
Note: When other accidental actions on bridges have to be considered, rules on simultaneity with traffic actions shall be specified.

C2.2 Combinations of actions

(1) P For each critical load case, the design values of the effects of actions shall be determined by combining the values of actions which occur simultaneously. ENV 1991-1, 9.4.2 applies.

C2.3 Partial factors for road bridges (fatigue excluded)

(1) For verifications governed by the strength of structural material or of the ground, the partial factors on actions for ultimate limit states in the persistent, transient and accidental design situations are given in Table C.1.

Note: For bridge design Table C.1 and the following notes cover cases B and C specified for buildings in Table 9.2 of ENV 1991-1. For case A, see (2) below.

Table C.1: Partial factors on actions: ultimate limit states for road bridges

<table>
<thead>
<tr>
<th>Action</th>
<th>Symbol</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent actions: self weight of structural and non structural elements, permanent actions caused by ground, ground-water and free water(^1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>unfavourable</td>
<td>γ(_G)sup</td>
<td>[1.35(^2),3,4)</td>
</tr>
<tr>
<td>favourable</td>
<td>γ(_G)inf</td>
<td>[1,00(^2),3,4)</td>
</tr>
<tr>
<td>Prestress</td>
<td>γ(_P)</td>
<td>[1,00(^5)]</td>
</tr>
<tr>
<td>Settlement</td>
<td>γ(_G)set</td>
<td>[1,00(^6)]</td>
</tr>
<tr>
<td>Traffic actions(^7)</td>
<td>γ(_Q)</td>
<td>[1.35]</td>
</tr>
<tr>
<td>unfavourable</td>
<td></td>
<td>[0]</td>
</tr>
<tr>
<td>favourable</td>
<td></td>
<td>[1.50]</td>
</tr>
<tr>
<td>Other variable actions</td>
<td>γ(_Q)</td>
<td>[0]</td>
</tr>
<tr>
<td>unfavourable</td>
<td></td>
<td>[1,00]</td>
</tr>
<tr>
<td>favourable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accidental actions</td>
<td>γ(_A)</td>
<td></td>
</tr>
</tbody>
</table>

P - Persistent situation   T - Transient situation   A - Accidental situation

1) Instead of using γ\(_G\) (1.35) and the usual γ\(_Q\) for lateral earth pressure actions, the design ground properties may be introduced in accordance with ENV 1997. A model factor γ\(_Sd\) is applied.

2) In this verification the characteristic values of all permanent actions from one source are multiplied by [1.35] if the total resulting action effect is unfavourable and by [1,00] if the total resulting action effect is favourable. See also the note given in ENV 1991-1 clause 9.4.2(3a).
3) Unless otherwise specified the factors apply to the appropriate characteristic values defined in Part 2.1 (especially for the weight of road pavement).

4) In cases where the limit state is sensitive to variations in space of permanent actions, the upper and lower characteristic values of these actions should be taken in accordance with 4.2 (3)P of ENV 1991-1.

5) Unless otherwise specified. For prestress by tendons, this factor applies to the appropriate characteristic values defined in the relevant design Eurocode. Where prestress is induced by deformations imposed on the structure, the factors on G and the imposed deformations should be as defined in the relevant design Eurocode.

6) Applicable only where settlements are to be assessed as the best estimate (see the design Eurocodes).

7) The components of traffic actions are introduced in combinations as one action, by the relevant group of loads gri, the favourable components of these groups being neglected.

(2) For verifications with regard to loss of static equilibrium and in some other cases where the variabilities of strengths of the structural material and of the ground have a relatively minor importance, the favourable and unfavourable parts of permanent actions should be considered as individual actions and, unless otherwise specified (see in particular the relevant design Eurocode), the unfavourable and favourable parts should be associated with \( \gamma_{Gsup} = 1.05 \) and \( \gamma_{Ginf} = 0.95 \) respectively. The other partial factors on actions (especially on variable actions) are as in (1).

Note: See the relevant design Eurocode.

**C2.4 \( \Psi \) factors for road bridges**

(1) Unless otherwise specified (e.g. in the relevant Part of ENV 1991 devoted to specific actions), \( \psi \) factors for road bridges are as given in Table C.2. For traffic actions, they apply, as relevant, as well to the groups of loads defined in 4.5 as to the dominant component actions of the groups where they are considered separately.
Table C.2 - $\psi$ factors for road bridges

<table>
<thead>
<tr>
<th>Action</th>
<th>Symbol</th>
<th>$\psi_0$</th>
<th>$\psi'_1$</th>
<th>$\psi_1$</th>
<th>$\psi_2$</th>
</tr>
</thead>
</table>
| Traffic | gr1 (LM1)<sup>2)</sup> | TS<br>UDL<sup>3)</sup> | [0.75]<br>[0.40] | [0.80]<br> [0.80] | [0.75]<br> [0.40] | [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0]<br> [0}<sup>1)</sup> is a $\psi$-factor intended to define infrequent loads (see 2.2).

