EN 1990 “Eurocode: Basis of Structural Design

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Chairman of CEN/TC250
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)
### Design situations

<table>
<thead>
<tr>
<th>Design situation</th>
<th>Verifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Persistent</strong></td>
<td>Normal use</td>
</tr>
<tr>
<td><strong>Transient</strong></td>
<td>Execution, temporary conditions applicable to the structure, e.g. maintenance or repair</td>
</tr>
<tr>
<td><strong>Accidental</strong></td>
<td>Normal use</td>
</tr>
<tr>
<td></td>
<td>During execution</td>
</tr>
<tr>
<td><strong>Seismic</strong></td>
<td>Normal use</td>
</tr>
<tr>
<td></td>
<td>During execution</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>$A_{Ed} = \gamma IA_{Ek}$</td>
</tr>
<tr>
<td><strong>Combination value</strong></td>
<td></td>
<td>$\psi_0Q_k$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Frequent value</strong></td>
<td></td>
<td>$\psi_1Q_k$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Quasi-permanent value</strong></td>
<td></td>
<td>$\psi_2Q_k$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Permanent actions

Small variability

High variability

Distribution

$G_k = G_{0,50}$

$G_{k,inf} = G_{0,05}$

$G_{k,sup} = G_{0,95}$
EN 1990 – Section 6, Annexes A1 & A2

Variable actions

Instantaneous value of $Q$

Characteristic value $Q_k$

Combination value $\psi_0 Q_k$

Frequent value $\psi_1 Q_k$

Quasi-permanent value $\psi_2 Q_k$

Return period

$R : \text{reference period (e.g. 1 year or 50 years)}$

$p : \text{probability of exceedance during the reference period}$

$T \approx -\frac{R}{\ln(1-p)} \approx \frac{R}{p}$
Material and product properties

EN 1990 – Section 6, Annexes A1 & A2

Resistance parameters

Stiffness parameters

Values of property $f$

$\text{Distribution function}$

$f_{k,\text{inf}} = 0.05$

$f_{k,\text{sup}} = 0.95$

$f_m$
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
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.

How to establish a combination of actions

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, Annexes A1 & A2

Design values

\[ F_{d,i} = \gamma_{f,i} F_{k,i} \]

\[ E_d = \gamma_{Sd} E(F_{d,i} ; a_d) \]

\[ E_d = E(\gamma_{F,i} F_{k,i} ; a_d) \]

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

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

Geometrical data \( a_d \)

Actions

\( F_i \)

\( X_i \)

\( X_{k,i} \)

\( F_{k,i} \)

\( X_{d,i} = (\eta_i / \gamma_{m,i}) X_{k,i} \)

Resistances
### Ultimate limit states

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</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
EN 1990 – Section 6, Annexes A1 & 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.
## Combinations of actions

<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>$\sum_{j \geq 1} \gamma_{G,j} G_{k,j} + \gamma_p P + \gamma_{Q,1} Q_{k,1} + \sum_{i&gt;1} \gamma_{Q,i} \psi_{0,i} Q_{k,i}$</td>
</tr>
<tr>
<td><strong>Accidental</strong>&lt;br&gt;(for accidental design situations)</td>
<td>6.10 a/b</td>
<td>$\left{ \begin{align*} &amp;\sum_{j \geq 1} \gamma_{G,j} G_{k,j} + \gamma_p P + \gamma_{Q,1} Q_{k,1} + \sum_{i&gt;1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \ &amp;\sum_{j \geq 1} \xi_j \gamma_{G,j} G_{k,j} + \gamma_p P + \gamma_{Q,1} Q_{k,1} + \sum_{i&gt;1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \end{align*} \right}$ for $0.85 \leq \xi_j \leq 1.00$ for unfavourable permanent actions $G$</td>
</tr>
<tr>
<td><strong>Seismic</strong>&lt;br&gt;(for seismic design situations)</td>
<td>6.11</td>
<td>$\sum_{j \geq 1} G_{k,j} + P + A_d (\psi_{1,1} \text{ ou } \psi_{2,1}) Q_{k,1} + \sum_{i \geq 1} \psi_{2,i} Q_{k,i}$</td>
</tr>
<tr>
<td></td>
<td>6.12</td>
<td>$\sum_{j \geq 1} G_{k,j} + P + A_{Ed} + \sum_{i \geq 1} \psi_{2,i} Q_{k,i}$</td>
</tr>
</tbody>
</table>
Origin of expressions 6.10 and 6.10 a/b

\[ 1.35G_k + 1.5Q_k \]

\[ \rho = \frac{Q_k}{G_k + Q_k} \]
« Equivalent » safety factor for a combination based on a unique permanent action and a unique variable action acting together unfavourably, with $\psi_0 = 0,7$ and $\xi = 0,85$
6.5.3 Serviceability limit states: combinations of actions

