The Second-Generation Eurocodes

Key changes and benefits through design examples

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What are the important changes in the new Eurocode 8?

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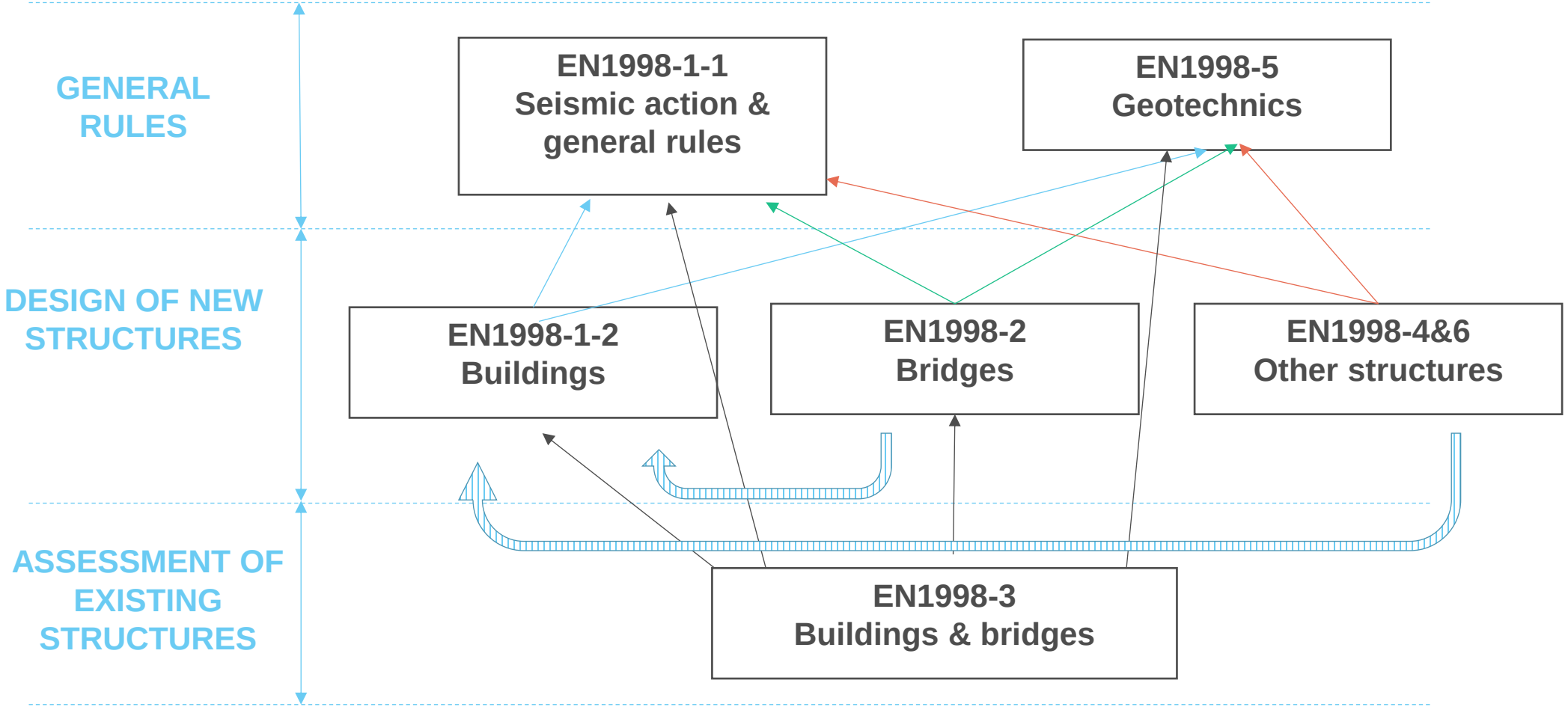
- General organisation
- Safety choices
- Seismic action
- Principles of aseismic design
- Analysis
- Main developments
- A simple example for comparison

General organisation

Organisation of EN1998

Restructuration of EN 1998 in three levels



Eurocode 8 in the frame of the Eurocode set

Consequence classes

1st GENERATION IMPORTANCE CLASSES		2nd GENERATION CONSEQUENCE CLASSES (EC0)
PART 1 buildings	PART 2 bridges	
I	I	CC1
II	II	CC2
III	III	CC3a
IV		CC3b

Seismic situation & limit states

- Homogenisation of Limit States definition through all parts with better consistency with EN1990 (ULS and SLS)
- Verification of Operational (OP) limit state

1st GENERATION

PARTS 1 & 2	PART 3
	NEAR COLLAPSE
NO COLLAPSE	SIGNIFICANT DAMAGE
DAMAGE LIMITATION	DAMAGE LIMITATION

2nd GENERATION

	Limit state
ULS	NEAR COLLAPSE (NC)
	SIGNIFICANT DAMAGE (SD)
SLS	DAMAGE LIMITATION (DL)
	OPERABILITY (OP)

Qualitative description of the Limit States

- **a) LS of Near Collapse (NC) shall be defined as one in which the structure is heavily damaged, with large permanent drifts, but retains its vertical load bearing capacity; most ancillary components, where present, have collapsed;**

- **b) LS of Significant Damage (SD) shall be defined as one in which the structure is significantly damaged, possibly with moderate permanent drifts, but retains its vertical load bearing capacity; ancillary components, where present, are moderately damaged (e.g. partitions and infills are damaged but have not yet failed out-of-plane). The structure is expected to be repairable but, in some cases, it may be uneconomic to repair;**

- **c) LS of Damage Limitation (DL) shall be defined as one in which the structure is only slightly damaged and economic to repair, with negligible permanent drifts, undiminished ability to withstand future earthquakes and structural members retaining their full strength with a limited decrease in stiffness; ancillary components, where present, exhibit only minor damage that can be economically repaired (e.g. partitions and infills may show distributed cracking);**

- **d) fully Operational LS (OP) shall be defined as one in which the structure is only slightly damaged and economic to repair, allowing continuous operation of systems hosted by the structure.**

Principles for verifications to LS

- **At least one ULS verification is mandatory (safety of the structure)**
- **The verification includes ancillary elements**
- **Choice of SLS to be verified is up to the NA or the contract**
- **For new structures**:
  - **Verification to SD is mandatory**

    but the rules of the codes are calibrated to cover also NC, without verifications
  - **Verifications to other LS (SLS) is left to the NA or the contract**
  - **ensure deformation capacity and cumulative energy dissipation capacity**
  - **avoid brittle failure or the premature formation of unstable mechanisms**

