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Loads to be considered in railway bridge design

Charges à prendre en considération dans le calcul des ponts-rails

Bei der Berechnung von Eisenbahnbrücken zu berücksichtigende Lasten



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Contents

Summary	1
1 - General principles.....	2
1.1 - Symbols.....	2
1.1.1 - Latin upper case letters.....	2
1.1.2 - Latin lower case letters	3
1.1.3 - Greek upper case letters.....	3
1.1.4 - Greek lower case letters	3
1.2 - General.....	4
1.2.1 - Design situations.....	4
1.2.2 - Combinations of actions.....	4
1.2.3 - Groups of loads.....	5
1.2.4 - Additional loading considerations	5
1.2.5 - Design acceptance criteria and limit states.....	5
1.3 - Actions.....	6
1.3.1 - Classification of actions	6
1.3.2 - Actions to be taken into account.....	6
1.4 - Characteristic values of actions.....	9
2 - Rail traffic actions and other actions for railway bridges	11
2.1 - Field of application.....	11
2.2 - Representation of actions - Nature of rail traffic loads.....	11
2.3 - Vertical loads - Characteristic values (static effects), eccentricity and distribution of loading.....	12
2.3.1 - General	12
2.3.2 - Load Model 71	12
2.3.3 - Load Models SW/0 and SW/2.....	13
2.3.4 - Load Model "unloaded train"	14
2.3.5 - Eccentricity and transverse distribution of vertical loads (Load Models 71 and SW/0)	14
2.3.6 - Transverse and longitudinal distribution of vertical loads	14
2.3.7 - Equivalent vertical loading for earthworks and earth pressure effects	14
2.3.8 - General maintenance loading for non-public footpaths	15
2.3.9 - Loading for platforms	15
2.3.10 - Loads on parapets and safety barriers	15

2.4 - Dynamic effects	15
2.4.1 - Introduction	15
2.4.2 - Dynamic factor Φ (Φ_2 , Φ_3)	15
2.5 - Horizontal forces - Characteristic values	19
2.5.1 - Centrifugal forces.....	19
2.5.2 - Nosing force.....	22
2.5.3 - Actions due to traction and braking.....	22
2.6 - Other actions for railway bridges	23
2.7 - Derailment	24
2.7.1 - Derailment actions from rail traffic on a railway bridge	24
2.7.2 - Derailment under or adjacent to a structure and other actions for other accidental design situations	25
2.8 - Application of traffic loads on railway bridges	26
2.8.1 - General	26
2.8.2 - Groups of loads - Characteristic values of the multicomponent action	27
2.8.3 - Groups of loads - Other representative values of the multicomponent actions	29
2.8.4 - Traffic loads for transient design situations.....	29
3 - Load combinations and appropriate partial factors	30
3.1 - General	30
3.2 - Ultimate limit state	30
3.3 - Serviceability limit state	31
3.4 - Combinations of actions	31
3.5 - Recommended design values, partial factors and ψ factors.....	33
3.6 - Fatigue.....	34
Appendix A - Design situations and combinations of actions	35
Appendix B - Determination of Load Models	39
Appendix C - Dynamic factors for Real Trains.....	41
Appendix D - Description of Groups of Loads.....	45
Bibliography	46

Summary

UIC Leaflet 776-1 describes the loads to be taken into account in the design of railway bridges.

The leaflet defines imposed loads (load models and characteristic values) associated with rail traffic which include:

- vertical loads for bridges,
- vertical loading for earthworks,
- dynamic effects,
- centrifugal actions,
- nosing action,
- braking and acceleration actions,
- and actions for Accidental Design Situations corresponding to the derailment of rail traffic on the bridge.

It gives also rules and methods for establishing combinations of actions and design values of actions to be taken into account in limit state design.

The commissioning party should specify additional requirements for the design of roofed bridges, moveable bridges or bridges carrying road and rail traffic or other structured carrying rail traffic loads (e.g. backfill behind a retaining wall).