- **Characteristic Combination (irreversible SLS)**

\[ \sum_{j \geq 1} G_{k,j} P + \sum_{i > 1} \psi_{0,i} Q_{k,i} \]

- **Frequent Combination (reversible SLS)**

\[ \sum_{j \geq 1} G_{k,j} P + \psi_{1,i} Q_{k,i} + \sum_{i > 1} \psi_{2,i} Q_{k,i} \]

- **Quasi-permanent Combination (reversible SLS)**

\[ \sum_{j \geq 1} G_{k,j} P + \sum_{i \geq 1} \psi_{2,i} Q_{k,i} \]
Annex A1 (normative) Application for Buildings

A1.1 Field of application
A1.2 Combinations of actions
   A1.2.1 General
   A1.2.2 Values of $\psi$ factors
A1.3 Ultimate limit states
   A1.3.1 Design values of actions in persistent and transient design situations
   A1.3.2 Design values of actions in the accidental and seismic design situations
A1.4 Serviceability limit states
   A1.4.1 Partial factors for actions
   A1.4.2 Serviceability criteria
   A1.4.3 Deformations and horizontal displacements
   A1.4.4 Vibrations
### Table A1.1 - Recommended values of $\psi$ factors for buildings

<table>
<thead>
<tr>
<th>Action</th>
<th>$\psi_0$</th>
<th>$\psi_1$</th>
<th>$\psi_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imposed loads in buildings, category (see EN 1991-1-1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category A: domestic, residential areas</td>
<td>0,7</td>
<td>0,5</td>
<td>0,3</td>
</tr>
<tr>
<td>Category B: office areas</td>
<td>0,7</td>
<td>0,5</td>
<td>0,3</td>
</tr>
<tr>
<td>Category C: congregation areas</td>
<td>0,7</td>
<td>0,7</td>
<td>0,6</td>
</tr>
<tr>
<td>Category D: shopping areas</td>
<td>0,7</td>
<td>0,7</td>
<td>0,6</td>
</tr>
<tr>
<td>Category E: storage areas</td>
<td>1,0</td>
<td>0,9</td>
<td>0,8</td>
</tr>
<tr>
<td>Category F: traffic area, vehicle weight $\leq 30\text{kN}$</td>
<td>0,7</td>
<td>0,7</td>
<td>0,6</td>
</tr>
<tr>
<td>Category G: traffic area, $30\text{kN} &lt;$ vehicle weight $\leq 160\text{kN}$</td>
<td>0,7</td>
<td>0,5</td>
<td>0,3</td>
</tr>
<tr>
<td>Category H: roofs</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Snow loads on buildings (see EN 1991-1-3)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Finland, Iceland, Norway, Sweden</td>
<td>0,70</td>
<td>0,50</td>
<td>0,20</td>
</tr>
<tr>
<td>– Remainder of CEN Member States, for sites located at altitude $H &gt; 1000\text{m}\text{a.s.l.}$</td>
<td>0,70</td>
<td>0,50</td>
<td>0,20</td>
</tr>
<tr>
<td>– Remainder of CEN Member States, for sites located at altitude $H \leq 1000\text{m}\text{a.s.l.}$</td>
<td>0,50</td>
<td>0,20</td>
<td>0</td>
</tr>
<tr>
<td>Wind loads on buildings (see EN 1991-1-4)</td>
<td>0,6</td>
<td>0,2</td>
<td>0</td>
</tr>
<tr>
<td>Temperature (non-fire) in buildings (see EN 1991-1-5)</td>
<td>0,6</td>
<td>0,5</td>
<td>0</td>
</tr>
</tbody>
</table>

**NOTE** The $\psi$ values may be set by the National annex.

* For countries not mentioned below, see relevant local conditions.
EN 1990 – Section 6, Annexes A1 & A2

DESIGN VALUES OF ACTIONS

ULS EQU

ULS STR
without geotechnical actions

ULS STR
with geotechnical actions

ULS GEO

TABLES

A1.2(A)