Safety choices

Safety choices (through NDPs) by structure type

- **On the action effects side**
  - ❑ Level of seismic hazard as input data
  - ❑ Global safety choice
- **On the resistance side**
  - ❑ Partial factors are deduced from the choice of the probability of failure
  - ❑ A simplified reliability-based verification format is given in part 1-1 (Informative Annex F)
  - ❑ A consistent family of partial factors for resistance is given in the different parts, by Limit State

Seismic hazard as an input data

- **This is a safety choice by type of structure = NDP (ex: buildings)**

Return periods in years				
Limit state (LS)	Consequence class			
	CC1	CC2	CC3-a	CC3-b
NC	800	1600	2500	5000
SD	250	475	800	1600
DL	50	60	60	100

10% of exceedance in 50y

Performance factors				
Limit state (LS)	Consequence class (IC)			
	CC1	CC2	CC3-a	CC3-b
NC	1,2	1,5	1,8	2,2
SD	0,8	1	1,2	1,5
DL	0,4	0,5	0,5	0,6

- **Used for the definition of seismic action considered in analysis**

Global safety choice: seismicity index

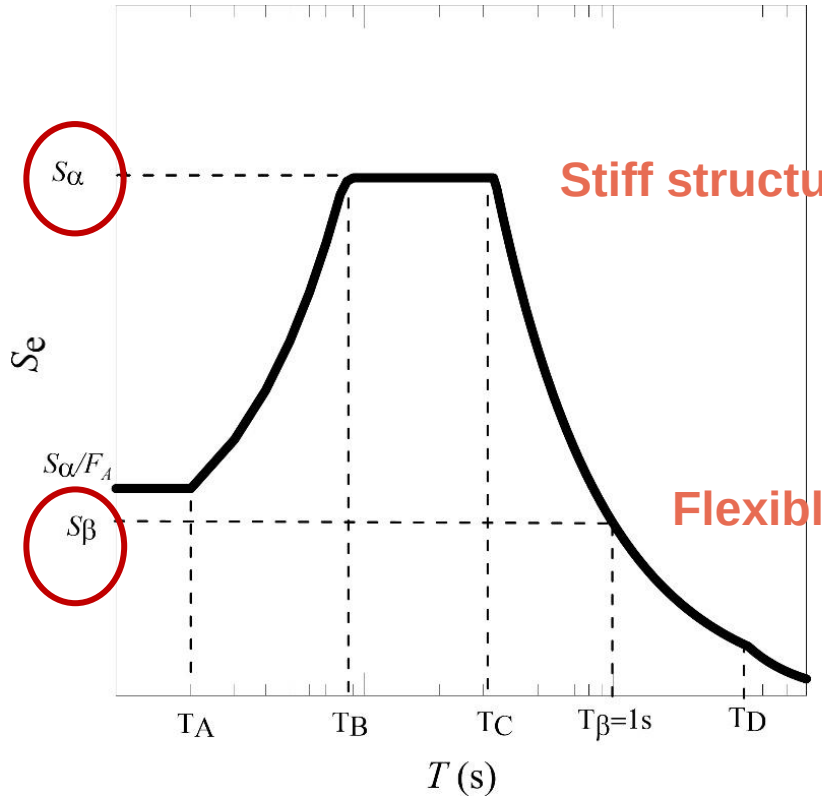
- **Ranges of S_δ values for seismic action classes**

Seismic action class	Range of seismic action index S_d (m/s^2)
Very low	$S_d < 1{,}30$ m/s^2
Low	$1{,}30$ m/s^2 $\leq S_d < 3{,}25$ m/s^2
Moderate	$3{,}25$ m/s^2 $\leq S_d < 6{,}50$ m/s^2
High	$S_d \geq 6{,}50$ m/s^2

- **Use of seismicity index or of seismic action class: f.e. limits of application of ductility classes**

Seismic action

New definition of elastic spectrum



Classification of sites

	Ground class	stiff	medium stiffness	soft
Depth class	$v_{s,H}$ range / H_{800} range	400 m/s ≤ $v_{s,H}$ < 800 m/s	250 m/s ≤ $v_{s,H}$ < 400 m/s	150 m/s ≤ $v_{s,H}$ < 250 m/s
Very shallow	$H_{800} \leq 5$ m	A	A	E
Shallow	5 m < $H_{800} \leq 30$ m	B	E	E
Intermediate	30 m < $H_{800} \leq 100$ m	B	C	D
Deep	$H_{800} > 100$ m	B	F	F

Construction of elastic response spectra

$$S_\alpha = F_T F_\alpha S_{\alpha,RP} \quad \gamma_{LS,CC}\, S_{\alpha,ref} \qquad S_\beta = F_T F_\beta S_{\beta,RP}$$

