PROTA 30th ANNIVERSARY SYMPOSIUM

"NEW GENERATION OF SEISMIC CODES AND NEW TECHNOLOGIES IN EARTHQUAKE ENGINEERING"

ANKARA, FEB. 26 & 27, 2015

Next Eurocode 8 and Performance-based seismic design philosophy

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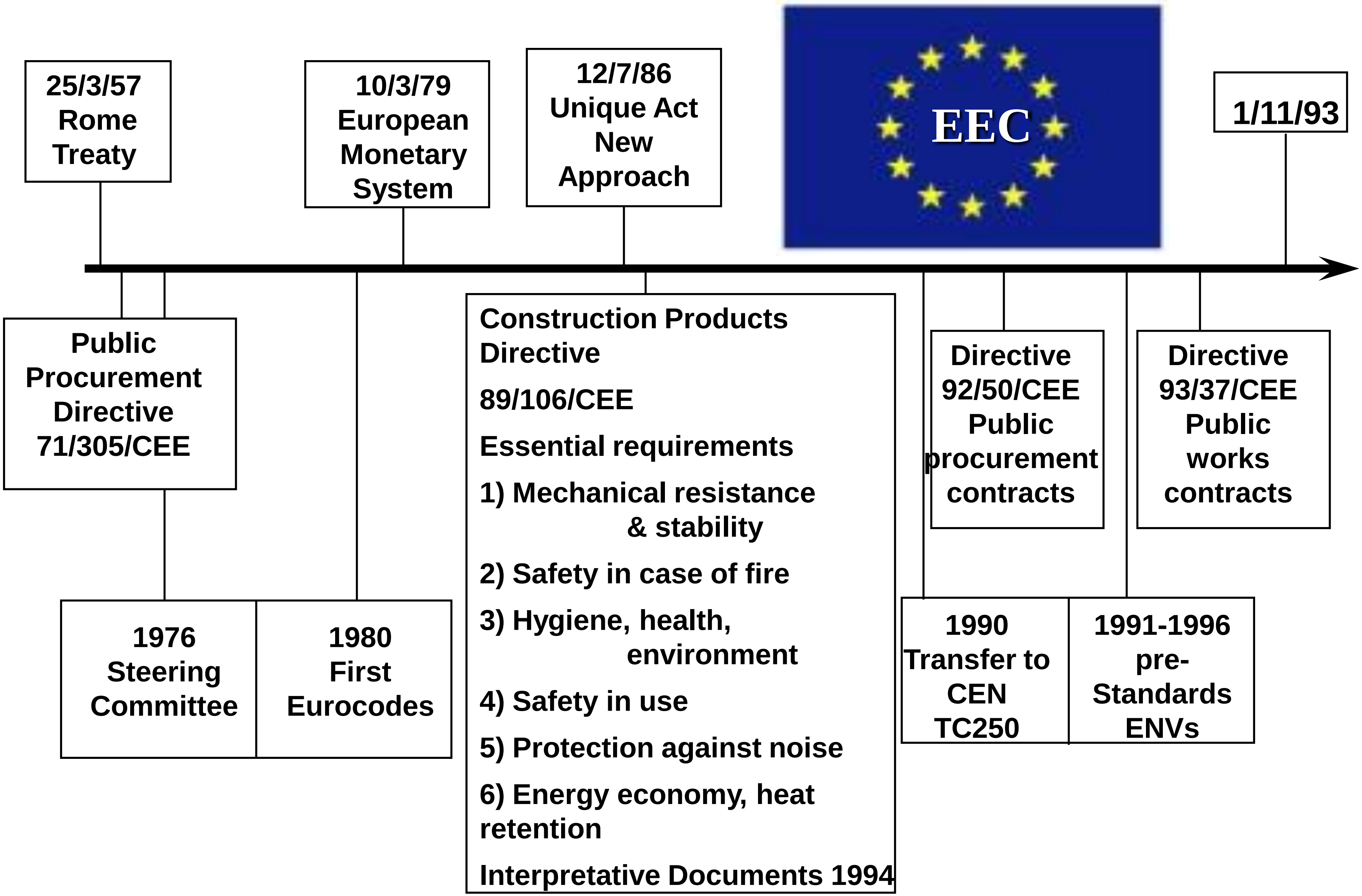
The Context

The Eurocodes in the European Economic Community



The Eurocodes in the European Union

1/11/93

Directive 97/52/CE

1998 «Conversion» of ENVs to ENs starts

2002 First Standards EN

The Commission's Recommendation to EU Member States

03/C4639 /CEE

Implementation & use of Eurocodes

1) Adopt ECs

2) Use ECs in Specs for public sector & energy, water, transport, telecom works

3) Member States competent on safety & economy: Nationally Determined Parameters (NDPs)

4) Compare, harmonize NDPs

2006 All ENs published

Construction Products Regulation

305/2011/EU

Essential requirements

1) Mechanical resistance & stability
2) Safety in case of fire
3) Hygiene, health, environment
4) Safety in use
5) Protection against noise
6) Energy economy, heat retention
7) Sustainable use of resources

Dec. 2012 Mandate M515: EC invited CEN to develop work program for 2nd generation EN-Eurocodes