A1.2(B)

A1.2(C)

APPROACH 1

APPROACH 2

APPROACH 3

ULS EQU

ULS STR
without geotechnical actions

ULS STR
with geotechnical actions

ULS GEO

EN 1990 – Section 6, Annexes A1 & A2
EN 1990 – Section 6, Annexes A1 & A2

Approaches 2 and 3 in geotechnical design

\[ k_a = \tan^2 \left( \frac{\pi}{4} - \frac{\varphi}{2} \right) \]

\[ \varphi = \varphi_k \quad F_{a,d} = \gamma_F a F_a(\varphi_k) \]

\[ \varphi = \varphi_d \quad F_{a,d} = F_a(\varphi_d) \]

\[ p(z) = k_a \gamma z \]

\[ F_a = \frac{1}{2} k_a \gamma H^2 \]
**Table A1.2(A) – Design values of actions (EQU) (Set A)**

<table>
<thead>
<tr>
<th>Persistent and transient design situations</th>
<th>Permanent actions</th>
<th>Leading variable action (*)</th>
<th>Accompanying variable actions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unfavourable</td>
<td>Unfavourable</td>
<td>Main (if any)</td>
</tr>
<tr>
<td></td>
<td>Favourable</td>
<td>Favourable</td>
<td>Others</td>
</tr>
<tr>
<td>(Eq. 6.10)</td>
<td>$\gamma_{Gj,\text{sup}}$ $G_{kj,\text{sup}}$</td>
<td>$\gamma_{Gj,\text{inf}}$ $G_{kj,\text{inf}}$</td>
<td>$\gamma_{Q,1}$ $Q_{k,1}$</td>
</tr>
<tr>
<td>(*) Variable actions are those considered in Table A1.1</td>
<td>$\gamma_{Q,i}$ $\psi_{0,i}$ $Q_{k,i}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NOTE 1 The $\gamma$ values may be set by the National annex. The recommended set of values for $\gamma$ are:

$\gamma_{Gj,\text{sup}} = 1,10$

$\gamma_{Gj,\text{inf}} = 0,90$

$\gamma_{Q,1} = 1,50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1,50$ where unfavourable (0 where favourable)

NOTE 2 In cases where the verification of static equilibrium also involves the resistance of structural members, as an alternative to two separate verifications based on Tables A1.2(A) and A1.2(B), a combined verification, based on Table A1.2(A), may be adopted, if allowed by the National annex, with the following set of recommended values. The recommended values may be altered by the National annex.

$\gamma_{Gj,\text{sup}} = 1,35$ ; $\gamma_{Gj,\text{inf}} = 1,15$ ; $\gamma_{Q,1} = 1,50$ where unfavourable (0 where favourable)

$\gamma_{Q,i} = 1,50$ where unfavourable (0 where favourable)

provided that applying $\gamma_{Gj,\text{inf}} = 1,00$ both to the favourable part and to the unfavourable part of permanent actions does not give a more unfavourable effect.
EN 1990 – Section 6, Annexes A1 & A2

Table A1.2(B) - Design values of actions (STR/GEO) (Set B)

<table>
<thead>
<tr>
<th>Persistent and transient design situation</th>
<th>Permanent actions</th>
<th>Prestress</th>
<th>Leading variable action (*)</th>
<th>Accompanying variable actions (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unfavourable</td>
<td>Favourable</td>
<td>γP</td>
<td>γQ,1 Qk,1</td>
</tr>
<tr>
<td>(Eq. 6.10)</td>
<td>γGj, sup Gkj, sup</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>γGj, inf Gkj, inf</td>
<td></td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>(Eq. 6.10a)</td>
<td>γGj, sup Gkj, sup</td>
<td></td>
<td>P</td>
<td>γQ,1 ψ0,1 Qk,1</td>
</tr>
<tr>
<td>(Eq. 6.10b)</td>
<td>γGj, sup Gkj, sup</td>
<td></td>
<td>P</td>
<td>γQ,1 ψ0,1 Qk,1</td>
</tr>
<tr>
<td></td>
<td>γGj, inf Gkj, inf</td>
<td></td>
<td>P</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>γQ,1 Qk,1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>γQ,1 ψ0,1 Qk,1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>γQ,1 ψ0,1 Qk,1</td>
</tr>
</tbody>
</table>

(*) Variable actions are those considered in Tables A2.1 to A2.3.
NOTE 1 The choice between 6.10, or 6.10a and 6.10b will be in the National annex. In case of 6.10a and 6.10b, the National annex may in addition modify 6.10a to include permanent actions only.

