Second Generation of Eurocode 8

Organisation and concepts of EN1998

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- Link of EN1998 with other ECs
- New features in EN1998
- General objectives of EN1998
- Ductility requirements and analysis

Second generation of Eurocodes

General frame and organisation

Purpose of the Eurocodes revision (2nd generation)

- ❑ To satisfy the Mandate given to CEN by the European Commission for:
  - ✓ **Simplifying the use of Eurocodes**
  - ✓ **Convergence in harmonization**
  - ✓ **Covering new topics**
- ❑ To take into account the results of the systematic review from CEN members

Ease of use

PRINCIPLES of "ease of use":

- ✓ Improve clarity
- ✓ Simplify routes through the code
- ✓ Avoid rules of little practical use
- ✓ Avoid alternative procedures
- ✓ Take into account feedback from users

♥ Primary target = competent design engineer

- ➲ Include state-of-the-art material commonly accepted and validated with practical experience
- ➲ Do not cover the complex cases
- ➲ Re-organisation of Eurocode 8

Verb forms in requirements

- "shall" means a requirement strictly to be followed in order to conform to the Eurocodes and from which no deviation is permitted
- "should" gives a strong recommendation. Subject to national regulation and any relevant contractual provisions, alternative approaches could be appropriate where technically justified
- "may" indicates a course of action permissible within the limits of the Eurocodes

➲ Restrict PRINCIPLES to Objectives / Performance / Concepts

NOTES give a complementary information and facts and do not use these verbs

Reduction of NDPs

- PRINCIPLES:

✓ NDPs linked to Safety (e.g. partial factors) are legitimate

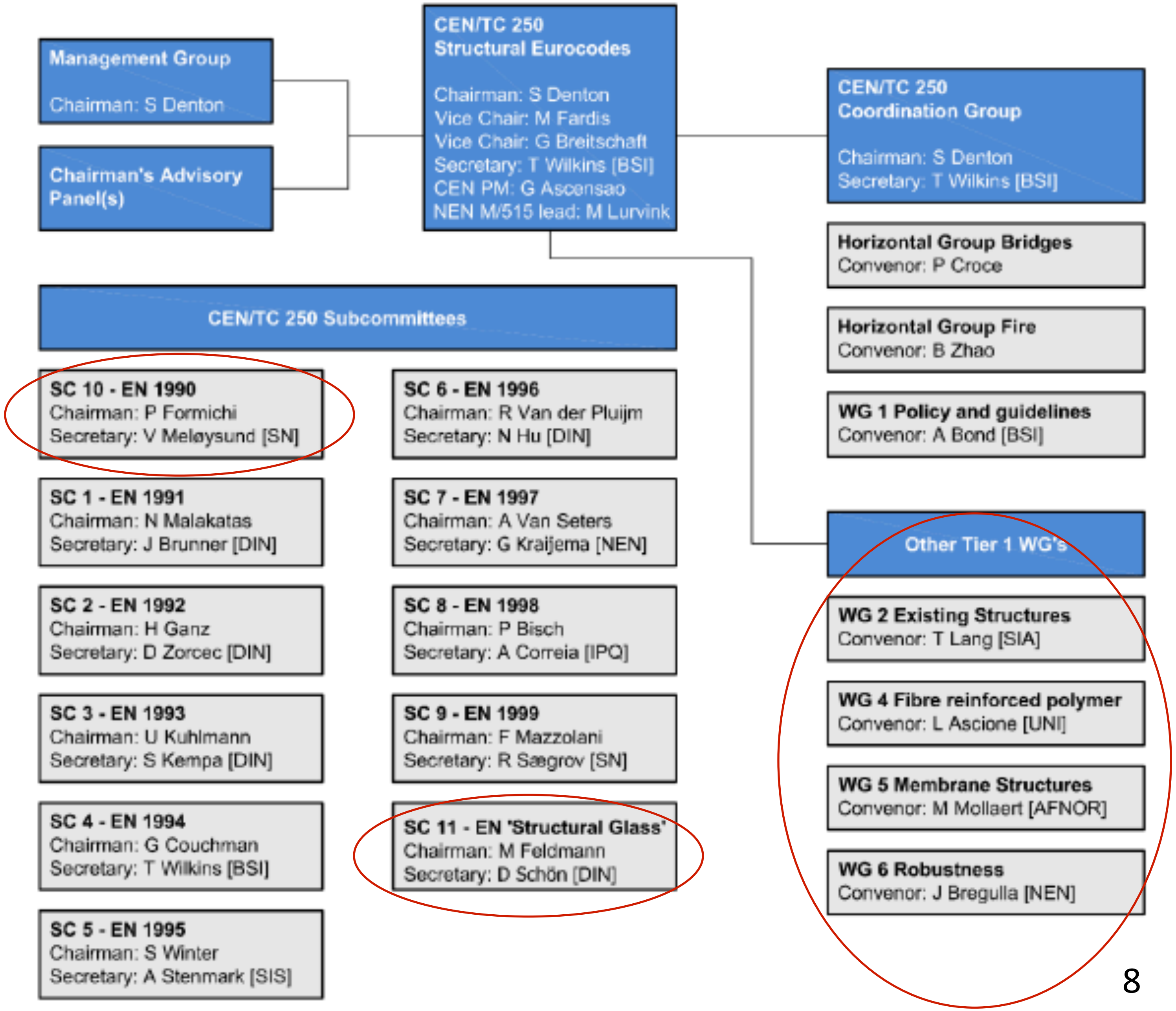
✓ NDPs linked to physical models should be avoided

