“Application of Eurocodes for bridges”

Introduction, Traffic Loads on Bridges & Combinations of actions

Jean-Armand Calgaro
Chairman of CEN/TC250

Athens, 20 October 2008
Design of Bridges with the Eurocodes

EN 1991
Self-weights + Traffic loads + Climatic actions + Accidental actions + Actions during execution

EN 1990
Basis of Structural design
Combinations of actions

Design Eurocodes
EN 1992, EN 1993
EN 1994, EN 1995

Product Standards
EN 1337 Bearings
Technical Approvals

Execution Standards
EN 13670
Concrete
EN 1090 Steel

EN 1997
Design of foundations

EN 1998
Design of structures for earthquake resistance

Material Standards
EN 201-1
Concrete
EN 10025 Steel
EN 1991-2 « Traffic Loads on Bridges »

Eurocode 1 : Actions on structures – Part 2: Traffic Loads on Bridges
EN 1991-2 « Traffic Loads on Bridges »

- FOREWORD
- SECTION 1 GENERAL
- SECTION 2 CLASSIFICATION OF ACTIONS
- SECTION 3 DESIGN SITUATIONS
- SECTION 4 ROAD TRAFFIC ACTIONS AND OTHER ACTIONS SPECIFICALLY FOR ROAD BRIDGES
- SECTION 5 ACTIONS ON FOOTWAYS, CYCLE TRACKS AND FOOTBRIDGES
- SECTION 6 RAIL TRAFFIC ACTIONS AND OTHER ACTIONS SPECIFICALLY FOR RAILWAY BRIDGES
<table>
<thead>
<tr>
<th>ANNEX</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (I)</td>
<td>Models of special vehicles for road bridges</td>
</tr>
<tr>
<td>B (I)</td>
<td>Fatigue life assessment for road bridges – Assessment method based on recorded traffic</td>
</tr>
<tr>
<td>C (N)</td>
<td>Dynamic factors $1+\varphi$ for real trains</td>
</tr>
<tr>
<td>D (N)</td>
<td>Basis for the fatigue assessment of railway structures</td>
</tr>
<tr>
<td>E (I)</td>
<td>Limits of validity of load model HSLM and the selection of the critical universal train from HSLM-A</td>
</tr>
<tr>
<td>F (I)</td>
<td>Criteria to be satisfied if a dynamic analysis is not required</td>
</tr>
<tr>
<td>G (I)</td>
<td>Method for determining the combined response of a structure and track to variable actions</td>
</tr>
<tr>
<td>H (I)</td>
<td>Load models for rail traffic loads in transient situations</td>
</tr>
</tbody>
</table>
TRAFFIC LOAD MODELS FOR ROAD BRIDGES

Traffic load models

- Vertical forces: LM1, LM2, LM3, LM4
- Horizontal forces: braking and acceleration, centrifugal, transverse

Groups of loads

- gr1a, gr1b, gr2, gr3, gr4, gr5
- characteristic, frequent and quasi-permanent values

Combination with actions other than traffic actions
Load Model Nr. 1
Concentrated and distributed loads (main model – For general and local verifications)

Load Model Nr. 2
Single axle load (semi-local and local verifications)

Load Model Nr. 3
Set of special vehicles (general and local verifications)

Load Model Nr. 4
Crowd loading: 5 kN/m² (general verifications)
The main load model (LM1)

EN 1991-2 « Traffic Loads on Bridges »

TS : Tandem system
UDL : Uniformly distributed load
The main load model (LM1)

Example of values for $\alpha$ factors (National Annexes)

1\textsuperscript{st} class: international heavy vehicle traffic

2\textsuperscript{nd} class: «normal» heavy vehicle traffic

<table>
<thead>
<tr>
<th>Classes</th>
<th>$\alpha_{Q1}$</th>
<th>$\alpha_{Qi} \ i \geq 2$</th>
<th>$\alpha_q$</th>
<th>$\alpha_{qi} \ i \geq 2$</th>
<th>$\alpha_{qr}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\textsuperscript{st} class</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2\textsuperscript{nd} class</td>
<td>0,9</td>
<td>0,8</td>
<td>0,7</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Example of influence surface (transverse bending moment) for a deck slab
EN 1991-2 « Traffic Loads on Bridges »