NOTE 2 The $\gamma$ and $\xi$ values may be set by the National annex. The following values for $\gamma$ and $\xi$ are recommended when using expressions 6.10, or 6.10a and 6.10b.

\[ \gamma_{Gj,\text{sup}} = 1.35 \]
\[ \gamma_{Gj,\text{inf}} = 1.00 \]
\[ \gamma_{Q,1} = 1.50 \text{ where unfavourable (0 where favourable)} \]
\[ \gamma_{Q,i} = 1.50 \text{ where unfavourable (0 where favourable)} \]
\[ \xi = 0.85 \text{ (so that } \xi \gamma_{Gj,\text{sup}} = 0.85 \times 1.35 \approx 1.15). \]

See also EN 1991 to EN 1999 for $\gamma$ values to be used for imposed deformations.
NOTE 3 The characteristic values of all permanent actions from one source are multiplied by $\gamma_{G,\text{sup}}$ if the total resulting action effect is unfavourable and $\gamma_{G,\text{inf}}$ if the total resulting action effect is favourable. For example, all actions originating from the self weight of the structure may be considered as coming from one source; this also applies if different materials are involved.

NOTE 4 For particular verifications, the values for $\gamma_G$ and $\gamma_Q$ may be subdivided into $\gamma_g$ and $\gamma_q$ and the model uncertainty factor $\gamma_{Sd}$. A value of $\gamma_{Sd}$ in the range 1.05 to 1.15 can be used in most common cases and can be modified in the National annex.
### Table A1.2(C) - Design values of actions (STR/GEO) (Set C)

<table>
<thead>
<tr>
<th>Persistent and transient design situation</th>
<th>Permanent actions</th>
<th>Leading variable action (*)</th>
<th>Accompanying variable actions (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unfavourable</td>
<td>Favourable</td>
<td>Main (if any)</td>
</tr>
<tr>
<td>(Eq. 6.10)</td>
<td>$\gamma_{Gj,\text{sup}} G_{kj,\text{sup}}$</td>
<td>$\gamma_{Gj,\text{inf}} G_{kj,\text{inf}}$</td>
<td>$\gamma_{Q,1} Q_{k,1}$</td>
</tr>
</tbody>
</table>

(*) Variable actions are those considered in Table A1.1

**NOTE**  The $\gamma$ values may be set by the National annex. The recommended set of values for $\gamma$ are:
- $\gamma_{Gj,\text{sup}} = 1.00$
- $\gamma_{Gj,\text{inf}} = 1.00$
- $\gamma_{Q,1} = 1.30$ where unfavourable (0 where favourable)
- $\gamma_{Q,i} = 1.30$ where unfavourable (0 where favourable)
### Table A1.3 - Design values of actions for use in accidental and seismic combinations of actions

<table>
<thead>
<tr>
<th>Design situation</th>
<th>Permanent actions</th>
<th>Leading accidental or seismic action</th>
<th>Accompanying variable actions (**)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unfavourable</td>
<td>Favourable</td>
<td>Main (if any)</td>
</tr>
<tr>
<td>Accidental (*)</td>
<td>$G_{kj,\text{sup}}$</td>
<td>$G_{kj,\text{inf}}$</td>
<td>$A_d$</td>
</tr>
<tr>
<td>(Eq. 6.11a/b)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seismic</td>
<td>$G_{kj,\text{sup}}$</td>
<td>$G_{kj,\text{inf}}$</td>
<td>$\gamma A_{E_k}$ or $A_{E_d}$</td>
</tr>
<tr>
<td>(Eq. 6.12a/b)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) In the case of accidental design situations, the main variable action may be taken with its frequent or, as in seismic combinations of actions, its quasi-permanent values. The choice will be in the National annex, depending on the accidental action under consideration. See also EN 1991-1-2.