✓ Economy may be considered

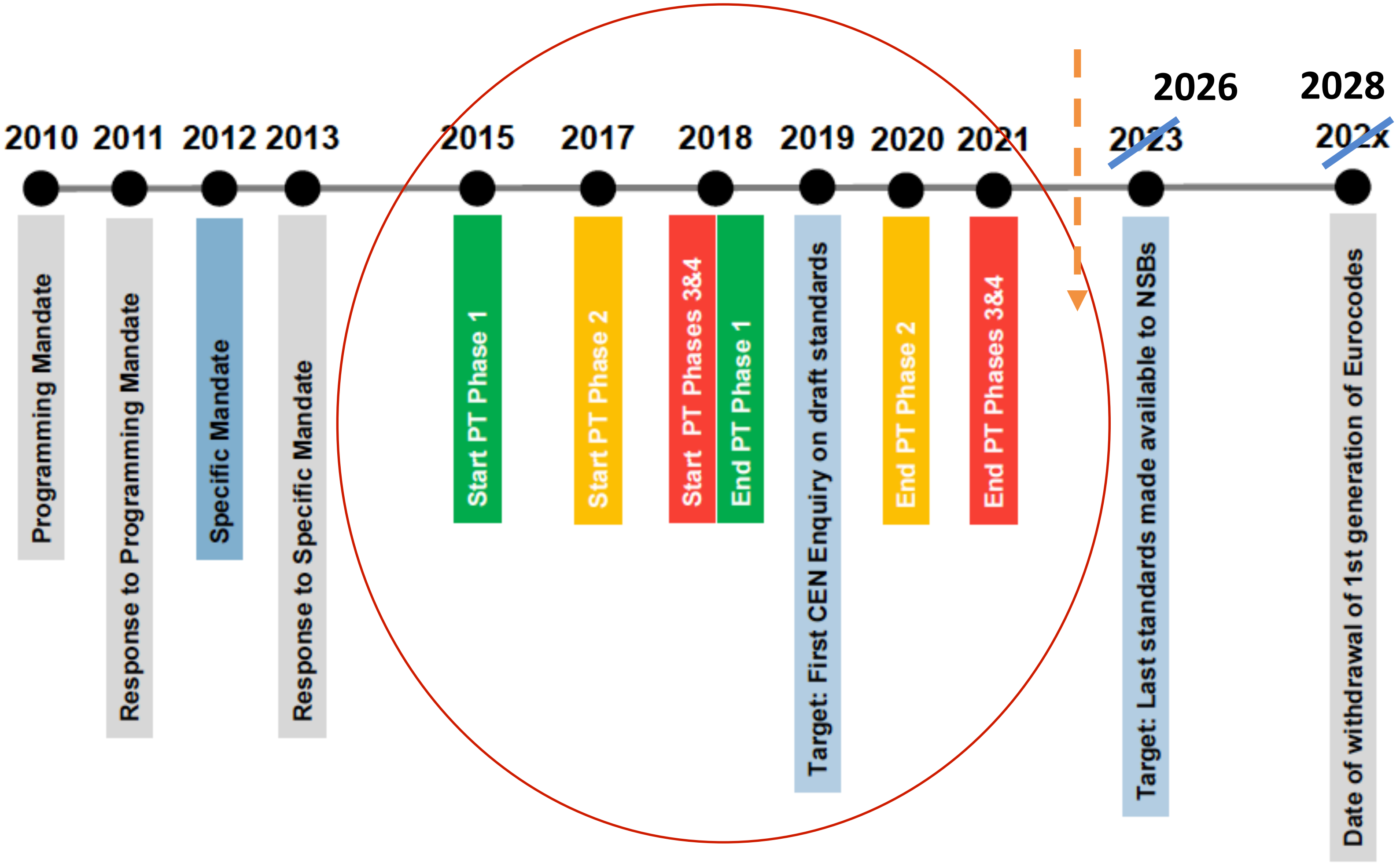
Case of Eurocode 8 (evaluation)

