Eurocode 8
General rules and seismic actions

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Eurocode 8 - Design of structures for earthquake resistance

- EN1998-1: **General rules, seismic actions and rules for buildings**
- EN1998-2: **Bridges**
- EN1998-3: **Assesment 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

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EN 1998-1

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English version

Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings

Eurocode 8: Calcul des structures pour leur résistance aux séismes - Partie 1: Règles générales, actions sismiques et règles pour les bâtiments

Eurocode 8: Auslegung von Bauwerken gegen Erdbeben - Teil 1: Grundlagen, Erdbebeneinwirkungen und Regeln für Hochbauten

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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** γ_I

Importance classes for buildings

EN 1998-1:2004 (E)

Table 4.3 Importance classes for buildings

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

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):

γ_I **= 0,8; 1,0; 1,2 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 g)

No application of EN 1998 for **very low seismicity** cases (a_g < 0,04 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 strutural 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

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	–	–
B	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.	360 – 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
E	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 > 800 m/s.			
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	–	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1			

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 γ_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 (EN1998-2) required in some special cases

Definition of the horizontal elastic response spectrum

(four branches)

$0 \le T \le T_B$ $\quad S_e(T) = a_g \,.\, S \,.\, (1+T/T_B \,.\, (\eta \,.\, 2{,}5 - 1))$

$T_B \le T \le T_C$ $\quad S_e(T) = a_g \,.\, S \,.\, \eta \,.\, 2{,}5$

$T_C \le T \le T_D$ $\quad S_e(T) = a_g \,.\, S \,.\, \eta \,.\, 2{,}5\, (T_C / T)$

$T_D \le T \le 4$ s $\quad S_e(T) = a_g \,.\, S \,.\, \eta \,.\, 2{,}5\, (T_C \,.\, T_D / T^2)$

$S_e(T)$	**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)
η	**damping** correction factor (η = 1 for 5% damping)

Additional **information** for $T > 4$ s in Informative Annex

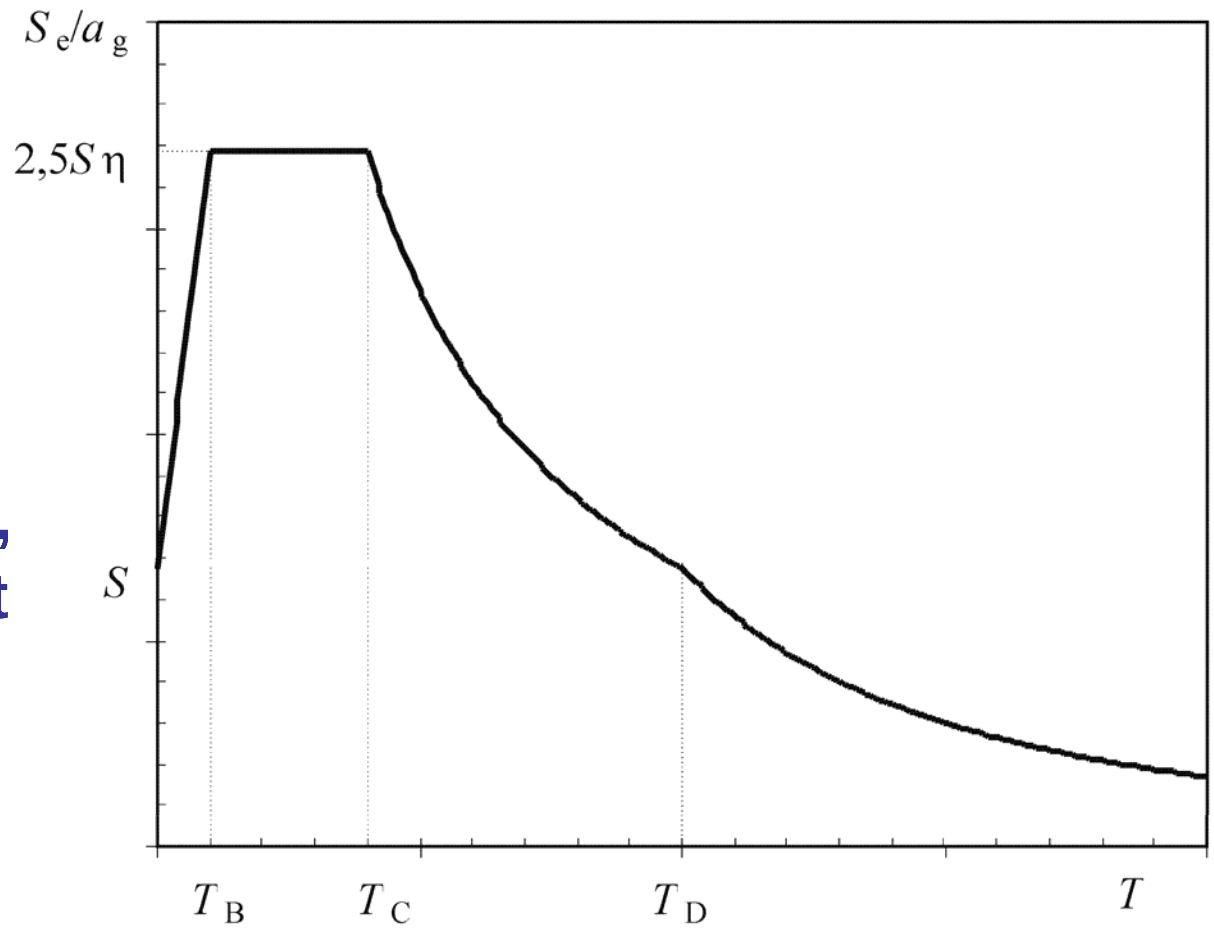
Normalised elastic response spectrum (standard shape)