(**) Variable actions are those considered in Table A1.1.
Table A1.4 - Design values of actions for use in the combination of actions (SLS)

<table>
<thead>
<tr>
<th>Combination</th>
<th>Permanent actions $G_d$</th>
<th>Variable actions $Q_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unfavourable</td>
<td>Favourable</td>
</tr>
<tr>
<td>Characteristic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent</td>
<td>$G_{kj, sup}$</td>
<td>$G_{kj, inf}$</td>
</tr>
<tr>
<td>Quasi-permanent</td>
<td>$G_{kj, sup}$</td>
<td>$G_{kj, inf}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Annex A2 - Application for bridges (N)

National Annex for EN 1990 Annex A2

A2.1 Field of application

A2.2 Combination of actions

A2.3 Ultimate limit states (verifications for fatigue excluded)

A2.4 Serviceability and other specific limit states
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.
Group of loads gr1a : LM1 + reduced (combination) value of pedestrian and cycle loads

Group of loads gr1b : LM2 (single axle)

Group of loads gr2 : characteristic values of horizontal forces, frequent values of LM1

EN 1990 – Section 6, Annexes A1 & A2
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)
### Table A2.1
**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><strong>Traffic loads</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(see EN 1991-2, Table 4.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gr1a (LM1+pedestrian or cycle-track loads) (^1)</td>
<td>TS</td>
<td>0.75</td>
<td>0.75</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>UDL</td>
<td>0.40</td>
<td>0.40</td>
<td>0</td>
</tr>
<tr>
<td>Pedestrian+cycle-track loads</td>
<td>0.40</td>
<td>0.40</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>gr1b (Single axle)</td>
<td></td>
<td>0</td>
<td>0.75</td>
<td>0</td>
</tr>
<tr>
<td>gr2 (Horizontal forces)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>gr3 (Pedestrian loads)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>gr4 (LM4 – Crowd loading)</td>
<td></td>
<td>0</td>
<td>0.75</td>
<td>0</td>
</tr>
<tr>
<td>gr5 (LM3 – Special vehicles)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Wind forces</strong></td>
<td>$F_{W,k}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent design situations</td>
<td></td>
<td>0.6</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Execution</td>
<td></td>
<td>0.8</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>$F_{W}^*$</td>
<td></td>
<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Thermal actions</strong></td>
<td>$T_k$</td>
<td>0.6 (^3)</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Snow loads</strong></td>
<td>$Q_{Sn,k}$ (during execution)</td>
<td>0.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Construction loads</strong></td>
<td>$Q_c$</td>
<td>1.0</td>
<td>-</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1) The recommended values of $\psi_0$, $\psi_1$ and $\psi_2$ for gr1a and gr1b are given for road traffic corresponding to adjusting factors $\alpha_Q$, $\alpha_{qi}$, $\alpha_{qf}$ and $\beta_Q$ equal to 1. Those relating to UDL correspond to common traffic scenarios, in which a rare accumulation of lorries can occur. Other values may be envisaged for other classes of routes, or of expected traffic, related to the choice of the corresponding $\alpha$ factors. For example, a value of $\psi_2$ other than zero may be envisaged for the UDL system of LM1 only, for bridges supporting severe continuous traffic. See also EN 1998.

2) The combination value of the pedestrian and cycle-track load, mentioned in Table 4.4a of EN 1991-2, is a “reduced” value. $\psi_0$ and $\psi_1$ factors are applicable to this value.

3) The recommended $\psi_0$ value for thermal actions may in most cases be reduced to 0 for ultimate limit states EQU, STR and GEO. See also the design Eurocodes.
### Persistent and Transient Design Situation

<table>
<thead>
<tr>
<th>Permanent actions</th>
<th>Prestress</th>
<th>Leading variable action (*)</th>
<th>Accompanying variable actions (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfavourable</td>
<td>Favourable</td>
<td>γ₀ for variable actions</td>
<td>γ₀ᵢψ₀ᵢ for variable actions (*)</td>
</tr>
</tbody>
</table>

(Eq. 6.10)

(**) Variable actions are those considered in Tables A2.1 to A2.3.

**NOTE 1** The γ values for the persistent and transient design situations may be set by the National Annex.

For persistent design situations, the recommended set of values for γ are:

- γ₆,₅ = 1.05
- γ₆,₈ = 0.95
- γ₀ = 1.35 for road and pedestrian traffic actions, where unfavourable (0 where favourable)
- γ₀ = 1.45 for rail traffic actions, where unfavourable (0 where favourable)
- γ₀ = 1.50 for all other variable actions for persistent design situations, where unfavourable (0 where favourable)

For transient design situations during which there is a risk of loss of static equilibrium, Qₖ,₁ represents the dominant destabilising variable action and Qₖ,ᵢ represents the relevant accompanying destabilising variable actions.