EC8 part	1st generation	2nd generation
EC8-1 general /EC8-1-1	18	13
EC8-1 materials /EC8-1-2	39	18
EC8-2	29	5
EC8-3	8	8
EC8-4+6	10+7	3
EC8-5	4	8
TOTAL	115	55

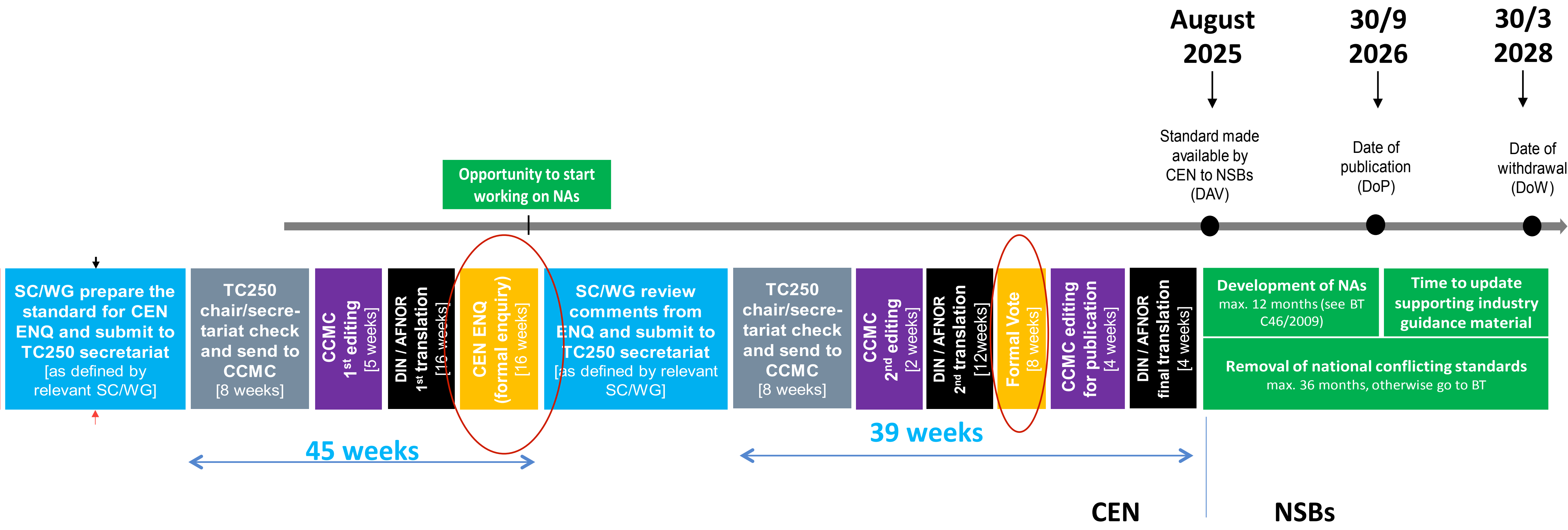
Organisation of CEN/TC250



Drafting Programme



Delivery Programme



Key dates for Eurocode 8 (not final)

	2022				2023				2024				2025				2026			
EN1998-1-1				ENQ						FV	DAV								DOP	
EN1998-1-2								ENQ						FV	DAV				DOP	
EN1998-2						ENQ					FV		DAV						DOP	
EN1998-3								ENQ						FV	DAV				DOP	
EN1998-4								ENQ						FV	DAV				DOP	
EN1998-5				ENQ						FV	DAV								DOP	