2) The boxed values of $\psi'_1$, $\psi_1$, $\psi_2$ for gr1 apply to routes with traffic corresponding to adjusting factors $\alpha_{Qi}$, $\alpha_{qi}$, $\alpha_{qr}$ and $\beta_Q$ equal to one. Those relating to UDL correspond to the most common traffic scenarios, in which an accumulation of lorries might occur, but not frequently. Other values of all $\psi'_1$ and $\psi_1$ factors, or of some of them, may be specified for other classes of routes, or of expected traffic, related to the choice of the corresponding $\alpha$ factors.

A value of $\psi_2$ other than zero may be specified, for the UDL system of LM1 only, for bridges supporting a severe continuous traffic.

3) The factors for UDL apply not only to the distributed part of LM1, but also to the reduced pedestrian load mentioned in Table 4.4.

4) When the wind action is treated as the dominant action (i.e. represented by $F_{Wk}$ or $F_{Wn}$), $\psi_0$ for gr1 should be taken as zero and the additional thickness specified in C.2.1.1(3) is not considered. When the traffic action is treated as dominant, the wind action $\psi_0F_{Wk}$ or $\psi_0F_{Wn}$ should be taken as not greater than $F_{W}$ (see C2.1.1(7)), and its representative value is calculated taking into account the additional thickness specified in C2.1.1(3).

5) Unless otherwise specified (e.g. in the case of brittle materials at low temperature - see the relevant design Eurocode). However, for SLS, see C3.4(1).
C3 - Serviceability limit states

C3.1 Simultaneity of load models with other actions

(1) The rules concerning simultaneity given in C2.1.1 are applicable.

C3.2 Combinations of actions

(1) For persistent and transient design situations the various combinations should be taken from ENV 1991-1, 9.5.2.

(2) In addition, if specified by the design Eurocode, the infrequent combination:

\[ \sum_{j \geq 1} G_{kj} + P_k + \psi_1 Q_{k1} + \sum_{i>1} \psi_{li} Q_{ki} \]  

should be considered.

C3.3 Partial factors

(1) For road bridges, the partial factors on actions for Serviceability Limit States in persistent and transient situations should be taken as [1.0] unless otherwise specified.

C3.4 \( \Psi \) factors for road bridges

(1) Values of \( \psi \) factors are given in Table C.2, excepted the \( \psi_0 \)-value applicable to thermal effects, which is equal to \( 0.6 \).

C4 - Fatigue

(1) The verification rules for fatigue depend on the Fatigue Load Model to be used and are specified in the design Eurocodes.
Basis of design - supplementary clauses to ENV 1991-1 for footbridges

Note: This annex is intended, at a later stage, to be incorporated into ENV 1991-1 "Basis of design".

D1 - General

(1) This annex gives rules on partial factors on actions ($\gamma$-factors), and on combinations of pedestrians and cycle traffic loads on footbridges with permanent actions, quasi-static wind, snow and temperature actions, and the relevant $\psi$-factors. If other actions need to be considered (e.g. mining subsidence, instability due to wind, water, floating debris and ice pressure for some verifications relating to foundations), the combinations should be supplemented to take them into account. This annex should also be supplemented and adapted for the erection phases (see the relevant design Eurocodes) and for some particular categories of footbridges (e.g. moving footbridges).

(2) Footbridges are categorized as:

- those on which pedestrian - and cycle traffic is not protected, or not fully protected, from all types of bad weather, and
- those on which traffic is fully protected.

D2 - Ultimate limit states

D2.1 Simultaneity of load models

D2.1.1 Models of variable actions

(1) When relevant, the vertical loads and horizontal forces due to traffic shall be considered as simultaneous in accordance with clauses 5.3 and 5.4 and taken into account as groups of loads. Characteristic values of these loads are given in Table D.1. For other representative values they are modified and generally simplified by introducing the relevant $\psi$-factors.

<table>
<thead>
<tr>
<th>Load type</th>
<th>Vertical forces</th>
<th>Horizontal forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load system</td>
<td>Uniformly Distributed Load</td>
<td>Service Vehicle</td>
</tr>
<tr>
<td>Groups of Loads</td>
<td>gr1</td>
<td>$F_k$</td>
</tr>
<tr>
<td></td>
<td>gr2</td>
<td>0</td>
</tr>
</tbody>
</table>

Table D.1 - Definition of groups of loads (Characteristic values)
For any combination of traffic loads together with actions specified in other Parts of ENV 1991, any such group should be considered as one action.

The characteristic wind action on footbridges may be assessed in ENV 1991-2-4 either as characteristic force \( F_{wk} \) or as normal force \( F_{Wn} \).

(2) The forces and constrained deformations resulting from relevant permanent and variable actions on bridges specified in other Parts of ENV 1991 shall be considered simultaneously in combinations with the traffic loads where relevant.