Load model Nr. 2 (LM2)

Recommended value: \( \beta_Q = \alpha_{Q_1} \) (National Annex)
EN 1991-2 « Traffic Loads on Bridges »

HORIZONTAL FORCES : BRAKING AND ACCELERATION (Lane Nr. 1)

\[ Q_{lk} = 0.6\alpha_{Q1} (2Q_{1k}) + 0.10\alpha_{q1} q_{1k} w_1 L \]

\[ 180\alpha_{Q1} kN \leq Q_{lk} \leq 900 kN \]

\[ Q_{lk} = 180 + 2.7L \]
For \( 0 \leq L \leq 1.2 \) m

\[ Q_{lk} = 360 + 2.7L \]
For \( L > 1.2 \) m
Group of loads gr1a:
LM1 + « reduced » value of pedestrian load on footways or cycle tracks (3 kN/m²)

Group of loads gr1b: LM2
(single axle load)

Group of loads gr2:
characteristic values of horizontal forces, frequent values of LM1
Group of loads gr3: loads on footways and cycle tracks

Group of loads gr4: crowd loading

Group of loads gr5: special vehicles (+ special conditions for normal traffic)
# The “good” Table 4.4a - Assessment of groups of traffic loads (characteristic values of the multi-component action)

<table>
<thead>
<tr>
<th>Groups of Loads</th>
<th>Load type</th>
<th>CARRIAGEWAY</th>
<th>FOOTWAYS AND CYCLE TRACKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reference</td>
<td>4.3.2</td>
<td>4.3.3 4.3.4 4.3.5</td>
</tr>
<tr>
<td>Load system</td>
<td>LM1 (TS and UDL systems)</td>
<td>LM2 (Single axle)</td>
<td>LM3 (Special vehicles)</td>
</tr>
<tr>
<td>Groups of Loads</td>
<td>gr1a</td>
<td>Characteristic values</td>
<td></td>
</tr>
<tr>
<td></td>
<td>gr1b</td>
<td>Characteristic value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>gr2</td>
<td>Frequent values</td>
<td>Characteristic value</td>
</tr>
<tr>
<td></td>
<td>gr3</td>
<td>Frequent values</td>
<td>Characteristic value</td>
</tr>
<tr>
<td></td>
<td>gr4</td>
<td></td>
<td>Characteristic value</td>
</tr>
<tr>
<td></td>
<td>gr5</td>
<td>See annex A</td>
<td>Characteristic value</td>
</tr>
</tbody>
</table>

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

- **a** May be defined in the National Annex.
- **b** May be defined in the National Annex. The recommended value is 3 kN/m².
- **c** See 5.3.2.1-(2). One footway only should be considered to be loaded if the effect is more unfavourable than the effect of two loaded footways.
- **d** This group is irrelevant if gr4 is considered.
FATIGUE LOAD MODELS

- Load Model Nr. 1 (FLM1): Similar to Load Model Nr. 1
  \[ 0.7 \times Q_{ik} - 0.3 \times q_{ik} - 0.3 \times q_{rk} \]

- Load Model Nr. 2 (FLM2): Set of « frequent » lorries

- Load Model Nr. 3 (FLM3): Single vehicle

- Load Model Nr. 4 (FLM4): Set of « equivalent » lorries (to create an artificial traffic)

- Load Model Nr. 5 (FLM5): Use of recorded traffic effects
EN 1991-2 « Traffic Loads on Bridges »

Fatigue Load Model Nr.3 (FLM3)

A second vehicle may be taken into account:
Recommended axle load value $Q = 36$ kN
Minimum distance between vehicles: 40 m
Verification procedure with Load Model FLM 3

- Determination of the maximum and minimum stresses resulting from the transit of the model along the bridge
  \[ \Delta \sigma_{LM} = \left| \text{Max} \sigma_{LM} - \text{Min} \sigma_{LM} \right| \]

- The stress variation is multiplied by a local dynamic amplification factor in the vicinity of expansion joints
  \[ \Delta \varphi_{fat} \]

- The model is normally centered in every slow lane defined in the project specification.