The EN-Eurocodes in the context of European (CEN) Standards

<table>
<tr><td colspan="2">Design standards, by CEN: The Eurocodes</td></tr>
<tr><td>Material standards (steel, concrete, etc.)
Product standards (e.g., structural bearings); CEN</td><td>ETAs: European Technical Approvals (e.g., FRPs, prestressing systems, etc.), by EOTA</td></tr>
<tr><td colspan="2">Execution standards (e.g., standards for the execution of concrete or steel structures), by CEN</td></tr>
<tr><td colspan="2">Test standards, by CEN</td></tr>
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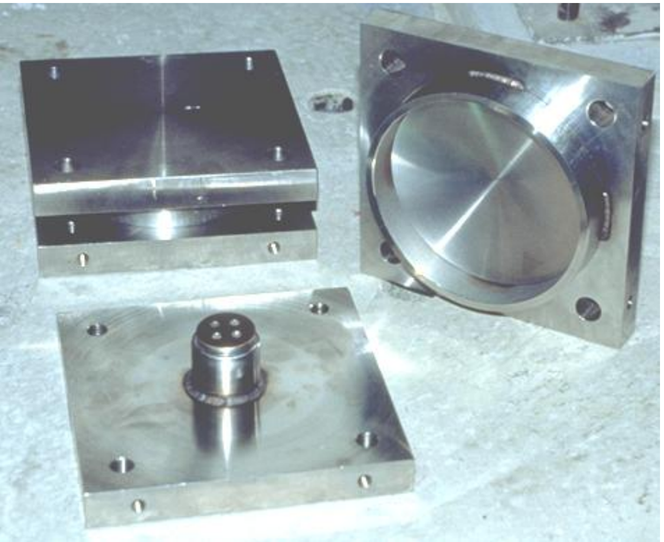


Objectives of the Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes :

→ as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC & European Regulation 305/2011/EU, particularly with Essential Requirements N°1 – Mechanical resistance and stability – and N°2 – Safety in case of fire;

→ as a basis for specifying contracts for construction works and related engineering services;

→ as a framework for drawing up harmonized technical specifications for construction products (ENs and ETAs)

➢ The Eurocodes will improve the functioning of the single market for products & engineering services, by removing obstacles arising from different nationally codified practices for structural design

THE EN-EUROCODES

EN 1990 Eurocode: Basis of structural design

EN 1991 Eurocode 1: Actions on structures

EN 1992 Eurocode 2: Design of concrete structures

EN 1993 Eurocode 3: Design of steel structures

EN 1994 Eurocode 4: Design of composite (steel-concrete) structures

EN 1995 Eurocode 5: Design of timber structures

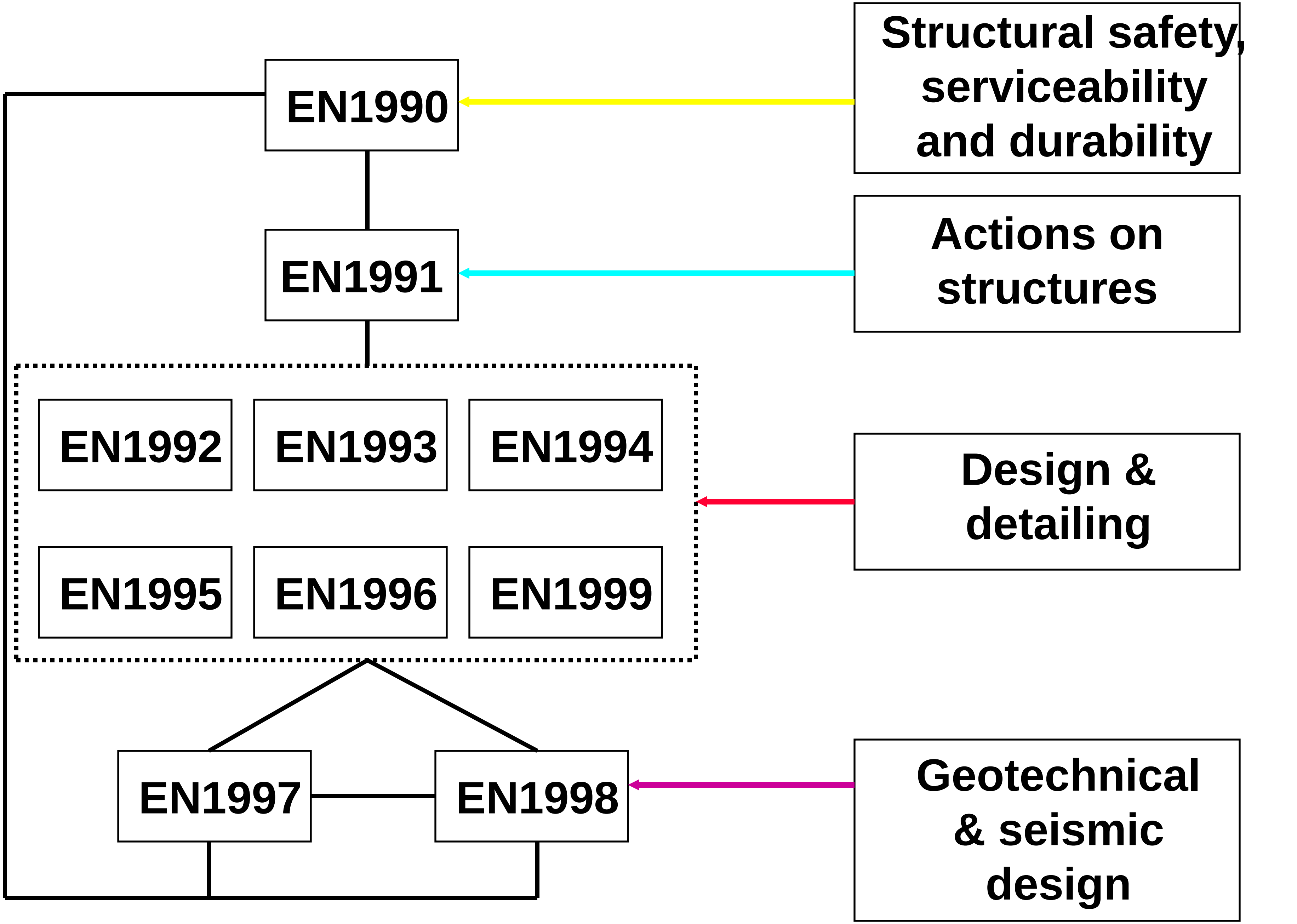
EN 1996 Eurocode 6: Design of masonry structures