During execution, if the construction process is adequately controlled, the recommended set of values for γ are:

- γ₆,₅ = 1.05
- γ₆,₈ = 0.95
- γ₀ = 1.35 for construction loads (0 where favourable)
- γ₀ = 1.50 for all other variable actions, where unfavourable (0 where favourable)

………..
Table A2.4(B) - Design values of actions (STR/GEO) (Set B)

<table>
<thead>
<tr>
<th>Persistent and transient design situation</th>
<th>Permanent actions</th>
<th>Prestress</th>
<th>Leading variable action (*)</th>
<th>Accompanying variable actions (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Eq. 6.10)</td>
<td>Unfavourable</td>
<td>Favourable</td>
<td>$\gamma P$</td>
<td>$\gamma Q,1 Q_{k,1}$</td>
</tr>
<tr>
<td></td>
<td>$\gamma G_{j,\text{sup}} G_{k,j,\text{sup}}$</td>
<td>$\gamma G_{j,\text{inf}} G_{k,j,\text{inf}}$</td>
<td>($\gamma P$)</td>
<td>($\gamma Q,1 Q_{k,1}$)</td>
</tr>
<tr>
<td>(Eq. 6.10a)</td>
<td>$\gamma G_{j,\text{sup}} G_{k,j,\text{sup}}$</td>
<td>$\gamma G_{j,\text{inf}} G_{k,j,\text{inf}}$</td>
<td>$\gamma P$</td>
<td>$\gamma Q,1 \psi_{0,1} Q_{k,1}$</td>
</tr>
<tr>
<td>(Eq. 6.10b)</td>
<td>$\xi \gamma G_{j,\text{sup}} G_{k,j,\text{sup}}$</td>
<td>$\gamma G_{j,\text{inf}} G_{k,j,\text{inf}}$</td>
<td>$\gamma P$</td>
<td>$\gamma Q,1 Q_{k,1}$</td>
</tr>
</tbody>
</table>

(*) Variable actions are those considered in Tables A2.1 to A2.3.
1) The recommended values of $\psi_0$, $\psi_1$, and $\psi_2$ for gr1a and gr1b are given for road traffic corresponding to adjusting factors $\alpha_{Qi}$, $\alpha_{qi}$, $\alpha_{qr}$ and equal to 1. Those relating to UDL correspond to common traffic scenarios, in which a rare accumulation of lorries can occur. Other values may be envisaged for other classes of routes, or of expected traffic, related to the choice of the corresponding $\alpha$ factors. For example, a value of $\psi_2$ other than zero may be envisaged for the UDL system of LM1 only, for bridges supporting a severe continuous traffic. See also EN 1998.

2) The combination value of the pedestrian and cycle-track load, mentioned in Table 4.4a of EN 1991-2, is a “reduced” value. $\psi_0$ and $\psi_1$ factors are applicable to this value.

3) The recommended $\psi_0$ value for thermal actions may in most cases be reduced to 0 for ultimate limit states EQU, STR and GEO. See also the design Eurocodes.
### Table A2.4(C) - Design values of actions (STR/GEO) (Set C)

<table>
<thead>
<tr>
<th>Persistent and Transient Design Situation</th>
<th>Permanent actions</th>
<th>Prestress</th>
<th>Leading variable action (*)</th>
<th>Accompanying variable actions (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unfavourable</td>
<td>Favourable</td>
<td>γ_{p,1}P</td>
<td>γ_{Q,i}ψ_{0,i}Q_{k,i}</td>
</tr>
<tr>
<td>(Eq. 6.10)</td>
<td>γ_{G,\text{sup}}G_{k,\text{sup}}</td>
<td>γ_{G,\text{inf}}G_{k,\text{inf}}</td>
<td>γ_{Q,1}Q_{k,1}</td>
<td></td>
</tr>
</tbody>
</table>