CEN **NSBs**

Link of EC8 with other Eurocodes

consequence classes, seismic situation, limit states…

Consequence classes

1st GENERATION IMPORTANCE CLASSES

PART 1	PART 2
I	I
II	II
III	III
IV	

2nd GENERATION CONSEQUENCE CLASSES (EC0)

CC1
CC2
CC3a
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)

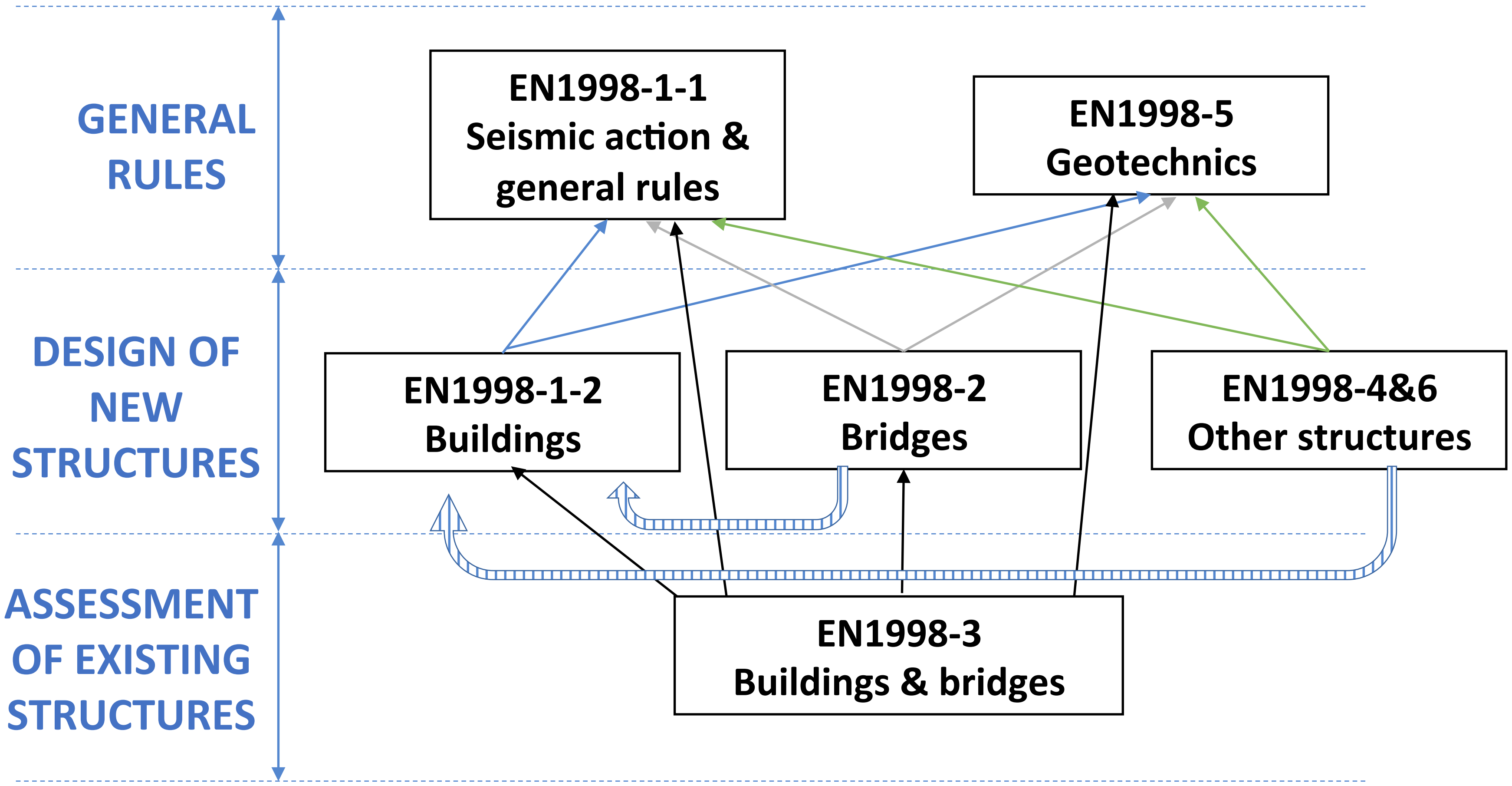
- At least one ULS verification is mandatory (safety of the structure)
- Choice of SLS to be verified is up to the NA or the contract