EN 1997 Eurocode 7: Geotechnical design

EN 1998 Eurocode 8: Design of structures for earthquake resistance

EN 1999 Eurocode 9: Design of aluminium structures

INTERRELATION OF EUROCODES



FLEXIBILITY WITHIN EUROCODE FRAMEWORK

- Eurocodes (ECs) or National Annexes cannot allow design with rules other than those in the ECs.
- National choice can be exercised through the National Annex, only where the Eurocode itself explicitly allows:
  1. Choosing a value for a parameter, for which a symbol or range of values is given in the Eurocode;
  2. Choosing among alternative classes/models detailed in the Eurocode;
  3. Adopting an Informative Annex or referring to alternative national document.
- Items of national choice in 1-2: Nationally Determined Parameters NDPs
- National choice through NDPs:
  - Wherever agreement on single choice cannot be reached;
  - On issues controlling safety, durability & economy (national competence) & where geographic or climatic differences exist (eg. Seismic Hazard)
- For cases 1 & 2, the Eurocode itself recommends (in a Note) a choice. The European Commission will urge countries to adopt recommendation(s), to minimize diversity within the EU.
- If a National Annex does not exercise national choice for a NDP, designer will make the choice, depending on conditions of the project.

Eurocode 8 Parts

EC8 Part	Title	CEN publication
1: EN1998-1	General rules, seismic actions, rules for buildings	Dec. 04
2: EN1998-2	Bridges	Nov. 05
3: EN1998-3	Assessment and retrofitting of buildings	June 05
4: EN1998-4	Silos, tanks, pipelines	July 06
5: EN1998-5	Foundations, retaining structures, geotechnical aspects	Nov. 04
6: EN1998-6	Towers, masts, chimneys	June 05

History of Eurocode 8
and of its performance aspects
to the present day

Performance-based Seismic Engineering

- Present-day seismic design codes for new buildings hide the ***ends***, i.e., the seismic performance target, and emphasize the (prescriptive) ***means***, e.g.:
  - the *q*-factor for the reduction of the elastic spectrum for linear analysis,
  - the member detailing rules, etc.
- Performance-based seismic design is transparent: it targets specific and measurable performance for a set of seismic hazard levels, e.g. for ordinary buildings (US “Vision 2000”):

Performance Level	Hazard Level	
Operational	**Frequent earthquake**	(25-72 yrs)
Immediate Occupancy	**Occasional earthquake**	(72-225 yrs)
Life Safety	**Rare earthquake**	(475 yrs)
Collapse Prevention	**Very rare earthquake**	(800-2500yrs)

  - Pros: Better property protection; flexibility in conceptual design
  - Cons: Extra work in design.

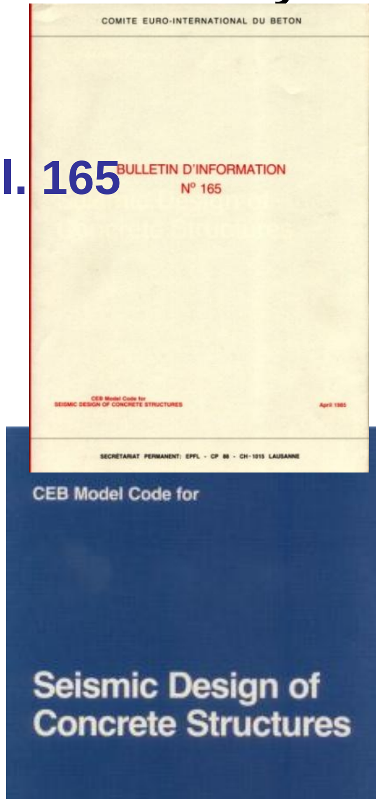
Limit State design in Europe: Early Performance-based design for all sorts of loadings

- The 1970 CEB "International Recommendations for the design and construction of concrete structures" introduced "Performance Levels" for any type of loading (not just for earthquake) under the name "Limit States":
- **Limit State (LS)** = state of unfitness to (intended) purpose:
  - **"Ultimate" LSs (ULS)** concern safety of people or structure;
  - **"Serviceability" LSs (SLS)** concerns operation of the facility and damage to property;
  - Intermediate "**Damageability" LSs**.
- Limit State concept: the backbone of all Eurocodes (as mandated by Eurocode 1990 "Basis of structural design"), including Eurocode 8.

The dawn of European seismic codes

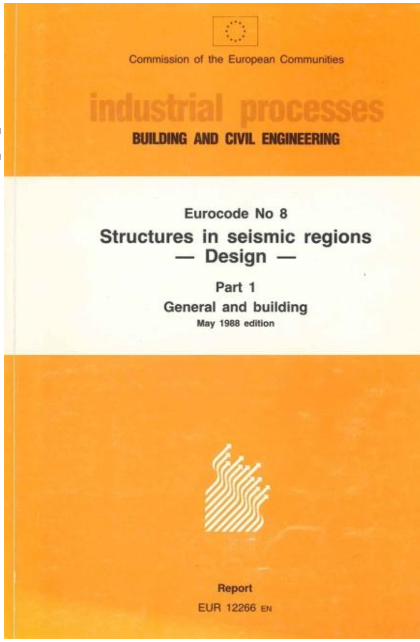
- The 1985 Seismic Model Code of CEB (Comite Euro-international du Beton)
  - Force-based: ULS dimensioning of members for internal forces from linear analysis for 5%-damped elastic spectrum of "design earthquake" (10% / 50yrs), reduced by "*q*-factor".
  - 3 Ductility Levels for RC buildings: prescribed "*q*-factors" with associated (prescriptive) member detailing rules for ductility.
  - In the upper two "Ductility Levels": "Capacity design" against:
    - shear failure of RC members and
    - soft story, weak-column/strong-beam frames.
  - Interstory drift under "design earthquake" ("equal displacement rule", uncracked section EI):
    - < 1%   for brittle partitions,
    - < 1.5%   for non-brittle ones,
    - < 2.5%   for the building's structure.