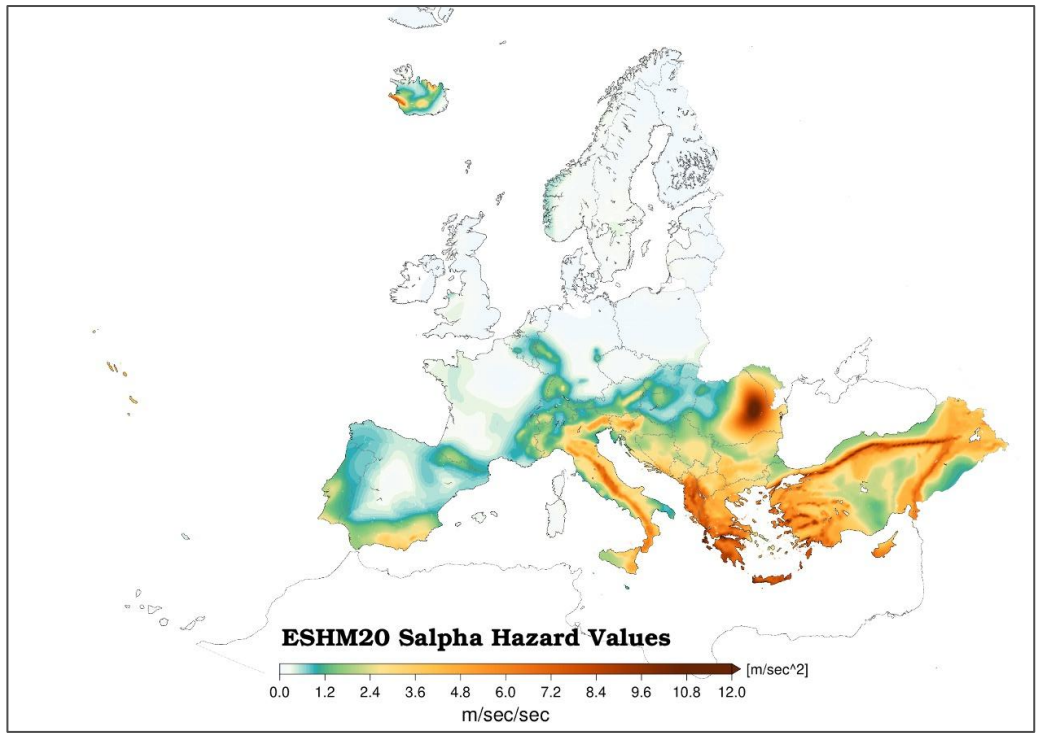
Site category	F_α		F_β	
	H_{800} and $v_{s,H}$ available	Default value	H_{800} and $v_{s,H}$ available	Default value
A	1,0	1,0	1,0	1,0
B	$\left(\frac{v_{s,H}}{800}\right)^{-0,4\, r_\alpha}$	$1,3\,(1-0,1\,S_{\alpha,RP}/g)$	$\left(\frac{v_{s,H}}{800}\right)^{-0,7\, r_\beta}$	$1,6\,(1-0,2\,S_{\beta,RP}/g)$
C		$1,6\,(1-0,2\,S_{\alpha,RP}/g)$		$2,3\,(1-0,3\,S_{\beta,RP}/g)$
D		$1,8\,(1-0,3\,S_{\alpha,RP}/g)$		$3,2\,(1-S_{\beta,RP}/g)$
E	$\left(\frac{v_{s,H}}{800}\right)^{-0,4\, r_\alpha \frac{H}{30}\left(4-\frac{H}{10}\right)}$	$2,2\,(1-0,5\,S_{\alpha,RP}/g)$	$\left(\frac{v_{s,H}}{800}\right)^{-0,7\, r_\beta \frac{H}{30}}$	$3,2\,(1-S_{\beta,RP}/g)$
F	$0,9\left(\frac{v_{s,H}}{800}\right)^{-0,4\, r_\alpha}$	$1,7\,(1-0,3\,S_{\alpha,RP}/g)$	$1,25\left(\frac{v_{s,H}}{800}\right)^{-0,7\, r_\beta}$	$4,0\,(1-S_{\beta,RP}/g)$
	with $r_\alpha = 1-\frac{S_{\alpha,RP}/g}{v_{s,H}/150}$ and $r_\beta = 1-\frac{S_{\beta,RP}/g}{v_{s,H}/150}$ (H in m, $v_{s,H}$ in m/s, g=9,81 m/s^2)			

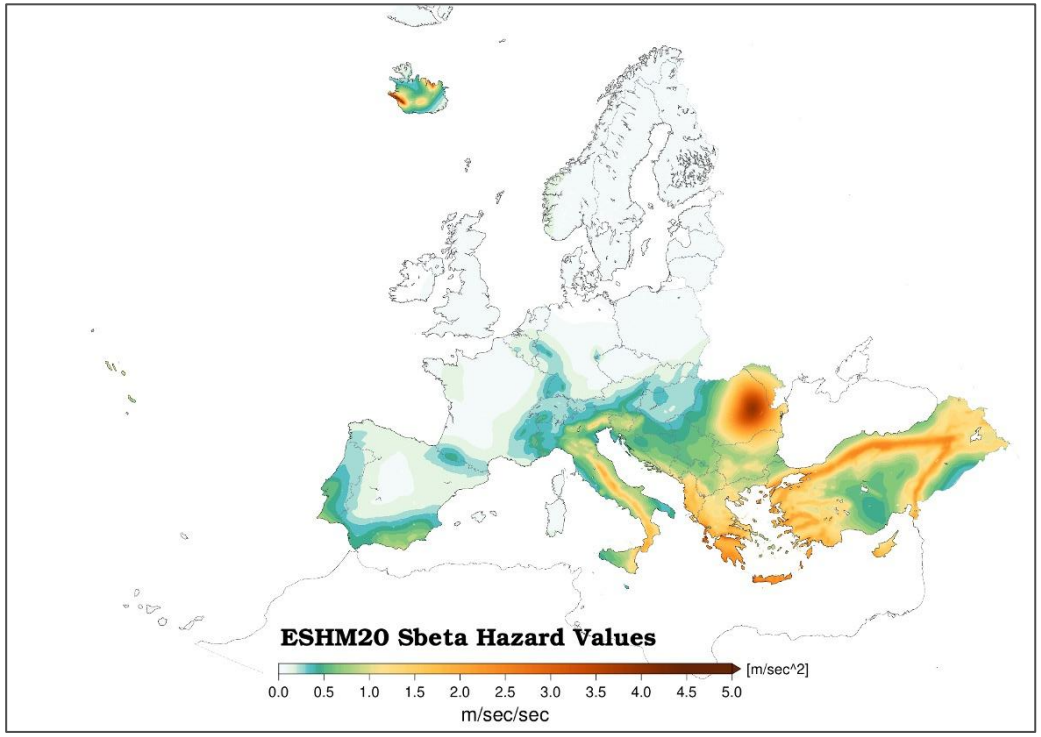
Other parameters for the seismic action

- Improvement of damping and topographic effects
- Elastic displacement response spectrum
- Elastic response spectrum for vertical component
- Ground peak value PGA_e , PGV_e , PGD_e
- Maximum ground relative displacement, $d_{ij,max}$, between two sites
- Conventional earthquake magnitude
- Input motions for response-history analysis
- Spatial model of the seismic action