New features in EN1998

new organisation of EN1998, new content & main changes

Restructuration of EN 1998 in three levels

Identification of a general part common to all other parts to avoid repetitions



New content included in scope of EN 1998

- Verification of Operational (OP) limit state
- Development of the displacement-based approach
- Structures equipped with antiseismic devices
- European Seismic Zonation
- Soil structure interaction
- Ancillary elements
- Flat slab systems (buildings)
- Infilled frames and claddings (buildings)
- Aluminium structures in part 1-2 (buildings)
- Bridges in part 3 (existing structures)
- Timber structures in part 2 (bridges) and part 3 (assessment of existing structures)

Key changes to EN 1998

- Homogenisation of seismic zones definition
- Simplification of the global safety choice (for Members) through seismic action classes (NDP)
- Resistance partial factors γ_{Rd} unified based on a single fractile of the resistance distribution - gives a consistent way to derive the partial factors (NDP)
- Better definition of site classification introducing the depth of the bedrock formation
- Redefinition of the elastic response spectrum using two parameters instead of a_g
- Spatial model of the seismic action

Key changes to EN 1998

- New definition of ductility classes
- Two possible approaches for analysis: force-based or displacement-based
- Improvement of linear analysis, simplified method and pushover
- Non-linear cyclic constitutive laws, deformation criteria and strength models for materials
- Better control of drift and 2nd order effects

General objectives of EN1998

compliance criteria

Introduction to Eurocode 8

- By nature, perfect protection (a null seismic risk) against earthquakes is practically not feasible, in particular because the knowledge of the hazard itself is characterised by a significant uncertainty. Therefore, in Eurocode 8, the seismic action is represented in a conventional form, proportional in amplitude to earthquakes likely to occur at a given location and representative of their frequency content. This representation is not the prediction of a particular seismic movement, and such a movement could give rise to more severe effects than those of the seismic action considered, inflicting damage greater than the one described by the Limit States contemplated in this Standard.
- Not only the seismic action cannot be predicted, but in addition, it should be recognised that engineering methods are not perfectly predictive when considering the effects of this specific action, under which structures are assumed to respond in the non-linear regime. Such uncertainties are taken into account according to the general EN 1990 frame with a residual risk of underestimation of the effects.

EUROCODE 8 is a purely technical text, SAFETY is in the hands of the Members

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

Design verification principles for new structures:

— verification of SD limit state mandatory

— ensure deformation capacity and cumulative energy dissipation capacity

— avoid brittle failure or the premature formation of unstable mechanisms

Description of Limit States (ULS)

- 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.
- 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 damaged (e.g., partitions and infills have not yet failed out-of-plane). The structure is expected to be repairable, but, in some cases, it may be uneconomic to repair.

+ Description of Damage Limitation (DL) and Operability (OP), both SLS

Safety choices for buildings (NDPs)

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

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

Global safety choice: seismicity index

- **Seismicity index**

$$S_d = \delta\, F_\alpha\, F_T\, S_{\alpha,475}$$

Seismic action

depends on the Consequence Class of the structure (NDP)

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

Seismic action class	Range of seismic action index S_δ (m/s²)
Very low	$S_\delta < 1{,}30$ m/s²
Low	$1{,}30$ m/s² $\leq S_\delta < 3{,}25$ m/s²
Moderate	$3{,}25$ m/s² $\leq S_\delta < 6{,}50$ m/s²
High	$S_\delta \geq 6{,}50$ m/s²