CEB Bull. 165



The 1985 CEB Seismic Model Code led to:

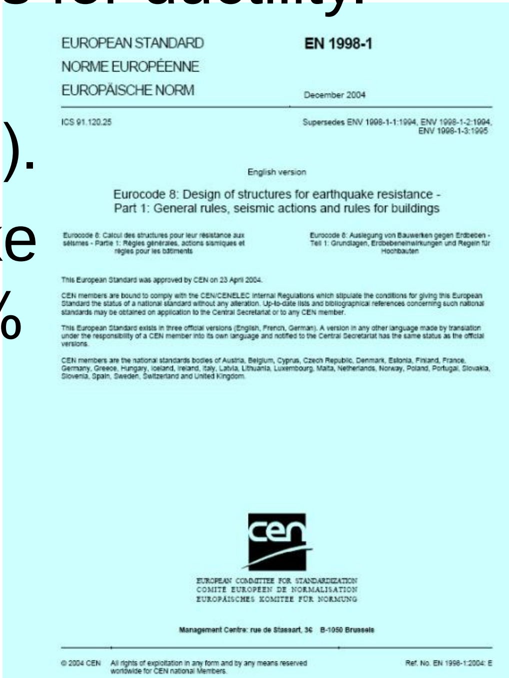
- The 1994 European Pre-standard (ENV) Eurocode 8 for seismic design of new concrete buildings (also of steel, timber or masonry).
  - "Capacity design" against shear failure of beams:
    - only in the uppermost "Ductility Class".
  - Interstory drifts under "serviceability" earthquake (: 50% of design earthquake):
    - < 0.4% for brittle partitions
    - < 0.6% for non-brittle ones.



- The 1996 European Pre-standard (ENV) Eurocode 8 for seismic strengthening and repair of buildings.
  - Interstory drifts not checked.
  - Evaluation and/or retrofitting for full conformity to one of the 3 Ductility Classes of the 1994 ENV for new buildings, under a reduced seismic action depending on the remaining lifetime.

The 1994 ENV-Eurocode 8 led to the: 2004 EN-Eurocode 8 Part 1

- For new concrete, steel, composite (steel-concrete), timber, or masonry buildings.
- Force-based: ULS dimensioning of members for internal forces from linear analysis for 5%-damped elastic spectrum of "design earthquake" (10% / 50yrs), reduced by "*q*-factor".
- 3 Ductility Classes for buildings: prescribed "*q*-factors" with associated (prescriptive) member detailing rules for ductility.
- In the upper two Ductility Classes: "Capacity design" across the board (of the foundation too).
- Interstory drifts under 50% of design earthquake (still via "equal displacement rule", but with 50% of uncracked section stiffness):
    - < 0.5% for brittle partitions,
    - < 0.75% for non-brittle ones,
    - < 1% for a bare structural system.


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1998-1

December 2004

ICS 91.120.25

Supersedes ENV 1998-1-1:1994, ENV 1998-1-2:1994, ENV 1998-1-3:1995

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

This European Standard was approved by CEN on 23 April 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 1998-1:2004: E

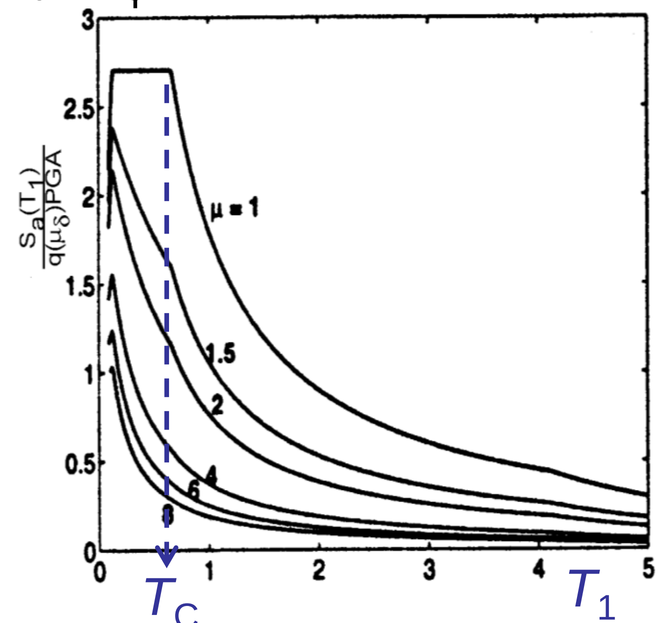
Performance-based seismic design of new buildings per 2004 EN-Eurocode 8

- Two-(and-a-half)tier design:
  - ULS design of the structure (for ductility) for **Life Safety;** for ordinary buildings, under a rare (475 years) earthquake.
  - SLS verification of partitions for **Damage Limitation** under a frequent (~100 years) earthquake.
  - (implicit **Collapse Prevention** under a very strong/rare, but unspecified, earthquake by enforcing Capacity Design across the board).

Direct relationship between force reduction factor q & RC member detailing in EN-Eurocode 8

In Ductility Class "Medium" or "High": the force reduction factor q of 5%-damped elastic spectrum depends on the type, layout, regularity & redundancy of structural system in a continuous (still prescriptive) way:

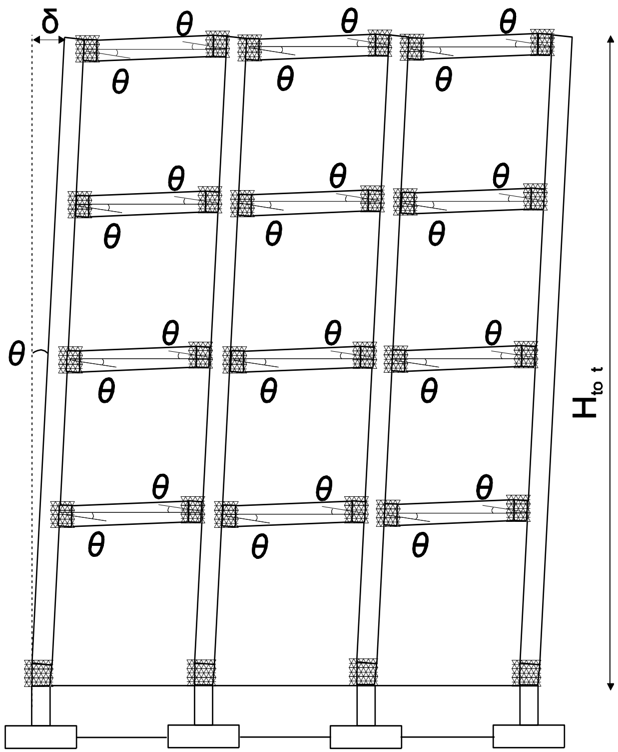
– The ductility factor, μ, underlying member detailing rules cannot assume discrete values:
  - One-to-one correspondence between q and displacement-, rotation-, curvature-ductility factors, μ_δ, μ_θ, μ_φ, for detailing:
    – ***Step 1*:**
    Correspondence between q & μ_δ
    Inelastic spectra of SDOF system
    (Vidic, Fajfar, Fischinger 1994):
      - If $T_1 \geq T_C$: $\boldsymbol{\mu_\delta = q}$
      - If $T_1 < T_C$: $\boldsymbol{\mu_\delta = 1+(q-1)T_C/T_1}$



Relationship: force reduction factor q & RC detailing in EN-Eurocode 8 *(cont'd)*:

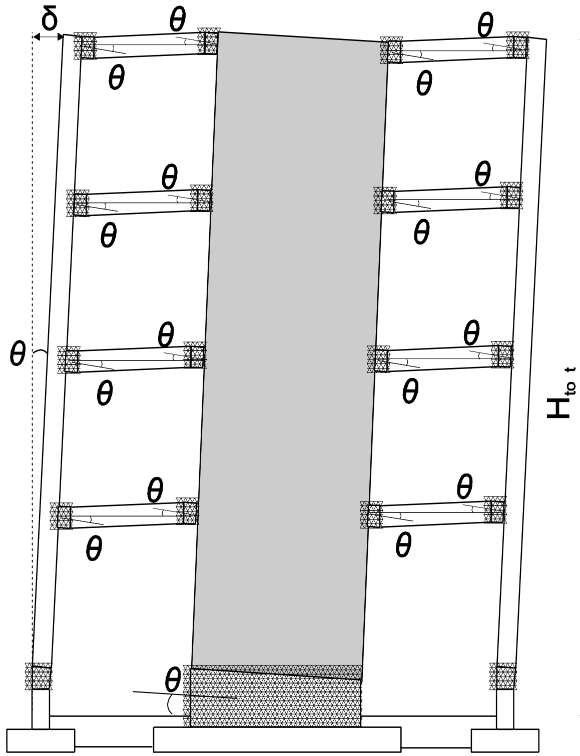
– *Step 2:* **Correspondence between μ_δ & μ_θ**

Ductility demands are uniformly spread throughout the plastic mechanism thanks to the building's stiff and strong vertical spine:



$$\theta = \delta / H_{tot}$$

$$\mu_\theta = \mu_\delta$$



Strong-column/weak-beam capacity design: $\sum M_{Rc} \geq 1.3 \sum M_{Rb}$

Walls take ≥ 50% of seismic base shear

Relationship: force-reduction factor q & RC detailing in EN-Eurocode 8 *(cont'd)*:

–*Step 3:* Correspondence: μ_θ, μ_φ and *q*-factor

$$\mu_\theta = 1 + (\mu_\varphi - 1)\frac{3L_{pl}}{L_s}\left(1 - \frac{L_{pl}}{2L_s}\right)$$

- L_s= *M*/*V* at end section,
- L_{pl} : plastic hinge length

Empirical expressions for L_{pl} in terms of L_s, etc (if confinement model in Eurocode 2 is used: ε^*_{cu}=0.0035+0.1$\alpha\omega_w$):

- in typical building columns L_{pl}: 0.35L_s to 0.45L_s,
- in typical building beams L_{pl}: 0.25L_s to 0.35L_s,
- in typical building walls L_{pl}: 0.18L_s to 0.24L_s,

Safe-side value: L_{pl}~ 0.185L_s → $\mu_\varphi = 2\mu_\theta - 1 = 2\mu_\delta - 1$ →

- **μ_φ = 2q_o-1** if $T_1 \geq T_C$
- **μ_φ = 1+2(q_o-1)T_C/T_1** if $T_1 < T_C$

q_o: *q*-factor unreduced for heightwise irregularity (times M_{Ed}/M_{Rd} at wall base).

Relationship: force-reduction factor q & RC detailing in EN-Eurocode 8 *(cont'd)*:

$\mu_\varphi \rightarrow$ detailing rule for beams

– ***Step 4(a):***

- $\mu_\varphi=\varphi_u/\varphi_y$
- in unspalled section (size h_c x b_c)
  - $\varphi_u=\varepsilon_{cu}/\xi_u h_c$,
  - ε_{cu}= 0.0035,
  - $\xi_u \sim (\omega_1-\omega_2)/(1-\varepsilon_{co}/3\varepsilon_{cu})$ (equilibrium)
- $\varphi_y=1.54\varepsilon_y/d_c$ in beams (fitted to hundreds of tests)
- With material safety factors (γ_c=1.5, γ_s=1.15) & round-off →

➢ Maximum mechanical ratio of **tension steel** at beam ends:

$$\omega_1 - \omega_2 \leq 0.0018/\mu_\varphi \varepsilon_{yd}$$

(provides safety factor of ~2; → margin against $\mu_\theta \sim 2\mu_\delta$ at the lower stories)

Relationship: force-reduction factor q & RC detailing in EN-Eurocode 8 *(cont'd)*:

–Step 4(b): $\mu_\varphi \rightarrow$ detailing of columns & walls

- $\mu_\varphi=\varphi_u/\varphi_y$
- confined core (size h_o x b_o, index*: normalization to confined core)
  - $\varphi_u=\varepsilon^*_{cu}/\xi^*_u h_o$,
  - $\varepsilon^*_{cu}=0.0035+0.1\alpha\omega_w$
  - $\xi_u^* \sim (\nu^*_d+\omega^*_\nu+\omega^*_1-\omega^*_2)/(1-\varepsilon_{co}/3\varepsilon^*_{cu})f_c/f_c^* (h_c b_c)/(h_o b_o)$
- $\varphi_y=1.75\varepsilon_y/h_c$ in columns (fitted to thousands of tests),
- $\varphi_y=1.44\varepsilon_y/h_c$ in walls (fitted to hundreds of tests)
- With material safety factors (γ_c=1.5, γ_s=1.15) & round-off →

➤ Minimum effective mechanical ratio of confinement steel in plastic hinge of a column or wall with $\omega_1=\omega_2$:

$$\alpha\omega_{wd} \geq 30\mu_\varphi(\nu_d+\omega_{\nu d})\varepsilon_{yd}b_c/b_o-0.035$$

(gives safety factor >2.5; → margin for $\mu_\theta \sim 2\mu_\delta$ at lower stories).

The 2005 Part 3 of EN-Eurocode 8: Assessment & Retrofitting of buildings

- The 2005 European Standard (EN) for seismic assessment/retrofitting of buildings broke completely with:
  - the past (the 1996 ENV-Eurocode 8 on strengthening and repair of buildings), and
  - the concurrent present (the 2004 EN-Eurocode 8 on design of new buildings).

  and developed independently into a full-fledged:
  - **performance-based** and
  - **displacement-based**

  seismic standard:
  - the only one of the 58 Eurocodes about existing structures;
  - the first standard in Europe on seismic assessment & retrofitting.

Explicit Performance-based assessment & retrofitting in Part 3 of Eurocode 8 (2005)

- Up to three-tier seismic assessment/retrofitting:
  - Limit States (Performance Levels):
    - **“Damage Limitation” (: Immediate Occupancy)**
    - **“Significant Damage” (: Life Safety)**
    - **“Near Collapse”.**
  - Flexibility for country/owner/designer to choose how many and which Limit States to meet and under what Hazard Level.
  - A note mentions as objectives for ordinary new buildings:
    - Damage Limitation: Occasional earthquake (225 yrs???)
    - Significant Damage: Rare earthquake (475 yrs)
    - Near Collapse: Very rare earthquake (2500 yrs)

Displacement-based Seismic Engineering

- Seismic design/assessment/retrofitting based on displacements and their derivatives (: deformations).
  - The earthquake imposes displacements, not forces;
  - The forces due to imposed displacements are not controlled by the earthquake, but by the force resistance of members.
  - Structures collapse in earthquakes because of the horizontal displacements, which produce 2^{nd}-order moments due to gravity.
- **Force-based** seismic design still survives, because:
  - of strong tradition and familiarity with force-based design for force-controlled loadings (gravity and wind);
  - equilibrium provides a solid basis for force estimation.
- In the **displacement-based** paradigm:
  - Ductile modes of behavior (i.e., in flexure) are checked in terms of deformations;
  - Brittle modes of behavior (shear) checked in terms of forces;
  - Aim of the analysis: to estimate the (inelastic) seismic deformation demands (shears can be found via equilibrium).

Analysis for displacement-based assessment & retrofitting in EN-Eurocode 8-Part 3 (2005)

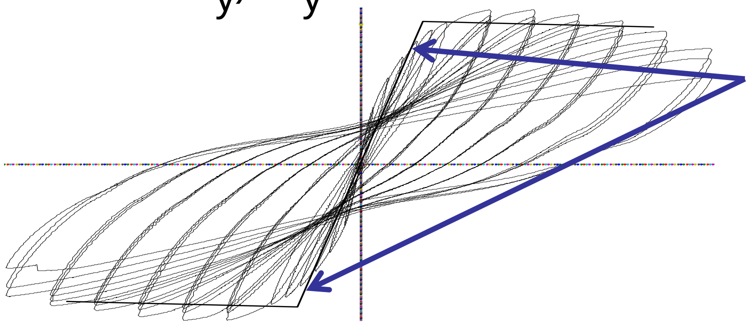
- Analysis to estimate peak seismic deformation demands:
  - Reference method (always applicable):
    - **Nonlinear** analysis (pushover, time-history)
    - For pushover analysis: N2-method with target displacement from inelastic spectrum in Vidic, Fajfar & Fischinger (1994) (: equal displacement rule, corrected at short-periods only).
    - Simple nonlinear models encouraged for members
    - More important than model sophistication: **member secant-to-yield-point stiffness**, to capture the dominant periods.
  - If ~uniformly spread over the structure inelastic deformations:
    - May be estimated by **linear** analysis with the **5%-damped elastic spectrum without reduction by *q***;
    - Lateral force method may replace modal response spectrum analysis as in new buildings: heightwise regular, insignificant higher mode response (rare, if stiffness values are realistic).

Linear analysis for estimation of inelastic seismic deformations in EN-Eurocode 8-Part 3 (2005)

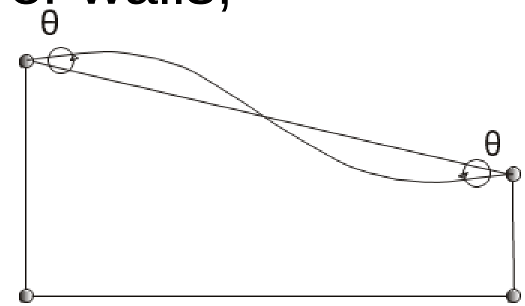
- Criterion for ~uniform distribution of inelasticity under seismic action (hazard level) of interest:
  - M_E/M_R: Elastic moment from the analysis to resisting moment at a member end (~member chord-rotation ductility ratio).
  - Linear analysis applicable if:
    - Ratio of maximum-to-minimum-M_E/M_R over all ductile member ends that go inelastic (ends of stronger elements framing into joint excluded) < limit between 2 and 3 (recommended: 2.5).
  - Criterion fairly restrictive: linear analysis permitted only if:
    - ~uniform distribution of overstrength throughout building, or
    - max chord-rotation ductility ratio < limit value of 2 to 3.
- Force demands from equilibrium with member end moments:
  - which are taken equal to moment resistance (cf capacity design);
  - or are estimated from the inelastic rotation at a member end via the applicable moment-rotation law.