Control variables

- S, T_B, T_C, T_D (NDPs)
- η (≥ 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 **vertical spectrum** (spectral amplification: **3,0**)

Elastic response spectrum

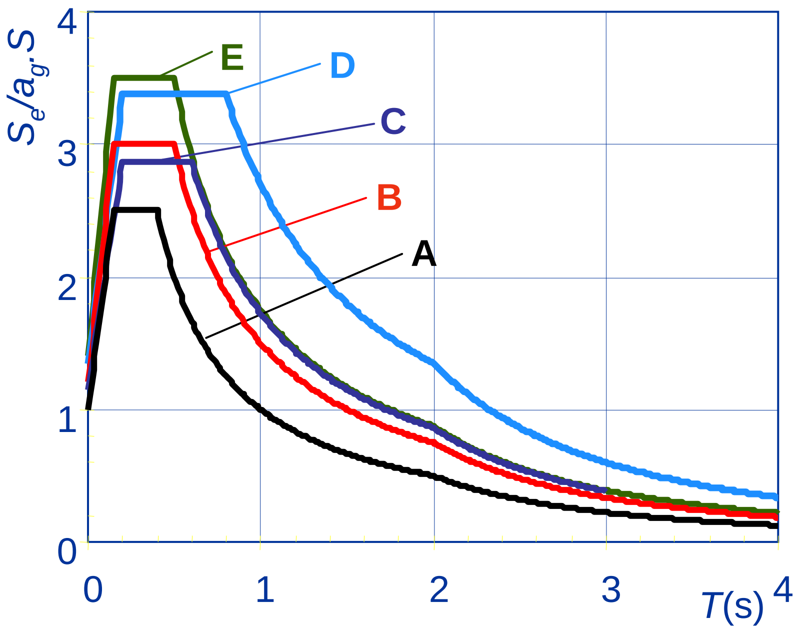
Two types of (recommended) spectral shapes

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

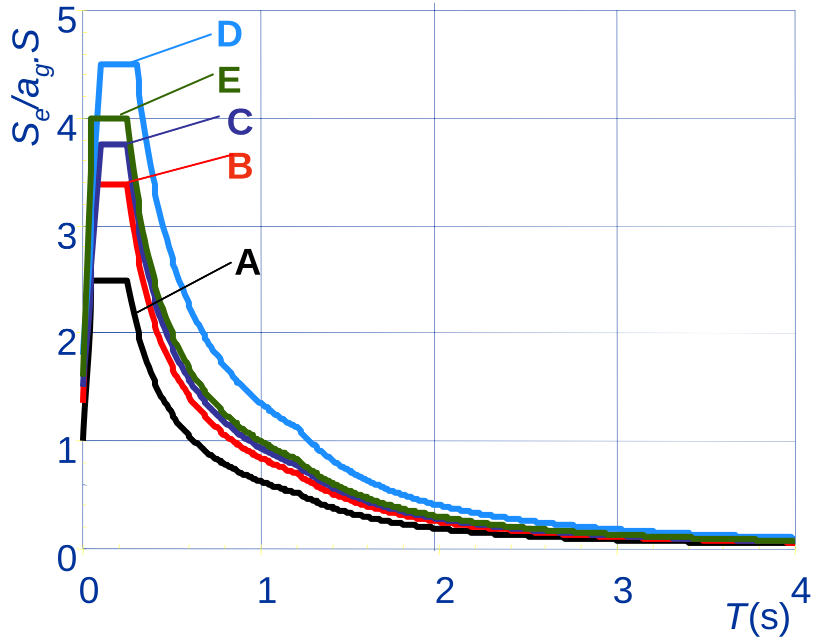
- **Type 1 - High and moderate seismicity regions (M_s > 5,5)**
- **Type 2 - Low seismicity regions ($M_s \leq$ 5,5); near field earthquakes**

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

Design spectrum for elastic response analysis

(derived from the elastic spectrum)

$0 \leq T \leq T_B$ $\quad S_d(T) = a_g \, . \, S \, . \, (2/3 + T/T_B \, . \, (2{,}5/q - 2/3))$

$T_B \leq T \leq T_C$ $\quad S_d(T) = a_g \, . \, S \, . \, 2{,}5/q$

$T_C \leq T \leq T_D$ $\quad S_d(T) = a_g \, . \, S \, . \, 2{,}5/q \, . \, (T_C / T)$
$\geq \beta \, . \, a_g$

$T_D \leq T \leq 4$ s $\quad S_d(T) = a_g \, . \, S \, . \, 2{,}5/q \, . \, (T_C \, . \, T_D / T^2)$
$\geq \beta \, . \, a_g$

$S_d(T)$ **design** spectrum

q **behaviour factor**

β **lower bound** factor (NDP recommended value: **0,2**)

Specific rules for **vertical action**:

a_{vg} = **0,9** . a_g or a_{vg} = **0,45** . 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 ($T_s \geq 10$ s)
  Minimum number of accelerograms: 3

- **Recorded or simulated accelerograms**

  Scaled to $a_g \cdot S$
  Match the elastic response spectrum for 5% damping