- Design value of the stress variation
  \[ \Delta \sigma_{fat} = \lambda \Delta \varphi_{fat} \Delta \sigma_{LM} \]
Rail traffic actions

\(s\) : gauge
\(u\) : cant
\(Q_s\): nosing force

(1) Running surface
(2) Longitudinal forces acting along the centreline of the track
The characteristic values are multiplied by a factor $\alpha$ on lines carrying rail traffic which is heavier or lighter than normal rail traffic.

This factor $\alpha$ shall be one of the following: 0,75 - 0,83 - 0,91 - 1,00 - 1,10 - 1,21 - 1,33 – 1,46.

The value 1,33 is normally recommended on lines for freight traffic and international lines (UIC CODE 702, 2003).
EN 1991-2 « Traffic Loads on Bridges »

LOAD MODELS SW/0 & SW/2 (heavy traffic)

![Diagram showing load models SW/0 and SW/2 with symbols q_\text{vk}, a, c.]

<table>
<thead>
<tr>
<th>Load model</th>
<th>$q_{vk}$ [kN/m]</th>
<th>$a$ [m]</th>
<th>$c$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW/0</td>
<td>133</td>
<td>15,0</td>
<td>5,3</td>
</tr>
<tr>
<td>SW/2</td>
<td>150</td>
<td>25,0</td>
<td>7,0</td>
</tr>
</tbody>
</table>
Example of a heavy weight waggon (DB, 32 axles, selfweight 246 t, pay load 457 t, mass per axle 22 t, $L_{tot} = 63.3$ m)

EN 1991-2 « Traffic Loads on Bridges »
EN 1991-2 « Traffic Loads on Bridges »

High speed trains: 2 load models HSLM-A and HSL-B
HSLM-A and HSLM-B together represent the dynamic load effects of articulated, conventional and regular high speed passenger trains in accordance with the requirements for the European Technical Specification for Interoperability

HSLM-A: (1) Power car (leading and trailing power cars identical); 2) End coach (leading and trailing end coaches identical); (3) Intermediate coach

HSLM-B: 4xP (1), 3xP (2), 2xP (3)
- Dynamic factors for static calculations:
  - $\Phi_2$ for carefully maintained track
  - $\Phi_3$ for standard track (means: poor track)
    (determinant lengths $L_\Phi$ due to table 6.2)
- Dynamic enhancement for real trains
  $$1 + \varphi = 1 + \varphi' + \left(\frac{1}{2}\right) \varphi''$$
- Dynamic enhancement for fatigue calculations
  $$\varphi = 1 + \frac{1}{2}(\varphi' + \left(\frac{1}{2}\right) \varphi'')$$
- Dynamic enhancement for dynamic studies
  $$\varphi'_{dyn} = \max \left| \frac{y_{dyn}}{y_{stat}} \right| - 1$$
Interaction model between the bridge and the track

(1) Track

(2) Superstructure (a single deck comprising two spans and a single deck with one span shown)

(3) Embankment

(4) Rail expansion device (if present)

(5) Longitudinal non-linear springs reproducing the longitudinal load/displacement behaviour of the track

(6) Longitudinal springs reproducing the longitudinal stiffness $K$ of a fixed support to the deck taking into account the stiffness of the foundation, piers and bearings etc.
Example of a real train for fatigue
(Nr. 1 of 12 types of trains defined in the Eurocode)

$\Sigma Q = 6630\text{kN} \quad V = 200\text{km/h} \quad L = 262,10\text{m} \quad q = 25,3\text{kN/m'}$
## EN 1991-2 « Traffic Loads on Bridges »

