Eurocode 8
General rules and seismic actions

E C Carvalho, Chairman TC250/SC8
Eurocode 8 - Design of structures for earthquake resistance

- **EN1998-1**: General rules, seismic actions and rules for buildings
- **EN1998-2**: Bridges
- **EN1998-3**: Assessment and retrofitting of buildings
- **EN1998-4**: Silos, tanks and pipelines
- **EN1998-5**: Foundations, retaining structures and geotechnical aspects
- **EN1998-6**: Towers, masts and chimneys

All parts published by CEN (2004-2006)
EN1998-1: General rules, seismic actions and rules for buildings

EN1998-1 to be applied in combination with other Eurocodes
EN1998-1: General rules, seismic actions and rules for buildings

- General
- Performance requirements and compliance criteria
- Ground conditions and seismic action
- Design of buildings
- Specific rules for:
  - Concrete buildings
  - Steel buildings
  - Composite Steel-Concrete buildings
  - Timber buildings
  - Masonry buildings
- Base isolation
Objectives

In the event of earthquakes:

- Human lives are protected
- Damage is limited
- Structures important for civil protection remain operational

Special structures – Nuclear Power Plants, Offshore structures, Large Dams – outside the scope of EN 1998
Fundamental requirements

No-collapse requirement:

Withstand the design seismic action without local or global collapse

Retain structural integrity and residual load bearing capacity after the event

For ordinary structures this requirement should be met for a reference seismic action with 10 % probability of exceedance in 50 years (recommended value) i.e. with 475 years Return Period
Fundamental requirements

**Damage limitation requirement:**

Withstand a more frequent seismic action without damage

Avoid limitations of use with high costs

For ordinary structures this requirement should be met for a **seismic action** with 10 % probability of exceedance in 10 years (recommended value) i.e. with **95 years Return Period**
Reliability differentiation

Target reliability of requirement depending on consequences of failure

Classify the structures into importance classes

Assign a higher or lower return period to the design seismic action

In operational terms multiply the reference seismic action by the importance factor $\gamma_I$
## Importance classes for buildings

**Table 4.3 Importance classes for buildings**

<table>
<thead>
<tr>
<th>Importance class</th>
<th>Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Buildings of minor importance for public safety, e.g. agricultural buildings, etc.</td>
</tr>
<tr>
<td>II</td>
<td>Ordinary buildings, not belonging in the other categories.</td>
</tr>
<tr>
<td>III</td>
<td>Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.</td>
</tr>
<tr>
<td>IV</td>
<td>Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.</td>
</tr>
</tbody>
</table>

NOTE Importance classes I, II and III or IV correspond roughly to consequences classes CC1, CC2 and CC3, respectively, defined in EN 1990:2002, Annex B.

### Importance factors for buildings (recommended values):

\[ \gamma_I = 0.8; 1.0; 1.2 \text{ and } 1.4 \]
Fundamental requirements

Compliance criteria (design verifications):

**Ultimate limit state**

- Resistance and Energy dissipation capacity
- Ductility classes and Behaviour factor values
- Overturning and sliding stability check
- Resistance of foundation elements and soil
- Second order effects
- Non detrimental effect of non structural elements

Simplified checks for **low seismicity** cases \((a_g < 0.08 \, \text{g})\)
No application of EN 1998 for **very low seismicity** cases \((a_g < 0.04 \, \text{g})\)
Fundamental requirements

Compliance criteria (design verifications):

**Damage limitation state**

Deformation limits (Maximum interstorey drift due to the “frequent” earthquake):

- 0,5 % for brittle non structural elements *attached* to the structure
- 0,75 % for ductile non structural elements *attached* to the structure
- 1,0 % for non structural elements *not interfering* with the structure

Sufficient stiffness of the structure for the operationality of vital services and equipment

DLS may control the design in many cases
Fundamental requirements

Compliance criteria (design verifications):

**Specific measures**

**Simple and regular forms (plan and elevation)**

**Control the hierarchy of resistances and sequence of failure modes (capacity design)**

**Avoid brittle failures**

**Control the behaviour of critical regions (detailing)**

**Use adequate structural model (soil deformability and non structural elements if appropriate)**

In zones of **high seismicity** formal **Quality Plan for Design, Construction and Use** is recommended
Ground conditions

Five ground types:

A - Rock
B - Very dense sand or gravel or very stiff clay
C - Dense sand or gravel or stiff clay
D - Loose to medium cohesionless soil or soft to firm cohesive soil
E - Surface alluvium layer C or D, 5 to 20 m thick, over a much stiffer material

2 special ground types $S_1$ and $S_2$ requiring special studies

Ground conditions defined by shear wave velocities in the top 30 m and also by indicative values for $N_{SPT}$ and $c_u$
## Ground conditions

### Table 3.1: Ground types

<table>
<thead>
<tr>
<th>Ground type</th>
<th>Description of stratigraphic profile</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.</td>
<td>( v_{s,30} ) (m/s)</td>
</tr>
<tr>
<td>B</td>
<td>Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.</td>
<td>( v_{s,30} ) (m/s)</td>
</tr>
</tbody>
</table>
# Ground conditions

## Table 3.1: Ground types

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<tr>
<td></td>
<td></td>
<td>$v_{s,30}$ (m/s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$N_{SPT}$ (blows/30cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$c_u$ (kPa)</td>
</tr>
<tr>
<td>C</td>
<td>Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.</td>
<td>180 – 360</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 - 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70 - 250</td>
</tr>
<tr>
<td>D</td>
<td>Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.</td>
<td>&lt; 180</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 70</td>
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## Ground conditions