(*) Variable actions are those considered in Tables A2.1 to A2.3

**NOTE** The γ values may be set by the National Annex. The recommended set of values for γ are:

- γ_{G,\text{sup}} = 1,00
- γ_{G,\text{inf}} = 1,00
- γ_{G,\text{set}} = 1,00
- γ_{Q} = 1,15 for road and pedestrian traffic actions where unfavourable (0 where favourable)
- γ_{Q} = 1,25 for rail traffic actions where unfavourable (0 where favourable)
- γ_{Q} = 1,30 for the variable part of horizontal earth pressure from soil, ground water, free water and ballast, for traffic load surcharge horizontal earth pressure, where unfavourable (0 where favourable)
- γ_{Q} = 1,30 for all other variable actions where unfavourable (0 where favourable)
- γ_{G,\text{set}} = 1,00 in case of linear elastic or non linear analysis, for design situations where actions due to uneven settlements may have unfavourable effects. For design situations where actions due to uneven settlements may have favourable effects, these actions are not to be taken into account.
- γ_{p} = recommended values defined in the relevant design Eurocode.
Fundamental combinations of actions based on expression 6.10

\[
\begin{align*}
\psi_{0, gr1a} & = 1,35(TS + UDL + q_{jk}^*) + 1,5 \times 0,6 F_{Wk,traffic} \\
1,35 g_{ri_{i=1b,2,3,4,5}} & = 1,5 T_k + 1,35(0,75TS + 0,4 UDL + 0,4 q_{jk}^*) \\
1,5 F_{Wk} & \\
1,5 Q_{Sn,k} & \\
\end{align*}
\]

\( q_{jk}^* \) 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, Annexes A1 & A2

Representation of the action of uneven settlements $G_{set}$.
Characteristic combinations of actions

\[
\psi_0 \text{gr1a} = (TS + UDL + q_{fk}^*) + 0.6F_{Wk,\text{traffic}}
\]
\[
g_{ri=1b,2,3,4,5} = 0.6T_k
\]
\[
\sum_{j\geq 1} (G_{kj,\text{sup}} + G_{kj,\text{inf}}) + P_k
\]

- \( P_k \) Characteristic value of the prestressing force
- \( G_{set} \) Uneven settlements to be taken into account where relevant
Frequent combinations of actions

\[
\left\{ \sum_{j \geq 1} (G_{kj,\text{sup}} + G_{kj,\text{inf}}) \right\}^{P_k}+(0,75TS + 0,4UDL) + 0,5T_k
\]

\[
0,75gr1b
\]

\[
0,75gr4 + 0,5T_k
\]

\[
0,6T_k
\]

\[
0,2F_{W_k}
\]

\[
0,5Q_{Sn,k}
\]

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 1991-2 – Groups of loads for footbridges

Group of loads gr1

Group of loads gr2
### Table A2.2

#### Recommended values of $\psi$ factors for footbridges

<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</td>
<td>gr1</td>
<td>0,40</td>
<td>0,40</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$Q_{fwk}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wind forces</td>
<td>$F_{wk}$</td>
<td>0,3</td>
<td>0,2</td>
<td>0</td>
</tr>
<tr>
<td>Thermal actions</td>
<td>$T_k$</td>
<td>0,6 $^1)$</td>
<td>0,6</td>
<td>0,5</td>
</tr>
<tr>
<td>Snow loads</td>
<td>$Q_{Sn,k}$ (during execution)</td>
<td>0,8</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Construction loads</td>
<td>$Q_c$</td>
<td>1,0</td>
<td>-</td>
<td>1,0</td>
</tr>
</tbody>
</table>

1) The recommended $\psi_0$ value for thermal actions may in most cases be reduced to 0 for ultimate limit states EQU, STR and GEO. See also the design Eurocodes.
**Fundamental combinations of actions based on expression 6.10**

\[
\left\{ \sum_{j \geq 1} (1.35G_{kj,\text{sup}} + 1.00G_{kj,\text{inf}}) \right\} + \gamma_P P_k + \\
1.35gr1 + 1.5 \times 0.3 \frac{F_w}{k}
\]

- **P**\textsubscript{k}  
  Prestressing: Definition in design Eurocodes. Usually \( P = P_m \) et \( \gamma_P = 1 \)

- **G**\textsubscript{set}  
  Uneven settlements to be taken into account where relevant, with \( \gamma_{Gset} = 1.20 \) or 1.00 in case of linear analysis.
Frequent combinations of actions

\[ \left\{ \sum_{j \geq 1} (G_{kj, sup} + G_{kj, inf}) \right\} + P_k + 0.4gr1 + 0.5T_k \]

Quasi-permanent combinations of actions

\[ \left\{ \sum_{j \geq 1} (G_{kj, sup} + G_{kj, inf}) \right\} + P_k + 0.5T_k \]
Some dates and backgrounds
Thank you for your attention