(3) The concentrated load \( Q_{fW} \) (see 5.3.2.(4)) should not be combined with any other variable non-traffic load.

(4) For footbridges, wind and thermal actions should not be taken into account as simultaneous.

(5) For the first category of footbridges defined in D1.(2), the traffic may be considered to be incompatible with significant wind and/or snow, unless otherwise specified.

(6) For the second category of footbridges defined in D1.(2), the fundamental combinations are the same as for buildings, unless otherwise specified (see ENV 1991-1), the imposed loads being replaced by the relevant group of loads, the partial factors on actions and the \( \psi_0 \) factors being applied in accordance with the design Eurocodes, and the other \( \psi \) factors for traffic actions being in accordance with D.2.4.

Note: This implies in principle at least four combinations, each of them including four variable actions with a series of load cases. It is recommended that the possibilities of simplifications be examined for particular projects.

**D2.1.2 Models including accidental actions**

(1) Where an accidental action is to be considered, no other accidental action or wind or snow actions should be considered to occur simultaneously.

(2) The simultaneity of accidental actions with variable traffic actions is defined below and where the relevant individual accidental actions are defined.

(3) When collisions due to traffic running under the bridges are considered (see 5.6.1 and 5.6.2), the frequent loads due to the traffic running on the bridges should be introduced as accompanying actions in the combinations, unless otherwise specified.

(4) When accidental actions due to the traffic running on bridges are considered (loads defined in 5.6.3), all accompanying traffic actions should be neglected, unless otherwise specified.

Note: When other accidental actions on bridges have to be considered, rules on simultaneity with traffic actions shall be specified.

**D2.2 Combinations of actions**
(1) For each critical load case, the design values of the effects of actions shall be determined by combining the values of actions which occur simultaneously. ENV 1991-1, 9.4.2 applies.

D2.3 Partial factors for footbridges

(1) The partial factors on actions for Ultimate Limit States in the persistent, transient and accidental design situations are the same as specified in annex C (C.2.3).

D2.4 $\psi$ factors for footbridges

(1) Unless otherwise specified (e.g. in the relevant Part of ENV 1991 devoted to specific actions), $\psi$ factors for the first category of footbridges are as given in Table D.2. For the second category, see D.2.1.1(6) above. For traffic action, in both cases, the factors apply as well to the groups of loads defined in Table D.1 as to the individual components of the groups where they are considered separately.

<table>
<thead>
<tr>
<th>Action</th>
<th>Symbol</th>
<th>$\psi_0$</th>
<th>$\psi_1^{1)}$</th>
<th>$\psi_1$</th>
<th>$\psi_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Loads</td>
<td>gr1</td>
<td>[0,40]</td>
<td>[0,80]</td>
<td>[0,40]</td>
<td>[0]</td>
</tr>
<tr>
<td></td>
<td>$Q_{f wk}$</td>
<td>0</td>
<td>[0]</td>
<td>[0]</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>gr2</td>
<td>[0]</td>
<td>[1,00]</td>
<td>[0]</td>
<td>[0]</td>
</tr>
<tr>
<td>Wind Force</td>
<td>$F_{Wk}$ or $F_W$</td>
<td>[0]$^2)$</td>
<td>[0,6]</td>
<td>[0,5]</td>
<td>[0]</td>
</tr>
<tr>
<td>Temperature Effect</td>
<td>$T_k$</td>
<td>[0]$^3)$</td>
<td>[0,8]</td>
<td>[0,6]</td>
<td>[0,5]</td>
</tr>
</tbody>
</table>

1) $\psi_1$ is a $\psi$ -factor intended to define infrequent loads (see 2.2)

2) If a dominant action other than traffic or temperature has to be considered, this value may have to be replaced by 0,3.

3) Unless otherwise specified (e.g. in the case of brittle materials at low temperature - see the relevant design Eurocode). However, for serviceability limit states, see D3.4.

D3 - Serviceability limit states

D3.1 Simultaneity of load models on footbridges

(1) The rules concerning simultaneity given in D2.1.1 are applicable.

D3.2 Combinations of actions
(1) For persistent and transient design situations the various combinations should be taken from ENV 1991 - 1, 9.5.2.
(2) In addition, if specified by the design Eurocode, the infrequent combination:
\[ \sum_{j \geq 1} G_{kj} \quad + \quad P_k \quad + \quad \psi_1 Q_{k1} \quad + \quad \sum_{i > 1} \psi_i Q_{ki} \]  
should be considered.

**D3.3 Partial factors**

(1) For footbridges, the partial factors on actions for serviceability limit states in persistent and transient situations should be taken as [1.0] unless otherwise specified.

**D3.4 \( \Psi \) factors for footbridges**

(1) Values of \( \psi \) factors are given in Table D.2, excepted the \( \psi_0 \)-value applicable to thermal effects on footbridges of the first category, which is equal to [0.6].