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<tr>
<td><strong>E</strong></td>
<td>A soil profile consisting of a surface alluvium layer with $v_s$ values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with $v_s &gt; 800$ m/s.</td>
<td>$v_{s,30}$ (m/s)</td>
</tr>
<tr>
<td><strong>$S_1$</strong></td>
<td>Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI &gt; 40) and high water content</td>
<td>$&lt; 100$ (indicative)</td>
</tr>
<tr>
<td><strong>$S_2$</strong></td>
<td>Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or $S_1$</td>
<td></td>
</tr>
</tbody>
</table>
Seismic zonation

Competence of National Authorities

Described by $a_{gR}$ (reference peak ground acceleration on type A ground)

Corresponds to the reference return period $T_{NCR}$

Modified by the Importance Factor $\gamma_I$ to become the design ground acceleration (on type A ground) $a_g = a_{gR} \cdot \gamma_I$

Objective for the future updating of EN1998-1: European zonation map with spectral values for different hazard levels (e.g. 100, 500 and 2,500 years)
Basic representation of the seismic action

Elastic response spectrum

Common shape for the ULS and DLS verifications

2 orthogonal independent horizontal components

Vertical spectrum shape different from the horizontal spectrum (common for all ground types)

Possible use of more than one spectral shape (to model different seismo-genetic mechanisms)

Account of topographical effects (EN 1998-5) and spatial variation of motion (EN 1998-2) required in some special cases
Definition of the horizontal elastic response spectrum 
(four branches)

\[ 0 \leq T \leq T_B \quad S_e (T) = a_g \cdot S \cdot (1+T/T_B \cdot (\eta \cdot 2,5 -1)) \]

\[ T_B \leq T \leq T_C \quad S_e (T) = a_g \cdot S \cdot \eta \cdot 2,5 \]

\[ T_C \leq T \leq T_D \quad S_e (T) = a_g \cdot S \cdot \eta \cdot 2,5 (T_C /T) \]

\[ T_D \leq T \leq 4 \text{ s} \quad S_e (T) = a_g \cdot S \cdot \eta \cdot 2,5 (T_C \cdot T_D /T^2) \]

- \( S_e (T) \): elastic response spectrum
- \( a_g \): design ground acceleration on type A ground
- \( T_B, T_C, T_D \): corner periods in the spectrum (NDPs)
- \( S \): soil factor (NDP)
- \( \eta \): damping correction factor (\( \eta = 1 \) for 5% damping)

Additional information for \( T > 4 \text{ s} \) in Informative Annex
Normalised elastic response spectrum \textit{(standard shape)}

**Control variables**
- \(S, T_B, T_C, T_D\) (NDPs)
- \(\eta \geq 0.55\) damping correction for \(\xi \neq 5\%\)

**Fixed variables**
- Constant acceleration, velocity & displacement spectral branches
- acceleration spectral amplification: 2.5

Different spectral shape for \textit{vertical spectrum} (spectral amplification: 3.0)
Elastic response spectrum

Two types of (recommended) spectral shapes

Depending on the characteristics of the most significant earthquake contributing to the local hazard:

• Type 1 - High and moderate seismicity regions \((M_s > 5.5)\)
• Type 2 - Low seismicity regions \((M_s \leq 5.5)\); near field earthquakes

Optional account of deep geology effects (NDP) for the definition of the seismic action
Recommended elastic response spectra

Type 1 - $M_s > 5.5$

Type 2 - $M_s \leq 5.5$
Recommended elastic response spectra

Type 1 - $M_s > 5.5$
Recommended elastic response spectra

Type 2 - $M_s \leq 5.5$
Design spectrum for elastic response analysis
(derived from the elastic spectrum)

\[
0 \leq T \leq T_B \quad S_d (T) = a_g \cdot S \cdot (2/3 + T/T_B \cdot (2.5/q - 2/3))
\]

\[
T_B \leq T \leq T_C \quad S_d (T) = a_g \cdot S \cdot 2.5/q
\]

\[
T_C \leq T \leq T_D \quad S_d (T) = a_g \cdot S \cdot 2.5/q \cdot (T_C/T) \geq \beta \cdot a_g
\]

\[
T_D \leq T \leq 4 \text{ s} \quad S_d (T) = a_g \cdot S \cdot 2.5/q \cdot (T_C \cdot T_D/T^2) \geq \beta \cdot a_g
\]

\( S_d (T) \) design spectrum
\( q \) behaviour factor
\( \beta \) lower bound factor (NDP recommended value: 0.2)

Specific rules for vertical action:
\( a_{vg} = 0.9 \cdot a_g \) or \( a_{vg} = 0.45 \cdot a_g \); \( S = 1.0; \ q \leq 1.5 \)
Alternative representations of the seismic action

Time history representation (essentially for NL analysis purposes)

Three simultaneously acting accelerograms

- **Artificial accelerograms**
  Match the elastic response spectrum for 5% damping
  Duration compatible with Magnitude \( T_s \geq 10 \text{ s} \)
  Minimum number of accelerograms: 3

- **Recorded or simulated accelerograms**
  Scaled to \( a_g \cdot S \)
  Match the elastic response spectrum for 5% damping