European seismic maps

- **For information in Informative Annex A of part 1-1**





Principles of aseismic design

Performance requirements

Objectives to be met with an appropriate degree of reliability

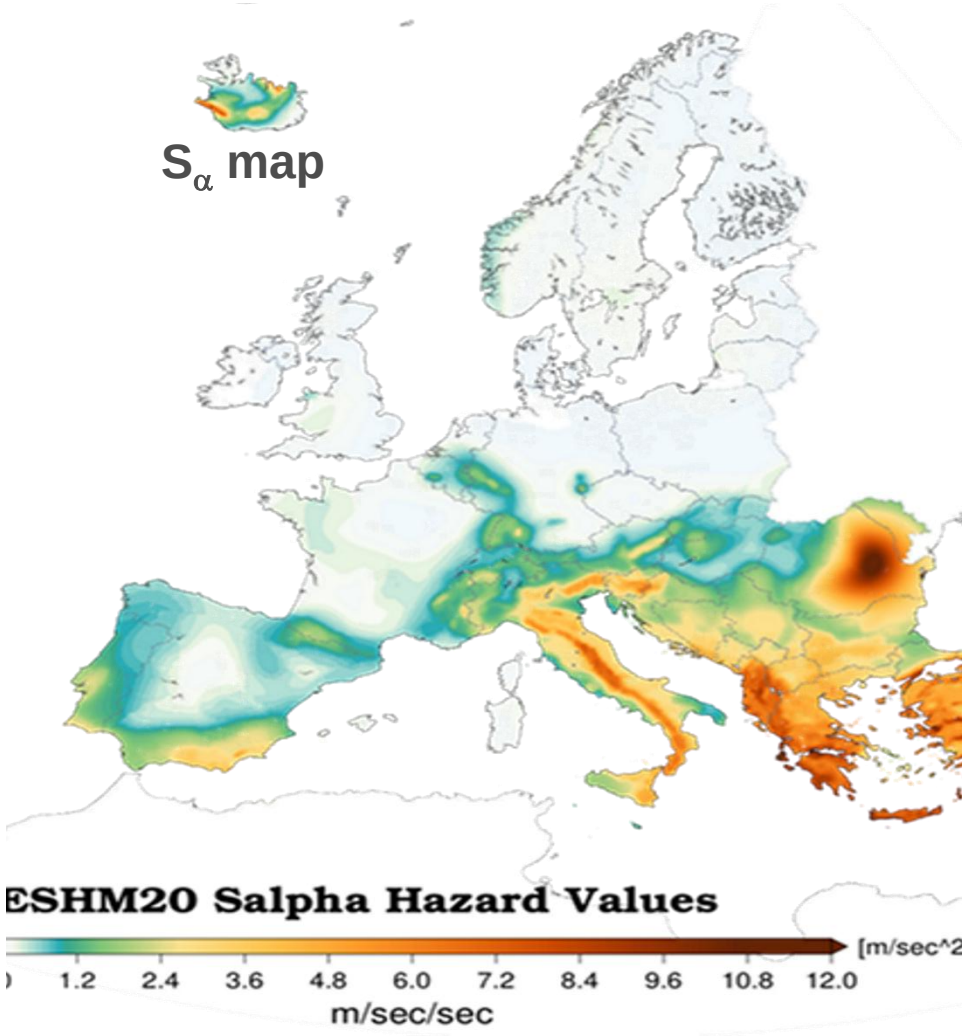
— human lives are protected

— damage is limited

— facilities important for civil protection remain operational

New definition of ductility classes

Linear elastic design, force approach (q = 1)	
DC1	Overstrength capacity (q = 1,5)
DC2	Overstrength capacity, local deformation capacity and local energy dissipation capacity
DC3	Ability of the structure to form a global plastic mechanism at SD limit state



Principle of design in the post-elastic domain

Ensure controlled post-elastic behaviour of the entire structure

- ✓ **Locate plastic zones in areas chosen for a good global behaviour**
- ✓ **Eliminate possible brittle failures and instabilities**

⇨ **Capacity design**

Improve ductility of plastic zones (capability of plastic deformation)

⇨ **Size of sections and geometry**

⇨ **Detailing**

⇨ **Two necessary compromises:**

- ✓ **between strength and ductility**
- ✓ **cost versus risk**

Easier use and flexibility in choices

- DC2 not the same as DCM and simpler to apply
- DC3 intermediate to DCM and DCH, simpler than DCH
- Existing rules more detailed for easier practice
- Simpler approach for choice of partial factors
- But important additional content which makes access less direct
    - Eurocode 8 not for very low seismicity
    - Simpler rules may be adopted in case of low seismicity (national choice)
    - Many openings to NCCI for local production (eg masonry)
    - Removal of most of ”shall”
    - Extensive use of “may”

Analysis

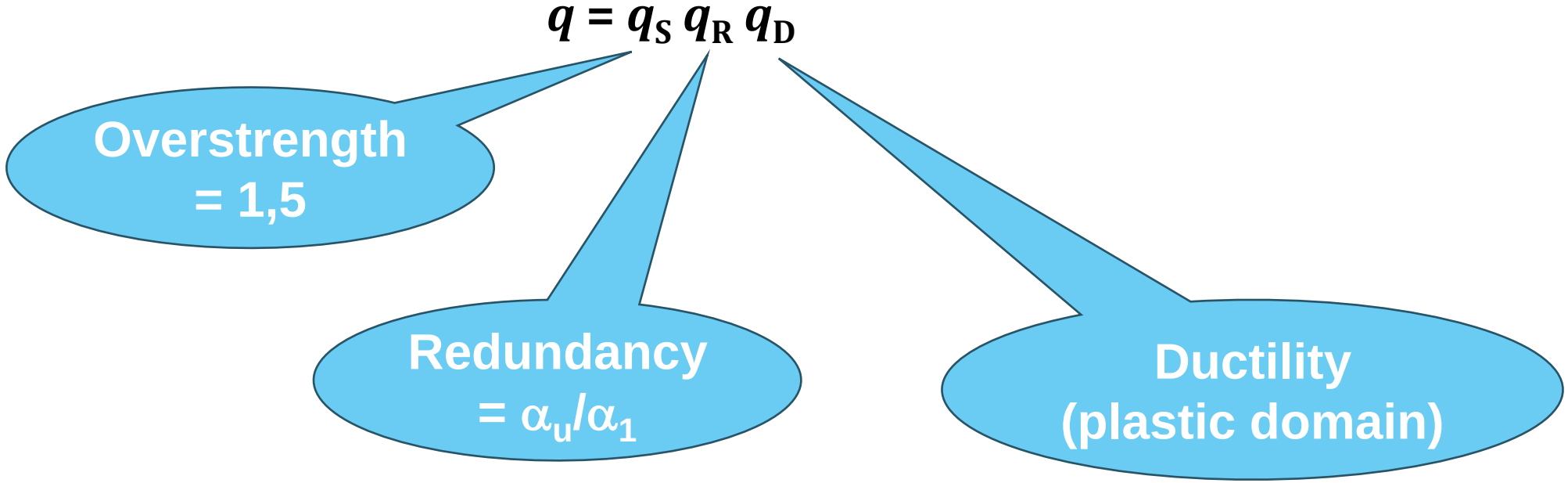
Possible methods and use

- **Force based approach with a behaviour factor and a reduced spectrum**
  - **For verifications at SD with criteria from other Eurocodes**
  - **Not for NC**
  - **For DL and OP with q = 1**
- **Displacement based approach with a pushover analysis (non-linear, quasi-static)**
- **Response-history analysis**