<table>
<thead>
<tr>
<th>number of tracks on structure</th>
<th>Groups of loads</th>
<th>Vertical forces</th>
<th>Horizontal forces</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reference EN 1991-2</td>
<td>6.3.2/6.3.3</td>
<td>6.3.3</td>
<td>6.3.4</td>
</tr>
<tr>
<td>1</td>
<td>gr11</td>
<td>T₁</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>gr12</td>
<td>T₁</td>
<td>1</td>
<td>0,5 (5)</td>
</tr>
<tr>
<td>1</td>
<td>gr13</td>
<td>T₁</td>
<td>1 (4)</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>gr14</td>
<td>T₁</td>
<td>1 (4)</td>
<td>0,5 (5)</td>
</tr>
<tr>
<td>1</td>
<td>gr15</td>
<td>T₁</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>gr16</td>
<td>T₁</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>gr17</td>
<td>T₁</td>
<td>1</td>
<td>0,5 (5)</td>
</tr>
<tr>
<td>2</td>
<td>gr21</td>
<td>T₁, T₂</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>gr22</td>
<td>T₁, T₂</td>
<td>1</td>
<td>0,5 (5)</td>
</tr>
<tr>
<td>2</td>
<td>gr23</td>
<td>T₁, T₂</td>
<td>1 (4)</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>gr24</td>
<td>T₁, T₂</td>
<td>1 (4)</td>
<td>0,5 (5)</td>
</tr>
<tr>
<td>2</td>
<td>gr26</td>
<td>T₁, T₂</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>gr27</td>
<td>T₁, T₂</td>
<td>1</td>
<td>0,5 (5)</td>
</tr>
<tr>
<td>≥3</td>
<td>gr31</td>
<td>T₁</td>
<td>0,75</td>
<td>0,75 (5)</td>
</tr>
</tbody>
</table>
Maximum permissible vertical deflection $\delta$ for railway bridges with 3 or more successive simply supported spans corresponding to a permissible vertical acceleration of $b_v = 1 \text{ m/s}^2$ in a coach for speed $V [\text{km/h}]$. 

EN 1990/A1 «Application for Bridges»
EN 1990 – Section 6, Annex A2

Eurocode – Basis of structural design
(includes amendment A1:2005)

This European Standard was approved by CEN on 29 November 2001; amendment A1:2005 was approved by CEN on 14 October 2004.

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

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

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EN 1990
"Eurocode : Basis of Structural Design"
EN 1990 – Section 6, Annex A2

Foreword
Section 1 : General
Section 2 : Requirements
Section 3 : Principles of limit states
Section 4 : Basic variables
Section 5 : Structural analysis and design assisted by testing
Section 6 : Verification by the partial factor method

Annex A1 : Application for buildings (N)
Annex A2 : Application for bridges (N) (EN 1990/A1)
Annex B : Management of structural reliability for construction works (I)
Annex C : Basis for partial factor design and reliability analysis (I)
Annex D : Design assisted by testing (I)
Section 6 - Verification by the partial factor method

6.1 General
6.2 Limitations
6.3 Design values
6.4 Ultimate limit states
6.5 Serviceability limit states
## EN 1990 – Section 6, Annex A2

<table>
<thead>
<tr>
<th>Design situations</th>
<th>Verifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Persistent</strong></td>
<td></td>
</tr>
<tr>
<td>Normal use</td>
<td>ULS, SLS</td>
</tr>
<tr>
<td><strong>Transient</strong></td>
<td></td>
</tr>
<tr>
<td>Execution, temporary</td>
<td>ULS, SLS</td>
</tr>
<tr>
<td>conditions applicable to</td>
<td></td>
</tr>
<tr>
<td>the structure, e.g.</td>
<td></td>
</tr>
<tr>
<td>maintenance or repair</td>
<td></td>
</tr>
<tr>
<td><strong>Accidental</strong></td>
<td></td>
</tr>
<tr>
<td>Normal use</td>
<td>ULS</td>
</tr>
<tr>
<td>During execution</td>
<td>ULS</td>
</tr>
<tr>
<td><strong>Seismic</strong></td>
<td></td>
</tr>
<tr>
<td>Normal use</td>
<td>ULS, SLS</td>
</tr>
<tr>
<td>During execution</td>
<td>ULS, SLS</td>
</tr>
</tbody>
</table>

The selected design situation shall be **sufficiently severe and so varied** as to encompass all conditions which can **reasonably** be foreseen to occur during the execution and use of the structure (3.2(3)P).
Representative values of actions