Effective elastic stiffness, *EI*, for linear or nonlinear analysis in Eurocode 8-Part 3

- *For displacement-based assessment per Eurocode 8-Part 3:*
  - Secant stiffness at yielding of the end of the shear span $L_s = M/V$
  - $L_s \sim L_{cl}/2$ for beams/columns, $\sim H_w/2$ in cantilever walls,
  - M_y, θ_y: moment & chord rotation at yielding.



$$EI = M_y L_s / 3\theta_y$$

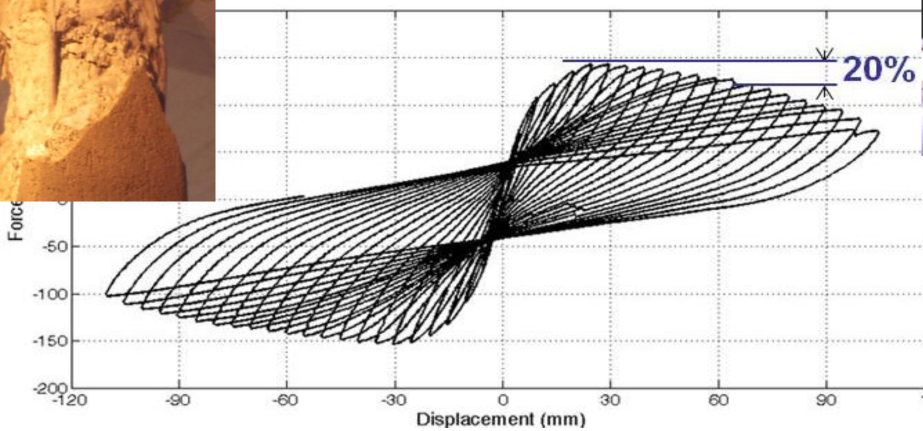


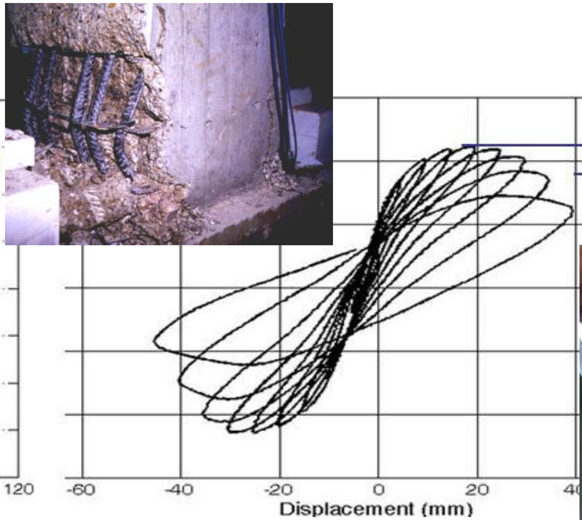
Chord rotation, θ: angle between normal to end section & chord connecting member ends at displaced position.

- *Note: in EN-Eurocode 8-Part 1 for the design of new buildings:*
  - *EI* (secant-to-yield-point)= 50% of uncracked section stiffness;
    - overestimates by ~2 realistic secant-to-yield-point stiffness;
    - safe-sided in force-based design (overestimates the forces);
    - unsafe in displacement-based evaluation (underestimates displacement demands).

ULS verification of inelastic flexural deformations

For seismic loading, material failure at the local level (even loss of a bar) is not by itself member failure. A plastic hinge fails owing to local material failures gradually accumulating during cycling of deformations, until it loses ~20% of its moment resistance





- Deformation measures used in the verifications should reflect the behaviour of the plastic hinge as a whole:
  - **Global safety factor** for the ULS verification of a plastic hinge.
- Appropriate deformation measure for plastic hinge: the **plastic part of chord rotation at a member end, $\boldsymbol{\theta_{pl}}$** (= plastic hinge rotation at member end, plus post-yield part of fixed-end-rotation, θ_{slip}, due to slippage of longitudinal bars from anchorage past the member end).

RC member verification in EN-Eurocode 8 Part 3

	Limit State (LS):	Damage Limitation	Significant Damage	Near Collapse
in flexure	primary member	$\theta_E \le \theta_y$	$\theta_E \le 0.75\theta_{u,m-\sigma}$	$\theta_E \le \theta_{u,m-\sigma}$
	secondary member		$\theta_E \le 0.75\theta_{um}$	$\theta_E \le \theta_{um}$
in shear	primary member	$V_E \le V_{Rd,EC8}/1.15$		
	secondary member	$V_E \le V_{Rm,EC8}$		

θ_E, V_E: chord-rotation and shear force demands

θ_y: chord-rotation at yielding; θ_{um}: mean value of ultimate chord rotation;

$\theta_{u,m-\sigma}$: mean-minus-sigma ult. chord rotation = $\theta_{um}/1.5$, or = $\theta_y+\theta^{pl}_{um}/1.8$;

V_{Rd}, V_{Rm}: shear resistance, design or mean value;

$V_{R,EC8}$: shear resistance of plastic hinge in cyclic loading after yielding.

Models for θ_y, θ_{um}, $V_{R,EC8}$ given in Part 3 of Eurocode 8 for:

- members detailed for ductility or not; and
- members retrofitted with RC-jackets, FRP or steel jackets.