Force-based approach

- **Reduced spectrum deducted from the elastic spectrum**
- **Behaviour factor**

$$q = q_S \, q_R \, q_D$$



Displacement based approach

- **Verifications to Limit State**

- DL and OP in the quasi-elastic domain
- SD in the middle of the plastic domain

$$\delta_{SD} = \frac{1}{\gamma_{Rd}}\left(\delta_y + \alpha_{SD,\theta}\delta_u^{pl}\right)$$

  - ✓ local verification (for each member)
  - ✓ or global verification (for the structure, on the pushover curve)

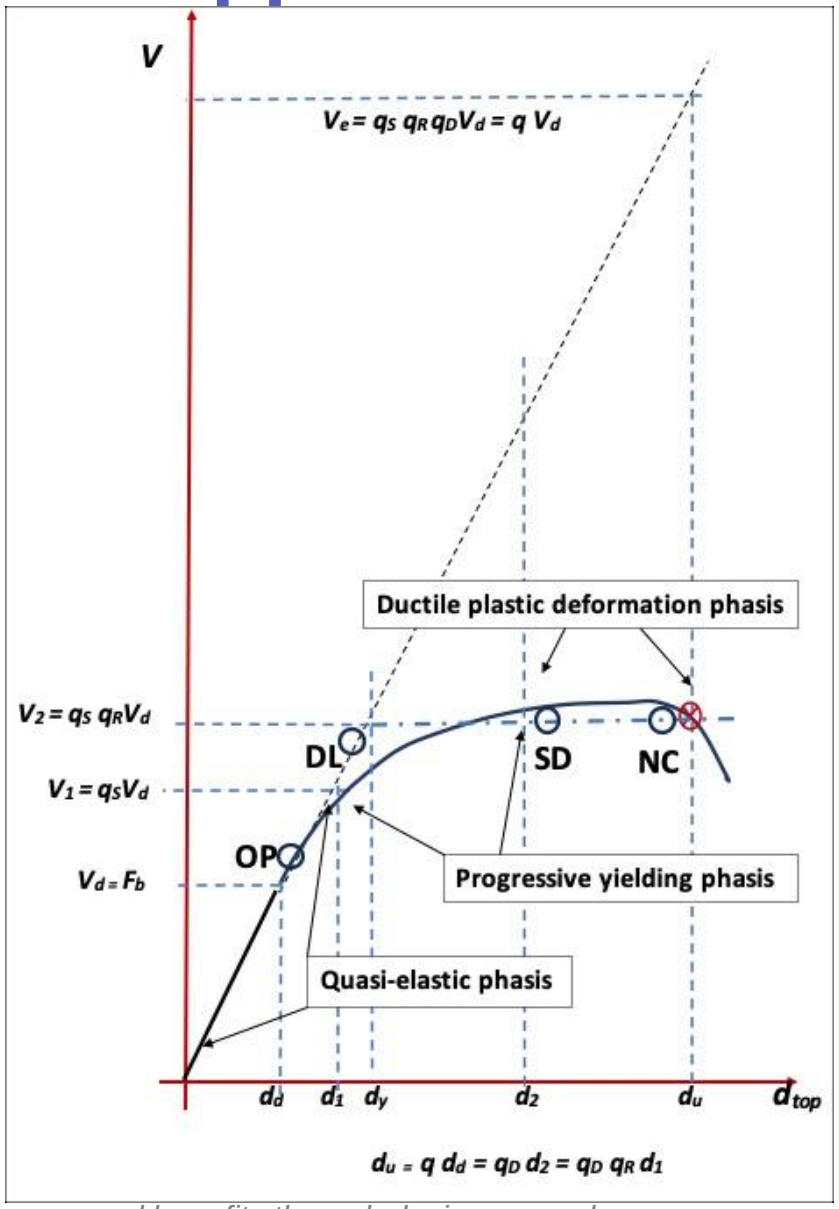
- NC at ultimate deformation

$$\delta_{NC} = \frac{1}{\gamma_{Rd}}\left(\delta_y + \delta_u^{pl}\right)$$

- Verification of brittle mechanisms to stresses $V_{R,LS} = \frac{V_R}{\gamma_{Rd}}$

- **Rules for deformations at yield and ultimate for members in a new chapter (concrete, steel & composite)**

Comparison of both approaches



Use of anti-seismic devices

- **Use of devices has been extended to be used for different types of structure**
- **Design and testing of devices is covered in EN 15129 in consistency with Eurocode 8**
- **The reliability aspect has been worked on, in particular to cover the NC LS**
- **A chapter has been developed for buildings to cover energy dissipation systems consisting of dissipative structural elements and specific dissipation devices, verification by**
  - ✓ **a displacement-based method, or**
  - ✓ **an energy-based method**

Main developments

Key changes to EN 1998-5 (geotechnics)

- ✓ Better consistency with EN 1990 and EN 1997
- ✓ Distinction between geotechnical systems and geotechnical structures
- ✓ Alignment of “basis of design” to the new concepts in EN1998-1-1
- ✓ Derivation of horizontal ground acceleration from new elastic spectra
- ✓ Development of the displacement-based approach for all topics
- ✓ Extension of analysis methods for liquefaction
- ✓ Rules for capacity design of foundations
- ✓ Rules for analysis and verification of piles
- ✓ Development of models for Soil-Structure Interaction
- ✓ New chapter on seismic action effects on underground structures (tunnels, large spaces, pipelines, etc)

Key changes to EN 1998-1-2 (new buildings)