Ductility requirements and analysis

principles of verification in DC1, DC2 and DC3

consequences on analysis and verification

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

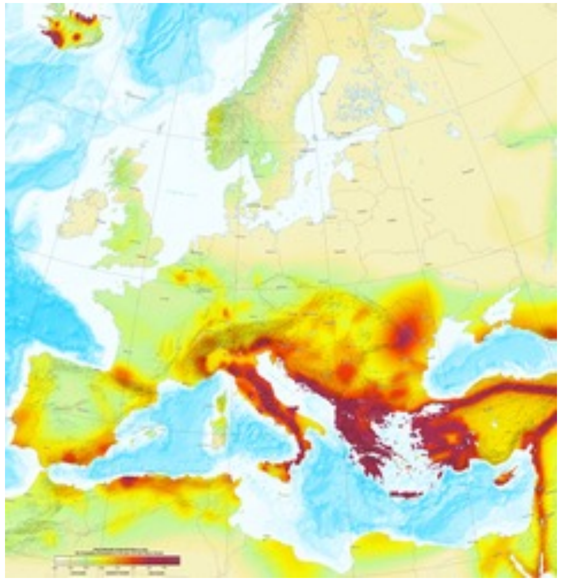
- Improve ductility of plastic zones (capability of plastic deformation)

⇨ Size of sections and geometry

⇨ Detailing

⇨ Two necessary compromises:
  - ✓ between strength and ductility
  - ✓ cost versus risk

New definition of ductility classes



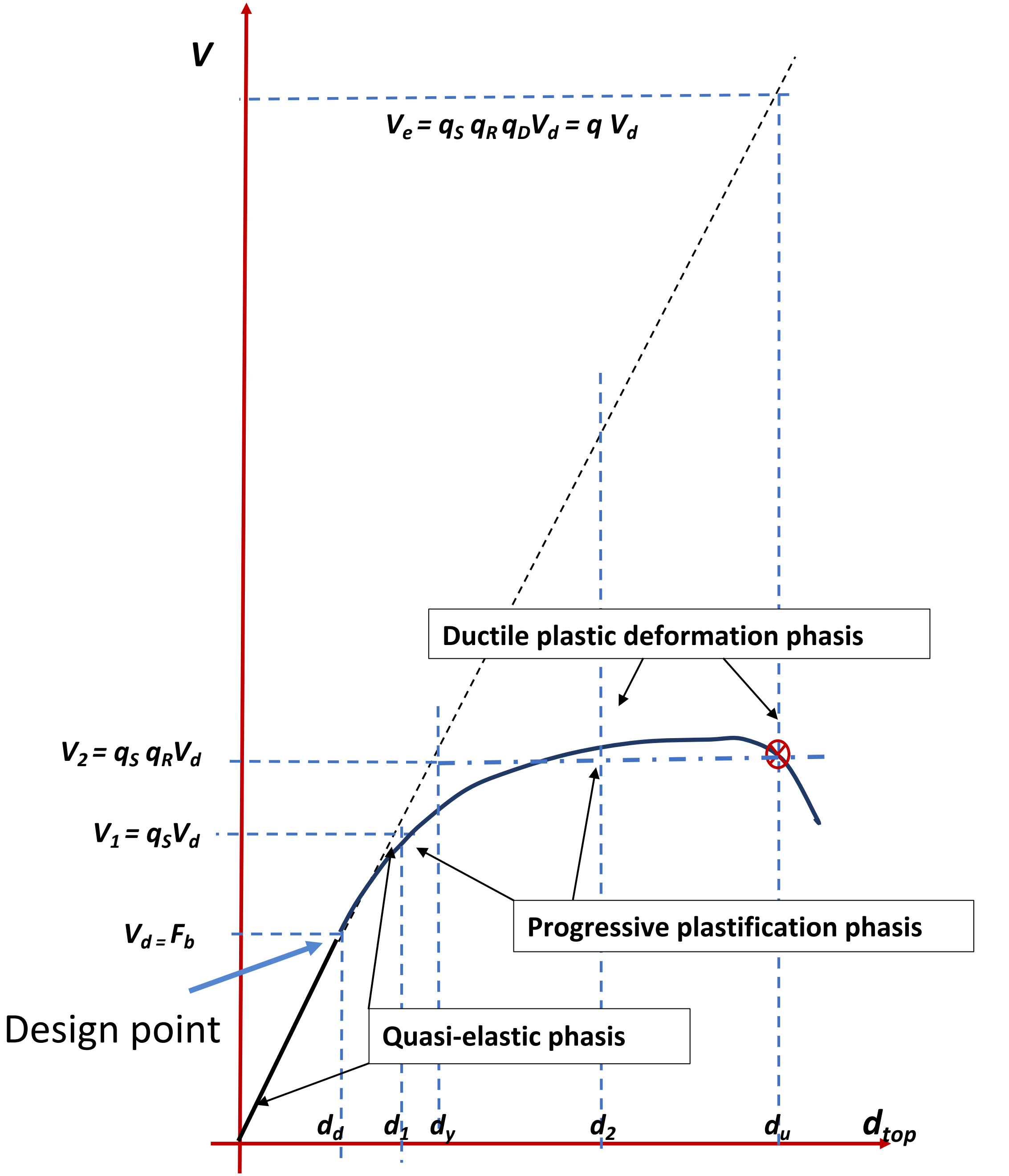
Linear elastic design, force approach (q = 1)	
DC1	Overstrength capacity (q = 1,5)
DC2	Overstrength capacity, local deformation capacity and local energy dissipation capacity
DC3	Ability of the structure to form a global plastic mechanism at SD limit state