<table>
<thead>
<tr>
<th></th>
<th>Permanent actions</th>
<th>Variable actions</th>
<th>Accidental actions</th>
<th>Seismic actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristic value</strong></td>
<td>$G_k$</td>
<td>$Q_k$</td>
<td></td>
<td>$A_{Ek}$ or</td>
</tr>
<tr>
<td><strong>Nominal value</strong></td>
<td></td>
<td></td>
<td>$A_d$</td>
<td>$A_{Ed} = \gamma I A_{Ek}$</td>
</tr>
<tr>
<td><strong>Combination value</strong></td>
<td></td>
<td>$\psi_0 Q_k$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Frequent value</strong></td>
<td></td>
<td>$\psi_1 Q_k$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Quasi-permanent value</strong></td>
<td></td>
<td>$\psi_2 Q_k$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EN 1990 – Section 6, Annex A2
How to establish a combination of actions

Turkstra’s rule (1972): within the set of variable actions applicable to a structure, one of them is selected and called « leading variable action »; the other variable actions are accompanying actions and are taken into account in the combinations of actions with their combination values.

The set including all permanent actions, the leading variable action and the relevant accompanying variable actions forms a combination of actions. The various values of actions used in the verifications are called « representative values ». 
EN 1990 – Section 6, Annex A2

**ACTIONS**

- $F_i$ → $F_{k,i}$ → $F_{d,i} = \psi \gamma_{f,i} F_{k,i}$ → $E(F_{d,i} ; a_d)$

  - **Action**
  - **Characteristic value of the action**
  - **Design value of the action**
  - **Effect of actions**

- $E_d = \gamma_{Sd} E(F_{d,i} ; a_d)$ → $E_d = E(\psi \gamma_{F,i} F_{k,i} ; a_d)$

  - **Design value of the effect of actions**
  - **Simplified expression**

  - $\gamma_{F,i} = \gamma_{f,i} \times \gamma_{Sd}$
$a_d$  Design value of geometrical data

$\gamma_f$  Uncertainty in representative values of actions

$\gamma_{Sd}$  Model uncertainty in actions and action effects

$\psi$  Is either 1,00 or $\psi_0$, $\psi_1$, or $\psi_2$,
EN 1990 – Section 6, Annex A2

**RESISTANCES**

Material property

Characteristic value of the material property

Design value of the material property

Structural Resistance

\[ X_i \rightarrow X_{k,i} \rightarrow X_{d,i} = (\eta_i / \gamma_{m,i})X_{k,i} \rightarrow R(X_{d,i} ; a_d) \]

\[ R_d = (1/\gamma_{Rd})R(X_{d,i} ; a_d) \]

\[ R_d = R((\eta_i / \gamma_{M,i})X_{k,i} ; a_d) \]

\[ \gamma_{M,i} = \gamma_{m,i} \times \gamma_{Rd} \]

Design value of the structural resistance

Design value of the structural resistance (simplified expression)
$a_d$  Design value of geometrical data

$\gamma_m$  Uncertainty in material properties, including the random part of the conversion factor $\eta$

$\gamma_{Rd}$  Model uncertainty in structural resistance

$\eta$  The mean value of the conversion factor taking into account:

- volume and scale effects,
- effects of moisture and temperature, and
- any other relevant parameters
## Ultimate limit states

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
</table>
| EQU  | Loss of static equilibrium of the structure or any part of it considered as a rigid body, in which:  
- minor variations in the value or the spatial distribution of actions from a single source are significant;  
- the strengths of construction materials or ground are generally not governing |
| STR  | Internal failure of the structure or structural elements, including footings, piles, basement walls, etc., in which the strength of construction materials or excessive deformation of the structure governs |
| GEO  | Failure or excessive deformation of the ground in which the strengths of soil or rock are significant in providing resistance |
| FAT  | Fatigue failure of the structure or structural elements |
Ultimate Limit States
EQU – STR – GEO for a bridge.
EN 1990 – Section 6, Annex A2
EN 1990 – Section 6, Annex A2

6.4.2 Verifications of static equilibrium and resistance

Ultimate limit states of static equilibrium (EQU) :
\[ E_{d,\text{dst}} \leq E_{d,\text{stb}} \]

Ultimate limit states of resistance (STR/GEO) :
\[ E_d \leq R_d \]

6.5 Serviceability limit states
\[ E_d \leq C_d \]

$C_d$ is the limiting design value of the relevant serviceability criterion.