1 - General principles

1.1 - Symbols

The following symbols apply:

1.1.1 - Latin upper case letters

A	Accompanying action
A_d	Design value of an accidental action
C_d	Design value of the relevant serviceability criterion
E_d	Design value of the effect of actions
$E_{d, dst}$	Design value of the effect of destabilising actions
$E_{d, stb}$	Design value of the effect of stabilising actions
R_d	Design value of the corresponding resistance of the structure
F_w^{**}	Wind force compatible with rail traffic
F_{wk}	Characteristic wind force
F_{wn}	Nominal wind force
G	Self-weight (general)
L	Length (general) Leading variable action
L_f	Influence length of the loaded part of curved track
L_i	Influence length
L_Φ	"Determinant" length (length associated with Φ)
M	Main accompanying variable action
O	Other accompanying variable action
P	Relevant representative value of a prestressing action
Q_{Ald}	Point load for derailment loading
Q_h	Horizontal force (general)
Q_k	Concentrated load
Q_{vk}	Concentrated vertical load
Q_{la}	Traction (acceleration) force
Q_{lb}	Braking force
Q_r	Rail traffic action (general, e.g. resultant of wind and centrifugal force)
Q_s	Nosing force
Q_t	Centrifugal force
Q_v	Vertical axle load
Q_{vi}	Wheel load
V	Speed in km/h Maximum Line Speed at the Site in km/h

1.1.2 - Latin lower case letters

a	Distance between rail supports, length of distributed loads (Load Models SW/0 and SW/2)
a_g	Horizontal distance to the track centre
c	Space between distributed loads (Load Models SW/0 and SW/2)
e	Eccentricity of vertical loads Eccentricity of resulting action (on reference plane) Base of natural logarithms
f	Reduction factor for centrifugal force
g	Acceleration due to gravity
h	Height (general)
h_t	Height of centrifugal force over running surface
m	Mass of structure per unit length
n_0	First natural bending frequency of the unloaded structure
q_{Ai}	Accidental line load
q_{A1d}, q_{A2d}	Distributed loading for derailment loading
q_f	Loading on non-public footpath
q_t	Centrifugal force
q_{vk}	Vertical distributed load
r	Radius of track curvature Transverse distance between wheel loads
s	Track gauge
u	Cant, relative vertical distance between the uppermost surface of the two rails at a particular location along the track
v	Speed in m/s
g_{ri}	Group of Loads, i is a number (i = 1 to n)

1.1.3 - Greek upper case letters

$\Phi(\Phi_2, \Phi_3)$ Dynamic factor for railway Load Models 71, SW/0 and SW/2

1.1.4 - Greek lower case letters

α	Load classification factor
γ	Partial factor (safety or serviceability)
$\varphi, \varphi', \varphi''$	Dynamic enhancement of static loading for Real Trains
ψ_0	Factor for the combination value of a variable action
ψ_1	Factor for the frequent value of a variable action
ψ_2	Factor for the quasi-permanent value of a variable action

1.2 - General

Railway bridges should be designed for the relevant actions associated with the types of loading listed in point 1.3 - page 6.

Recommendations for characteristic values of actions to be taken into account associated with rail traffic are given in point 2 - page 11.

The actions to be taken into account for loading other than due to rail traffic should be in accordance with the relevant international or national requirements.

1.2.1 - Design situations

Appropriate combinations of actions should be taken into account for the design of railway bridges, taking into account the circumstances under which the bridge is required to fulfil its function:

The following design situations should be taken into account:

- *Persistent design situations*, generally corresponding to conditions of normal use with a return period equal to the intended life of the structure;
- *Transient design situations*, corresponding to temporary conditions applicable to the structure with a return period much shorter than the life of the structure (including consideration of the execution of the structure, where a structure is brought into use in stages to carry railway traffic loading, etc. before construction is completed and loading requirements associated with maintenance of the bridge and tracks, etc.);
- *Accidental design situations*, including exceptional conditions, applicable to the structure including consideration of derailment on or in the vicinity of the bridge, impact from errant road traffic on the bridge, etc. and other relevant international and national requirements;
- *Seismic design situations*, where required in accordance with national requirements;
- any other design situations as required by the commissioning party;
- any other design situation as required by relevant international or national requirements.

NB : The commissioning party should specify:

- requirements relating to transient design situations,
- requirements relating to temporary bridges,
- the intended life of the structure which should generally be at least 100 years for a railway bridge.

1.2.2 - Combinations of actions

Guidance on appropriate combinations of actions to be taken into account is given in point 3 - page 30. Generally each action is considered in turn as a leading action with other actions taken as accompanying actions.