Global behaviour and *q*-factor

$q = q_R\, q_S\, q_D$

$q_S = 1{,}5$

$q_R = \alpha_u / \alpha_1$



$d_u = q\ d_d = q_D\, d_2 = q_D\, q_R\, d_1$

Values of the *q*-factor: example (RC)

<table>
<tr><th colspan="2" rowspan="2">Structural type</th><th rowspan="2">q_R</th><th colspan="2">q_D</th><th colspan="2">$q = q_R\, q_S\, q_D$</th></tr>
<tr><th>DC2</th><th>DC3</th><th>DC2</th><th>DC3</th></tr>
<tr><td rowspan="3">Moment resisting frame or moment resisting frame-equivalent dual structures</td><td>multi-storey, multi-bay moment resisting frames or moment resisting frame-equivalent dual structures</td><td>1,3</td><td rowspan="3">1,3</td><td rowspan="3">2,0</td><td>2,5</td><td>3,9</td></tr>
<tr><td>multi-storey, one-bay moment resisting frames</td><td>1,2</td><td>2,3</td><td>3,6</td></tr>
<tr><td>one-storey moment resisting frames</td><td>1,1</td><td>2,1</td><td>3,3</td></tr>
<tr><td>Moment resisting frame or moment resisting frame-equivalent dual structures with interacting masonry infills</td><td></td><td>1,1</td><td>1,2</td><td>1,7</td><td>2,0</td><td>3,0</td></tr>
<tr><td rowspan="4">Wall- or wall-equivalent dual structures</td><td>wall-equivalent dual structures</td><td>1,2</td><td>1,3</td><td rowspan="3">2,0</td><td>2,3</td><td>3,6</td></tr>
<tr><td>coupled walls structures</td><td>1,2</td><td>1,4</td><td>2,5</td><td>3,6</td></tr>
<tr><td>uncoupled walls structures</td><td>1,0</td><td>1,3</td><td>2,0</td><td>3,0</td></tr>
<tr><td>large walls structures</td><td>--</td><td colspan="2">--</td><td colspan="2">3,0 k_w</td></tr>
<tr><td colspan="2">Flat slab structures</td><td>1,1</td><td>1,2</td><td>--</td><td>2,0</td><td>--</td></tr>
</table>

Domain of application of ductility classes: example (Steel)

Structural type	Limits of seismic action index $S_\delta\,(\mathrm{m/s^2})$		
	DC1	DC2	DC3
Moment frames	5,0	6,5	no limit
Frames with concentric or eccentric bracings	5,0	6,5	no limit
Buckling-restrained braced frames	-	-	no limit
Dual frames (moment frames with bracings)	5,0	7,5	no limit
Steel structure with concrete cores/walls	5,0	7,5	no limit
Lightweight steel frame wall systems	5,0	7,5	no limit
Inverted pendulum	2,5	5,0	no limit
Moment resisting frames with unconnected interacting concrete or masonry infills	2,5	5,0	no limit
Moment resisting frames with non-interacting infills	5,0	6,5	no limit

Verifications to SD LS

- Equilibrium condition
- Control of second order effects
- Limitation of interstorey drift
- Verifications of members stability
- Capacity design in DC2 & DC3
- Verifications of resistance according to material Eurocodes (force based approach)
- (materials)

Verification to SD LS in case of displacement-based approach

Verification of resistance

- **Ductile mechanisms**

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

- **Brittle mechanisms**

$$V_{R,SD} = V_R / \gamma_{Rd,SD,V}$$

THANK YOU FOR YOUR ATTENTION

QUESTIONS?