- **General rules**
  - ✓ The rules for considering torsion (suppression of accidental eccentricity), second-order effects and limitation of drift have been reviewed and refined
  - ✓ Correction rules due to damping for high-rise buildings and for the consideration of soil-structure interaction
  - ✓ Design of transfer zones allowing frame changes between two levels
  - ✓ Verification of underground basements
  - ✓ Verification criteria for the displacement approach (all materials)
  - ✓ A complete chapter on the analysis and verification of auxiliary elements (in particular: infill elements and façades) and refinement of floor spectra necessary for their dimensioning
  - ✓ New chapter on the design and analysis of buildings equipped with energy dissipation systems

Key changes to EN 1998-1-2 (new buildings)

- **Rules for materials (1)**
  - ✓ Flat concrete slab systems on columns
  - ✓ Concrete: verification of shear and beam-column joints (continuity with Eurocode 2)
  - ✓ Extension of the rules for prefabricated concrete structures.
  - ✓ Complete overhaul of the clauses for steel and composite structures to incorporate the analyses of the European Convention for Structural Steel Structures
  - ✓ Design of connections for steel and composite structures
  - ✓ Lightweight steel structures
  - ✓ Design of the slab and its assembly to mixed steel-concrete frames

Key changes to EN 1998-1-2 (new buildings)

- **Rules for materials (2)**
  - ✓ Content of the chapter on timber completely revised in close collaboration with EN 1995
  - ✓ Re-evaluation of timber building typologies. Introduction of mixed timber-concrete systems
  - ✓ Harmonisation of masonry rules for better consistency with sections for other materials
  - ✓ Prevention of out-of-plane collapse of masonry walls
  - ✓ Better consideration of the diversity of masonry block production in Europe and thorough review of the rules for simple masonry buildings
  - ✓ New chapter on aluminium structures

Key changes to EN 1998-2 (new bridges)

- ✓ **Alignment with the general rules given in EN 1998-1-1 and removal of redundancies**
- ✓ **Development of displacement-based design for bridges**
- ✓ **New approach for considering the spatial variability of the seismic action**
- ✓ **Provisions for long bridges on non-uniform soil conditions**
- ✓ **Further development of the verification rules**
- ✓ **Specific rules for cable-stayed and extradosed bridges**
- ✓ **Specific rules for integral abutment bridges**
- ✓ **New informative annex on timber bridges**

Key changes to EN 1998-4 (other structures)

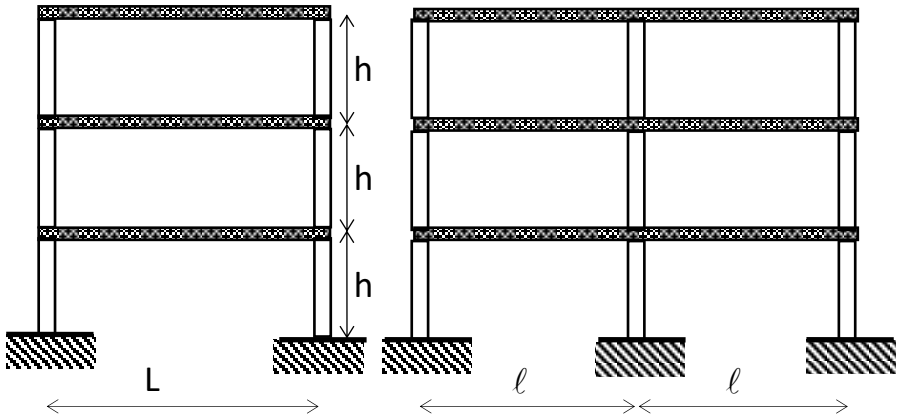
- ✓ Merging of previous Part 4 and Part 6 in one document and uniform normative structure for all clauses
- ✓ Redefinition of limit states and combination rules
- ✓ Simplification of damping approaches
- ✓ New combination rules of components for axisymmetric structures
- ✓ Improved consistency with EN 1992 and EN 1993 and clear separation from material-specific codes
- ✓ Silos: lateral force method considering vertical seismic actions
- ✓ Tanks: introduction of forced-based approach, incorporation of elevated tanks and tabulated values for hydrodynamic pressure functions in tanks
- ✓ Pipelines: design concepts and approaches for fault crossings and liquefaction and modelling approaches for soil-structure interaction in pipelines
- ✓ Towers, masts and chimneys: design without rotational spectra
- ✓ New chapter on ancillary elements

Key changes to EN 1998-3 (existing structures)

- ✓ Clarification of knowledge level according to three criteria (geometry, materials, detailing)
- ✓ Re-writing of analysis methods in line with EN1998-1-1
- ✓ Verification using the displacement-based approach using local or global criteria
- ✓ Normative chapters for concrete, steel, and masonry for assessment, completely rewritten
- ✓ New chapter for timber buildings
- ✓ Complementary deformation criteria (yield and ultimate) of structural materials
- ✓ All material partial factors γ_{Rd} unified based on a single fractile of the resistance distribution, depending on the knowledge level
- ✓ Resistance models for retrofitting introducing new methods of retrofit
- ✓ New chapter for bridges