1.2.3 - Groups of loads

Point 3 also lists appropriate combinations and partial γ and ψ factors to be used when railway loading is considered using the group of loads technique. The group of loads technique has been developed to simplify the design process. Rail traffic loading is treated as a single multi-component variable action. The single multi-component action is then combined with other actions as a single variable action. Groups of loads that may be used for the design of railway bridges are defined in Table 4 - page 28.

The group of loads technique is not suitable for use in all situations. For example individual rail traffic actions should also be taken into account in the design of bearings, for the assessment of maximum lateral and minimum vertical traffic loading, design of bearing restraints, the assessment of maximum overturning effects on abutments (especially for continuous bridges), etc.

Further information on the group of loads technique is given in Appendix D - page 45.

1.2.4 - Additional loading considerations

In addition, the design of a railway bridge should take into account the relevant loading:

- associated with the construction of the bridge,
- appropriate to the stage of construction,
- appropriate to the use of the bridge where the structure is brought into use in stages prior to the completion of construction,
- requirements for temporary loading situations defined by the railway operator associated, for example, with track maintenance, replacement of bearings, etc.

1.2.5 - Design acceptance criteria and limit states

Guidance on the relevant performance requirements and design acceptance criteria for railway bridges are given in *UIC Leaflet 774-3 and 776-2* (see Bibliography - page 46) and relevant international and national requirements.

Basic requirements relating to the design of railway bridges should be in accordance with the relevant international and national requirements regarding structural resistance, serviceability, durability, fitness for intended use, avoidance of damage from events not disproportionate to original cause, etc.

This leaflet assumes that requirements relating to the design of the structure are in accordance with the requirements of relevant international and national requirements (e.g. *Eurocode EN 1990*, see Bibliography - page 46) and that the design of the structure is in accordance with limit state principles.

Generally, the design of a railway bridge should consider the following limit states:

- the ultimate limit states associated with collapse of all or part of the structure and other similar forms of structural failure (e.g. buckling failure, loss of equilibrium, rupture, excessive deformation, failure or excessive deformation of the supporting ground, etc.),
- fatigue failure of all or part of the structure (limit states corresponding to fatigue are outside the scope of this leaflet),

- serviceability limit states corresponding to conditions beyond which the specified service requirements for the structure are no longer met (e.g. for durability of the structure or for general deformation requirements, etc.) and *inter alia* deformation and vibration limits for railway bridges given in *UIC Leaflet 776-2*. To include consideration of both reversible and irreversible serviceability limit states,
- checks on design criteria relating to ensuring the safety of railway traffic (see *UIC Leaflet 774-3* for longitudinal forces and *UIC Leaflet 776-2* for deformation and vibration limits relating to interaction between train, track and bridge),

in accordance with the requirements of relevant international and national requirements.

1.3 - Actions

1.3.1 - Classification of actions

In accordance with the relevant international or national requirements, actions may generally be classified by the manner in which they vary with time:

- *permanent actions* that are either constant, vary very slowly with time or only occasionally change, for example self weight, imposed loads, uneven settlement, etc.,
- *variable actions*, e.g. rail traffic actions, wind, temperature effects, etc.,
- *accidental actions*, e.g. from impact from vehicles on bridge supports or superstructure, derailment loads on the bridge deck, etc.

1.3.2 - Actions to be taken into account

Railway bridges should be designed to take the following actions into account:

1.3.2.1 - Permanent actions

Direct actions:

- self weight,
- horizontal earth pressure and if relevant, other soil/ structure interaction forces,
- track and ballast,
- movable loads:
 - self weight of non structural elements,
 - loading from overhead line equipment (vertical and horizontal),
 - loading from other railway infrastructure equipment.

Indirect actions:

- settlement (for some structures consideration of absolute settlement can be critical when considering differential movement between a structure and the kinematic envelope of a train),
- differential settlement (including the effects of mining subsidence where required by the commissioning party),
- shrinkage and creep,
- prestress.