$E_d$ is the design value of the effects of actions specified in the serviceability criterion, determined on the basis of the relevant combination.
### EN 1990 – Section 6, Annex A2
#### Combinations of actions ULS

<table>
<thead>
<tr>
<th>Combination</th>
<th>Reference EN 1990</th>
<th>General expression</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fundamental</strong>&lt;br&gt;(for persistent and transient design situations)</td>
<td>6.10</td>
<td>[ \sum_{j \geq 1} \gamma_{Gj} G_{kj} \gamma_{p} P_{kj} \gamma_{Q,1} Q_{k,1} + \sum_{i &gt; 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} ]</td>
</tr>
</tbody>
</table>
| | 6.10 a/b | \[ \left\{ \begin{array}{l} \sum_{j \geq 1} \gamma_{G,j} G_{k,j} \gamma_{p} P_{kj} \gamma_{Q,1} Q_{k,1} + \sum_{i > 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \\ \sum_{j \geq 1} \xi_{j} \gamma_{G,j} G_{k,j} \gamma_{p} P_{kj} \gamma_{Q,1} Q_{k,1} + \sum_{i > 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \end{array} \right. \\
| | | \quad 0.85 \leq \xi_{j} \leq 1.00 \text{ for unfavourable permanent actions} G |
| **Accidental**<br>(for accidental design situations) | 6.11 | \[ \sum_{j \geq 1} G_{kj} \gamma_{p} P_{kj} \gamma_{A,1} A_{d} + (\psi_{1,1} \text{ ou } \psi_{2,1}) Q_{k,1} + \sum_{i \geq 1} \psi_{2,i} Q_{k,i} \] |
| **Seismic**<br>(for seismic design situations) | 6.12 | \[ \sum_{j \geq 1} G_{k,j} \gamma_{p} P_{kj} \gamma_{A,d} A_{Ed} + \sum_{i \geq 1} \psi_{2,i} Q_{k,i} \] |
6.5.3 Serviceability limit states: combinations of actions

- **Characteristic Combination (irreversible SLS)**
  \[
  \sum_{j \geq 1} G_{k,j} + P + Q_{k,1} + \sum_{i>1} \psi_{0,i} Q_{k,i}
  \]

- **Frequent Combination (reversible SLS)**
  \[
  \sum_{j \geq 1} G_{k,j} + P + \psi_{1,1} Q_{k,1} + \sum_{i>1} \psi_{2,i} Q_{k,i}
  \]

- **Quasi-permanent Combination (reversible SLS)**
  \[
  \sum_{j \geq 1} G_{k,j} + P + \sum_{i \geq 1} \psi_{2,i} Q_{k,i}
  \]
EN 1990 – Section 6, Annex A2

**DESIGN VALUES OF ACTIONS**

**APPROACH 1**

**APPROACH 2**

**APPROACH 3**

---

**TABLES**

<table>
<thead>
<tr>
<th>A2.4(A)</th>
<th>A2.4(B)</th>
<th>A2.4(C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULS EQU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ULS STR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>without geotechnical actions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ULS STR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with geotechnical actions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ULS GEO</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

EN 1990 – Section 6, Annex A2
Examples of combinations of actions for road bridges

Note 1: The combinations of actions are based on the recommended values given in Annex A2.