A simple example for comparison

Structure data



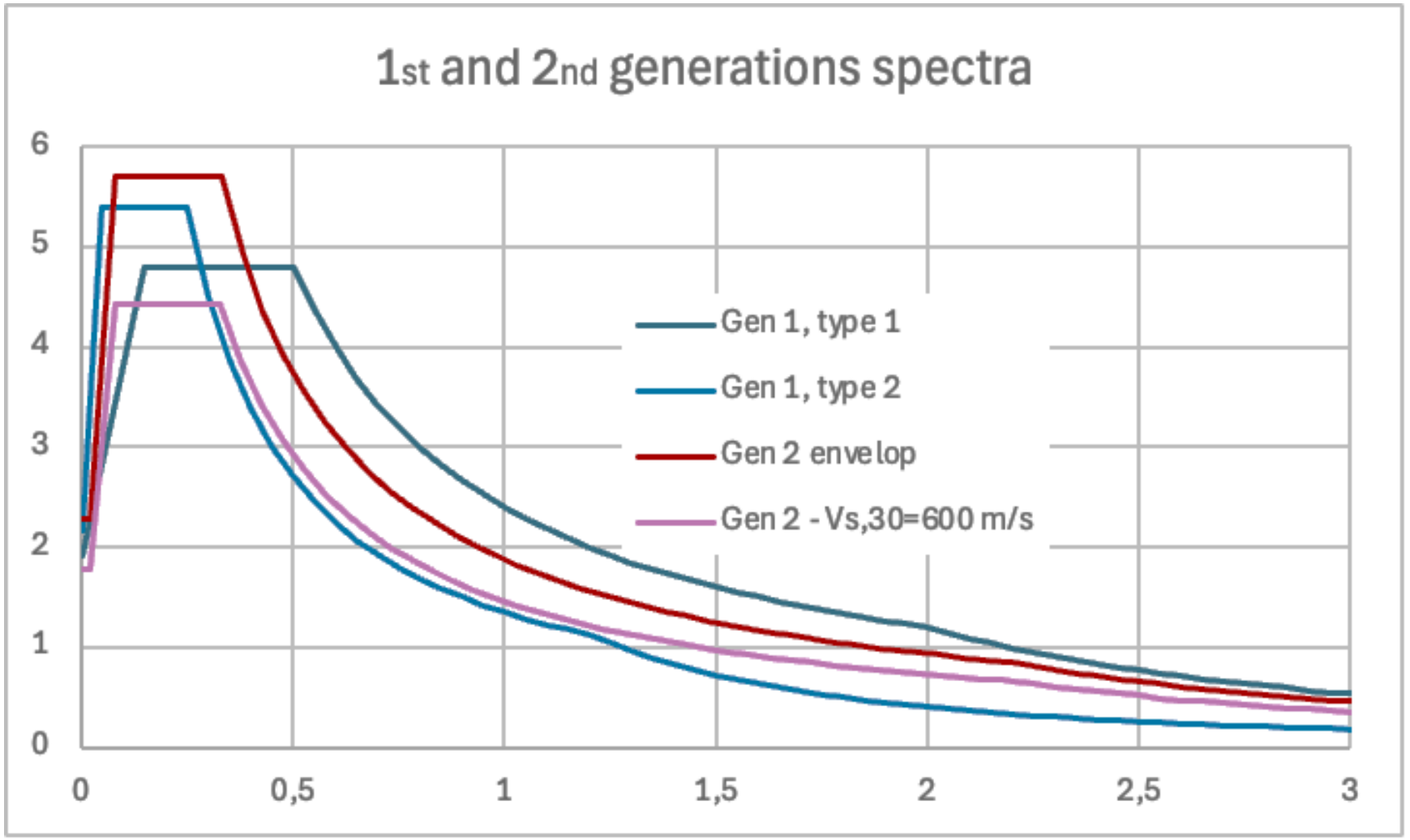
Structure data

L = 8 m
ℓ= 6 m
h = 3 m
mass of a floor: 180 T

Establishment of elastic response spectra

1st generation	2nd generation
Importance Category II, Importance factor $\gamma_I = 1$ (NDP)	Consequence class CC2, performance factor $\gamma_{LS,CC} = 1$ (for SD) (NDP)
-	In addition, a seismic action index can be chosen to determine the seismic action class. The standard value is $\delta = 1$ (NDP). In this case, seismic action index: $S_\delta = 5{,}71$ m/s^2, moderate seismic action class
The site is Class B. The site description is pretty much the same.	
$a_{gR} = 1{,}6$ m/s^2 (475 years)	$S_{\alpha,475} = 4$ m/s^2 moderate seismicity $S_{\beta,475} = 1{,}2$ m/s^2
Topographic amplification: no description in part 1	$F_T = 1$
Type 1: S = 1,2; $T_B = 0{,}15$ s; $T_C = 0{,}50$ s; $T_D = 2{,}0$ s Type 2: S = 1,35; $T_B = 0{,}05$ s; $T_C = 0{,}25$ s; $T_D = 1{,}2$ s	$F_\alpha = 1{,}427$; $F_\beta = 1{,}561$; $S_\alpha = 5{,}71$ m/s2; $S_\beta = 1{,}87$ m/s2 $T_A = 0{,}02$ s; $T_B = 0{,}082$ s; $T_C = 0{,}33$ s; $T_D = 2{,}2$ s (envelope spectrum)

Comparison of spectra



Ductility classes and behaviour factors

1st generation	2nd generation
DCM: q = 4 DCL design not recommended	DC2: q_D = 1,8; q_R = 1,3; q = 3,5 (S_δ = 5,71 < 6,5) Limit of the DC1 design: S_δ = 5,0

Structural analysis

1st generation	2nd generation
Conditions: regularity in elevation and limited T_1 **Calculation of the period by approximate formula (H<40m)** $T_1 = C_t H^{3/4} = 0{,}085 \times (9)^{3/4} = 0{,}44\ \text{s}$ **Calculation of the period by the simple Rayleigh method** $\delta = \frac{180}{218{,}4 \times 10^3} = 0{,}824 \times 10^{-3}\ \text{m}$ Top displacement due to gravity applied horizontally: $d = 6 \times 0{,}824 \times 10^{-3} \times 9{,}81 = 48{,}5 \times 10^{-3}\ \text{m}$ $\Rightarrow \quad T_1 = 2\sqrt{d} = 0{,}44\ \text{s}$	**Conditions: T_1 Limited and H Limited** **No approximate formula** **Generalised Rayleigh method** $T_1 = 2\sqrt{\frac{\sum m_i\, s_i^2}{\sum m_i\, s_i}} = 2\sqrt{5 \times 0{,}824 \times 10^{-3} \times 9{,}81}$ $= 0{,}402\ s$ The exact modal calculation gives 0,405 s, or a difference of 0,7%
Spectral Acceleration (Design Spectrum) Type 1: S_d(0,44 s) = 1,6 m/s^2 ×1,2×2,5/4= 1,20 m/s^2 Type 2: S_d(0,44 s) = 1,6 m/s^2 ×1,35×2,5×0,25/(4×0,44) = 0,77 m/s^2	**Spectral Acceleration (Design Spectrum)** S_d(0,402 s) = 1,87 m/s^2 / (0,402×3,5) = 1,33 m/s^2 (envelope spectrum) = 1,04 m/s^2 ($V_{s,30}$ = 600 m/s)