1.3.2.2 - Variable actions

1.3.2.2.1 - Rail traffic actions

- Vertical traffic actions (appropriate additional allowance to be made for dynamic effects):
 - UIC Load Model 71,
 - UIC Load Model SW/0,
 - UIC Load Model SW/2 (where required by the commissioning party),
 - Load Model HSLM (High Speed Load Model in accordance with *Eurocode 1991-2* (see [Bibliography - page 46](#)), where required by the Technical Specification for Interoperability of High Speed Traffic in accordance with the relevant EU Directive and/or the commissioning party (see also *UIC Leaflet 776-2*),
 - Load Model "unloaded train" (for checking lateral stability in conjunction with lateral rail traffic actions and wind loading on the bridge and rail vehicles),
 - Load effects from Real Trains (where required by the commissioning party).
- Centrifugal;
- Traction and braking;
- Nosing;
- Longitudinal forces (see also *UIC Leaflet 774-3* for load effects generated by the interaction between track and structure in resisting variable actions);
- Load effects generated by the interaction between train, track and structure in presence of variable actions (see *UIC Leaflet 776-2*);
- Live load surcharge horizontal earth pressure;
- Aerodynamic actions (slipstream effects from passing rail traffic, etc.) (*UIC Leaflet 779-1*, see [Bibliography - page 46](#)).

1.3.2.2.2 - Other traffic actions

- Actions on public footpaths (uniformly distributed and point loads).
- Loads on non-public footpaths (uniformly distributed and point loads).
- Loads on platforms.
- Loads on areas where vehicular traffic permitted.
- Horizontal loads on pedestrian parapets.
- Horizontal loads on vehicle parapets due to vehicle containment, etc.

1.3.2.2.3 - Other actions

- Other operating actions:
 - stressing or destressing continuous welded rails.
- Construction loading:
 - plant,
 - personnel,
 - storage of materials,
 - actions associated with method of construction.

1.3.2.2.4 - Natural actions

- Wind.

NB : Where permitted by the commissioning party a reduced maximum wind speed compatible with rail traffic operation may be specified.

- Thermal (uniform, temperature, gradient, etc.).
- Thermal restraint from bearing friction.
- Water pressure:
 - ground water,
 - free water,
 - moving water,
 - uplift, etc.
- The effects of scour.
- Water borne debris.
- Ice loads (where required by the relevant authority).
- Ice pressure (where required by the relevant authority).
- Snow loading (where required by the relevant authority).

- Avalanche (where required by the relevant authority).
- Mud slides (where required by the relevant authority).

1.3.2.3 - Accidental actions

- Actions corresponding to derailment of rail traffic on the bridge.
- Actions corresponding to derailment of rail traffic beneath or adjacent to the bridge (*UIC Leaflet 777-1 and 777-2*, see Bibliography - [page 46](#)).
- Accidental loading from errant road vehicles beneath the bridge.
- Accidental loading from over height road vehicles beneath the bridge.
- Ship impact.
- Actions due to the rupture of catenaries.
- Actions due to the accidental breakage of rails.
- Accidental loadings during construction.
- Fire (where required by the relevant authority).

1.3.2.4 - Seismic actions

- Actions due to earthquake loading (where specified by the relevant international and national requirements).

1.4 - Characteristic values of actions

The rail loadings given in point [2 - page 11](#) have been developed using deterministic methods.

Subject to the loadings specified in point [2](#) being enhanced by appropriate partial factors the loadings may be considered as characteristic values.

The values of γ and ψ factors given in point [3 - page 30](#) are based on comparative calibration studies against a selection of European national limit state codes, which in turn are generally based on empirical and historical (including permissible stress design codes) methods.

NB : The comparative studies were carried out to support the drafting of *ENV 1991-3* and no further comparative studies have been carried out by the UIC to support the conversion of *ENV 1991-3* to *EN 1991-2* and *EN 1990, Annex A2*. The relevant authorities should consider the need for further comparative calculations before adopting the γ and ψ values given in Tables 1 to 3 of Appendix A.

Requirements for either considering:

- a mean value of an action,
- or where the variability is significant, an upper and lower bound value,

should be in accordance with the relevant international or national requirements.

To take account of the variability of ballast depth an additional factor of either 1,33 (ballast load effect unfavourable) or 0,75 (ballast load effect favourable) should be applied to the nominal depth of ballast beneath the underside of the sleeper. The minimum and maximum nominal depths of ballast beneath the sleeper to be taken into account should be specified by the commissioning party. Any additional ballast provided below the nominal depth of ballast may be considered as an imposed moveable load. Additionally, the ballast density (or range of ballast densities) to be taken into account should be specified by the commissioning party.