Note 2: Except for roofed bridges, it is assumed that snow loads on road bridges may be assessed as snow loads on the ground.
## EN 1990 – Section 6, Annex A2

### Recommended values of $\psi$ factors for road bridges

<table>
<thead>
<tr>
<th>Action</th>
<th>Symbol</th>
<th>$\psi_0$</th>
<th>$\psi_1$</th>
<th>$\psi_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic loads (see EN 1991-2, Table 4.4)</td>
<td>gr1a (LM1+pedestrian or cycle-track loads)</td>
<td>TS</td>
<td>0,75</td>
<td>0,75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UDL</td>
<td>0,40</td>
<td>0,40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pedestrian+cycle-track loads</td>
<td>0,40</td>
<td>0,40</td>
</tr>
<tr>
<td></td>
<td>gr1b (Single axle)</td>
<td></td>
<td>0</td>
<td>0,75</td>
</tr>
<tr>
<td></td>
<td>gr2 (Horizontal forces)</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>gr3 (Pedestrian loads)</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>gr4 (LM4 – Crowd loading)</td>
<td></td>
<td>0</td>
<td>0,75</td>
</tr>
<tr>
<td></td>
<td>gr5 (LM3 – Special vehicles)</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wind forces</td>
<td>$F_{Wk}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Persistent design situations</td>
<td></td>
<td>0,6</td>
<td>0,2</td>
</tr>
<tr>
<td></td>
<td>Execution</td>
<td></td>
<td>0,8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$F_{W}^*$</td>
<td></td>
<td>1,0</td>
<td>-</td>
</tr>
<tr>
<td>Thermal actions</td>
<td>$T_k$</td>
<td></td>
<td>0,6</td>
<td>0,6</td>
</tr>
<tr>
<td>Snow loads</td>
<td>$Q_{Sn,k}$ (during execution)</td>
<td></td>
<td>0,8</td>
<td>-</td>
</tr>
<tr>
<td>Construction loads</td>
<td>$Q_c$</td>
<td></td>
<td>1,0</td>
<td>-</td>
</tr>
</tbody>
</table>
Fundamental combinations of actions based on expression 6.10

\[
\begin{align*}
\left\{ \sum_{j \geq 1} (1,35G_{kj,\text{sup}} + &"1,00G_{kj,\text{inf}}") + "\gamma_P P_k" + "1,35(0,75TS + 0,4UDL + 0,4q^*_f )" \\
&1,5T_k + 1,35(0,75TS + 0,4UDL + 0,4q^*_f ) \\
&1,5F_{Wk} \\
&1,5Q_{Sn,k} \right\}
\end{align*}
\]

\(q^*_f \) Reduced value of the load on footways for group gr1a – To be defined in the National Annex (for example : 2,5 kN/m²)

\(P_k\) Prestressing: Definition in design Eurocodes. Usually \(P = P_m \) et \(\gamma_P = 1\)

\(G_{set}\) Uneven settlements to be taken into account where relevant, with \(\gamma_{Gset} = 1,20\) or 1,00 in case of linear analysis.

EN 1990 – Section 6, Annex A2
EN 1990 – Section 6, Annex A2

Representation of the action of uneven settlements Gset.
Characteristic combinations of actions

\[
\begin{align*}
\text{gr1a} & \quad \left\{ \sum_{j \geq 1} (G_{kj,\text{sup}} + G_{kj,\text{inf}}) + P_k + \left( (TS + UDL + q_{f_k}^*) + 0.6 F_{Wk,\text{traffic}} \right) + 0.6 T_k \right. \\
& \quad \left. + (0.75TS + 0.4 UDL + 0.4 q_{f_k}^*) \right\} \\
& \quad \psi_0 \text{gr1a} \\
\end{align*}
\]

- \( P_k \) Characteristic value of the prestressing force
- \( G_{set} \) Uneven settlements to be taken into account where relevant
EN 1990 – Section 6, Annex A2

Frequent combinations of actions

\[
\left\{ \sum_{j \geq 1} (G_{kj,\text{sup}} + G_{kj,\text{inf}}) \right\} + P_k + \left\{ (0.75TS + 0.4UDL) + 0.5T_k \right\}
\]

0.75gr1b
0.75gr4 + 0.5T_k
0.6T_k
0.2F_{wk}
0.5Q_{Sn,k}

Quasi-permanent combinations of actions

\[
\left\{ \sum_{j \geq 1} (G_{kj,\text{sup}} + G_{kj,\text{inf}}) \right\} + P_k + 0.5T_k
\]
EN 1991-1-6 : Actions during execution
Thank You for your Attention