Structural analysis

1st generation	2nd generation
➢ **Shear force at the base:** $F_b = \lambda S_d(T_1) W = 0{,}85 \times 0{,}77 \times 180 \times 3 = 352\ \text{kN}$ ➢ **Seismic forces at the different levels:** $F_T = F_\text{b} \dfrac{m_r Z_r}{\sum m_i Z_I}$ $F_1 = 352 \times h \times \dfrac{1}{6h} = 58{,}7\ \text{kN}$ $F_2 = 2F_1 = 117{,}4\ \text{kN}$ $F_3 = 3F_1 = 176{,}0\ \text{kN}$ ➢ **Moment at the base** $M_b = (58{,}7 + 117{,}4 \times 2 + 176{,}0 \times 3)h = 2465\ \text{kNm}$	➢ **Shear force at the base:** $F_b = 0{,}85 \times 1{,}04 \times 180 \times 3 = 476\ \text{kN}$ ➢ **Seismic forces at the different levels:** $F_\text{i} = F_\text{b} \dfrac{s_\text{i}\, m_\text{i}}{\sum s_\text{j}\, m_\text{j}}$ $\sum s_\text{j}\, m_\text{j} = 180 \times (3\delta + 5\delta + 6\delta)$ $F_1 = \frac{3}{14} 476 = 102\ \text{kN}$ $F_2 = \frac{5}{14} 476 = 170\ \text{kN}$ $F_3 = \frac{6}{14} 476 = 204\ \text{kN}$ ➢ **Moment at the base** $M_\text{b} = (102 + 170 \times 2 + 204 \times 3)h = 3162\ \text{kNm}$ (with linear distribution: 3333 kNm)

Structural analysis

1st generation	2nd generation
➢ **Displacements** $d_1 = 4 \times \frac{58{,}7+117{,}4+176{,}0}{218400} = 6{,}4 \times 10^{-3}\ \mathrm{m}$ $d_2 = 6{,}4 \times 10^{-3} + 4 \times \frac{117{,}4 + 176{,}0}{218400}$ $= 11{,}8 \times 10^{-3}\ \mathrm{m}$ $d_3 = 11{,}8 \times 10^{-3} + 4 \times \frac{176{,}0}{218400} = 15{,}0 \times 10^{-3}\ \mathrm{m}$	➢**Displacements** $d_1 = 3{,}5 \times \frac{476}{218400} = 7{,}6 \times 10^{-3}\mathrm{m}$ $d_2 = 7{,}6 \times 10^{-3} + 3{,}5 \times \frac{170 + 204}{218400} = 13{,}6 \times 10^{-3}\mathrm{m}$ $d_3 = 13{,}6 \times 10^{-3} + 3{,}5 \times \frac{204}{218400} = 16{,}9 \times 10^{-3}\ \mathrm{m}$

Elements for calculating the action effects in the columns

1st generation	2nd generation
➢**Torsion (accidental eccentricity)** $\delta = 1 + 1{,}2\frac{x}{L_e}$ applied to shear forces in outermost columns $\frac{x}{L_e} = \frac{1}{2} \quad \Rightarrow \quad \delta = 1.6$ $V = \frac{352}{6} \times 1{,}6 = 93{,}9\ \text{kN}$ $M = 93{,}9\ \text{kN} \times 1{,}5\text{m} = 140{,}8\ \text{kNm}$	➢**Torsion (minimal eccentricity)** $M_\text{T} = 476\text{kN} \times 0{,}60\ \text{m} = 285{,}6\ \text{kN}$ Rotation: $\frac{285{,}6\ \text{kN}}{6{,}4110^6\ \text{kNm/Rd}} = 44{,}6 \times 10^{-6}\text{Rd}$ outermost displacement: $44{,}6 \times 10^{-6} \times 6\ \text{m} = 267 \times 10^{-6}\text{m}$ Maximum shear force in outermost columns: $V = \frac{476}{6} + 267 \times 10^{-6}\text{m} \times 36{,}4\ \text{MN/m} = 79 + 10 = 89\ \text{kN}$ $M = 89\ \text{kN} \times 1{,}5\text{m} = 134\ \text{kNm}$

Elements for calculating the action effects in the columns

1st generation	2nd generation
➢**Second-order effects** Verification at first level: $\theta = \frac{P_{tot}\, d_r}{V_{tot}\, h}$ $\theta = \frac{180 \times 3 \times 9{,}81 \times 6{,}4 \times 10^{-3}}{352 \times 3} = 0{,}032$ $< 0{,}10$	➢**Second-order effects** $\theta = \frac{P_{tot}\, d_{r,SD}}{q_R\, q_S\, V_{tot}\, h_s}$ $\theta = \frac{180 \times 9{,}81 \times 3 \times (7{,}6+0{,}2) \times 10^{-3}}{1{,}3 \times 1{,}5 \times 476 \times 3} = 0{,}0148 < 0{,}1$ ➢**Verification of drift** $\frac{d_r}{h} = \frac{7{,}6 \times 10^{-3}}{3} = 2{,}53 \times 10^{-3} < 0{,}020$

Elements for calculating the action effects in the columns

➢**Calculation of the action effects**

$\gamma_{ov} = 1{,}25$; $\Omega = 1$ (no overcapacity of the beams)

$$N_{Ed} = \frac{3 \times 180\text{T} \times 9{,}81}{6} \pm 1{,}1 \times 1{,}25 \times \frac{2465\ \text{kNm}}{3 \times 8\ \text{m}} \times 1{,}6 \quad = 657\ \text{kN ou } 1108\ \text{kN}$$

$$M_{Ed} = 1{,}1 \times 1{,}25 \times 140{,}8\ \text{kNm} = 194\ \text{kNm}$$

$$V_{Ed} = 1{,}1 \times 1{,}25 \times 93{,}9\ \text{kN} = 129\ \text{kN}$$

➢**Calculation of the action effects**

$\Omega = 2$

$$N_{\text{Ed}} = N_{\text{Ed,G}} + \Omega\ N_{\text{Ed,E}} = \frac{3 \times 180\text{T} \times 9{,}81}{6} \pm 2 \times \frac{3162\ \text{kNm}}{3 \times 8\ \text{m}} = 619\ \text{kN ou } 1146\ \text{kN}$$

$$M_{\text{Ed}} = M_{\text{Ed,G}} + M_{\text{Ed,E}} = 134\ \text{kNm}$$

$$V_{\text{Ed}} = V_{\text{Ed,G}} + V_{\text{Ed,E}} = 89\ \text{kN}$$

Thank you!

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