Generally, the design of a railway bridge should be verified using the partial factor method outlined in point 3 - page 30.

2 - Rail traffic actions and other actions for railway bridges

2.1 - Field of application

This point applies to rail traffic on the standard and wide track gauge.

The load models defined in this point do not describe actual loads. They have been selected so that their effects, with dynamic increments taken into account separately, represent the effects of service traffic. Where traffic outside the scope of the load models specified in this point needs to be considered, then alternative load models, with associated combination rules, should be specified for the individual project.

This point is not applicable for actions due to:

- narrow-gauge railways,
- tramways and other light railways,
- preservation railways,
- rack and pinion railways,
- funicular railways.

Designers should pay special attention to temporary bridges because of the flexibility of some types of temporary structures. The loading and requirements for the design of temporary bridges should be specified by the commissioning party.

2.2 - Representation of actions - Nature of rail traffic loads

General rules are given for the calculation of the associated dynamic effects, centrifugal forces, nosing force, traction and braking forces.

Actions due to railway operations are given for:

- vertical loads: Load Models 71, SW (SW/0 and SW/2), and "unloaded train",
- vertical loading for earthworks,
- dynamic effects,
- centrifugal forces,
- nosing force,
- traction and braking forces,
- aerodynamic and slipstream actions from passing trains,
- actions due to overhead line equipment and other railway infrastructure and equipment.

Guidance on the evaluation of the combined response of structure and track to variable actions is given in *UIC Leaflet 774-3*.

Derailment actions for accidental design situations are given for the effect of rail traffic derailment on a structure carrying rail traffic.

2.3 - Vertical loads - Characteristic values (static effects), eccentricity and distribution of loading

Recommendations concerning the application of the following load models are given in point 2.8 - page 26.

2.3.1 - General

Rail traffic actions are defined by means of load models. Four models of railway loading are given:

- Load Model 71 and Load Model SW/0 (for continuous bridges) to represent normal rail traffic on mainline railways (see *UIC Leaflet 702*, see Bibliography - page 46 for the relevant rules of application),
- Load Model SW/2 to represent heavy loads,
- Load Model "unloaded train" to represent the effect of an unloaded train.

NB : In *UIC Leaflet 776-2*, a Load Model HSLM (comprising HSLM-A and HSLM-B) is given to represent the loading from passenger trains at speeds exceeding 200 km/h.

Provision is made for varying the specified loading to allow for differences in the nature, volume and maximum weight of rail traffic on different railways, as well as different qualities of track.

2.3.2 - Load Model 71

Load Model 71 represents the static effect of vertical loading due to normal rail traffic.

The load arrangement and the characteristic values for vertical loads shall be taken as shown in Fig. 1.

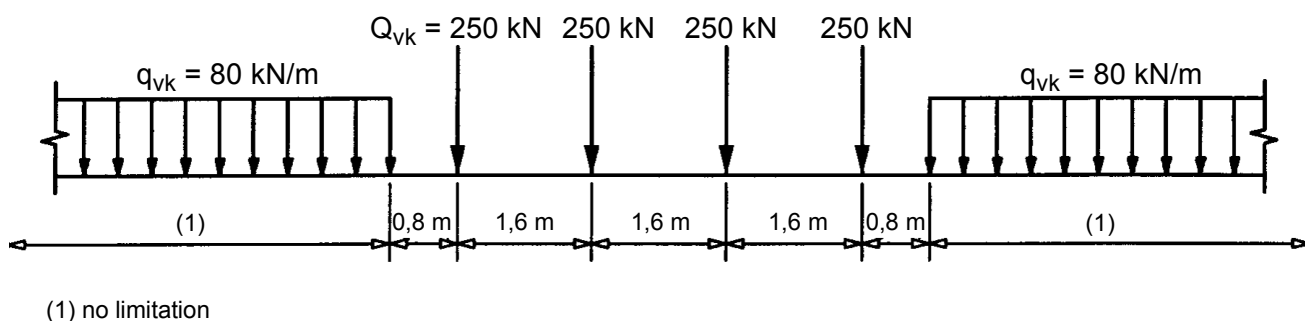


Fig. 1 - Load Model 71 and characteristic values for vertical loads