Critique of EN-Eurocode 8: Strengths & Weaknesses

Strengths

- Part of a comprehensive, integrated, user-friendly set of State-of-the-Art standards, serving the largest/most populous economic entity of the developed world (considered as world leader in excellence, tradition & achievements in structural engineering).
- Concerning design of new buildings: Most rational approach among current seismic codes
- Flexibility:
  - ❑ Range of analysis methods, from equivalent static to nonlinear time-history analysis, with modal analysis as the reference;
  - ❑ Alternative options for strength v. ductility (Ductility Classes);
  - ❑ Besides force-based design: displacement-based design allowed, with calculation of deformation demands via nonlinear analysis & direct verification against deformation capacities;
  - ❑ Through Nationally Determined Parameters (NDPs): countries choose the level of safety & economy provided by EC8 designs.

Weaknesses

- Voids:
  - Supplemental energy dissipation in buildings;
  - Flat-slab frames;
  - Prestressed primary members, etc.
- Seismic Hazard description: Obsolete.
  - Standard shape of spectrum per soil type;
  - Spectrum scaled linearly to single hazard parameter: PGA;
  - Discontinuities across national borders.
- (General drawback of all Eurocodes):

  Advanced, complex, demanding;
  - suits better specialized structural designers & fairly large design offices, than individuals working on a range of topics or types of projects.

Towards the 2nd Generation of EN-Eurocode 8 (2015-19)

General objectives

- Reduce number of Nationally Determined Parameters.
- Enhance “Ease of use” by:
  - Improving clarity;
  - Simplifying routes through the Eurocodes;
  - Limiting, where possible, alternative application rules;
  - Avoiding/removing rules of little practical use in design;
  - etc.
- Voids in scope: To be filled.
- Consolidation; short, succinct text.
- Stability for users: **Evolution, not Revolution**!

Overarching idea: Ease-of-Use

Principles (in decreasing importance; **most impact on EC8**):

1. Improve clarity/understandability of technical provisions;
2. Improve accessibility to technical provisions and ease of navigation between them;
3. Improve consistency within and between Eurocodes;
4. **Include State-of-the-Art material based on commonly accepted research results & validated by practical experience**
5. **No fundamental changes to design approach in 1st generation EN-Eurocodes & in document structure;**
6. Clear guidance for all common design cases;
7. **Limit coverage of special cases, very rarely encountered by designers, to only general and basic technical provisions;**
8. **Expert practitioners free to work from first principles & innovate;**
9. **Limit alternative application rules for the same situation.**
10. **Simplified methods only if a) of general application & for common situations, b) technically justified and safe-sided.**
11. Improve consistency with standards for products or execution;
12. **Avoid rules sensitive to execution tolerances unfeasible in situ.**

Implications of Ease-of-Use principles for EC8

- *"Include State-of-the-Art material, based on commonly accepted research results, validated through sufficient practical experience;*
- *No fundamental changes to design approach in 1st-generation EC8;*
- *Limit coverage of special & rare cases to general/basic technical provisions;*
- *Freedom of expert practitioners to work from first principles and innovate;*
- *Limit alternative application rules for the same situation.*
- *Simplified methods only if of general application in common situations, technically justified & safe-sided.*
- *No rules sensitive to execution tolerances unfeasible in situ.→*

▪ Limit range of alternatives (e.g., 3 Ductility Classes per main construction material, several analysis methods, two types of RC walls of DC M, etc)??

▪ New provisions only where EC8 has important gaps due to poor knowledge at the time of its writing, where common structural systems or technological solutions are not treated, or where parts are incomplete and cannot be applied without adding new provisions??

▪ Reduce length of current text to make room for new rules/enlarged scope.

▪ Revisit simplified design rules (eg, those for simple masonry buildings)?

▪ Re-evaluate difficult to construct detailing (Ductility Class High)?

▪ Room for new technologies, innovative concepts, etc (peer review)?

Scope of "Evolution" to 2nd-generation EN-Eurocodes

- National comments submitted in the framework of the "Systematic Review" (already submitted for Parts 1 & 3 of Eurocode 8):
  - Consider;
  - Adopt or reject;
  - Reply/justify.
- Specific issues identified by competent Sub-Committee (eg, SC8 for EC8) in response to the European Commission's Mandate M515 and included in the final mandate to CEN:
  - Elaborate;
  - Revise Eurocode accordingly.
- Reduction of NDPs.
- Improvement of Ease-of-Use.

Specific EN-EC8 “evolution” program in Mandate

1. **Phase 1 (2015-19):** General or material-independent parts of EN1998-1
   - European seismic hazard
   - Displacement-based design of buildings
   - Base isolation & Energy dissipation in buildings
2. **Phase 2 (2016-19):** Material-related parts of EN1998-1 (new buildings)
   - Flat slab RC frames
   - Steel buildings
   - Timber buildings
   - Masonry buildings
   - Infilled frames and claddings
   - Aluminium structures
3. **Phase 1 (2015-19):** EN1998-3 (Assessment & retrofitting of existing structures)
   - Buildings (all materials); Advances in S-o-A & ease of use: major overhaul.
   - Bridges: Totally new part for bridges.
4. **Phase 2 (2016-19):** EN1998-5 (Geotechnical & Foundations)
   - Soil-structure interaction for deep or shallow foundations. Piles.
5. **Phase 3 (2017-20):** EN1998-4 & EN1998-6 (Silos, tanks, pipelines, towers, masts & chimneys).
6. **Phase 3 (2017-20):** EN 1998-2 (Bridges)
   - Base isolation, additional damping, new technologies.

Same performance levels (limit states) in all EC8 parts

1. "Operational"

Practically no structural/non-structural damage; facility serves its original intention with little disruption of use, intact lifelines or back-up systems, **and**

Any repair, if needed, can take place in future, without disruption of normal use

2. "Immediate Use" or "Damage Limitation"

Interruption of normal use carried out safely and is temporary; **and**

Structure very lightly damaged; no residual drift or structural deformation; **and**

Risk to life negligible; **and**

Structure retains its earlier strength, stiffness & ability to withstand loading, **and**

Any damage to non-structural components is easily/economically repaired later.

3. "Life Safety" or "Significant Damage"

Structure significantly damaged but does not collapse (not even partly); **or**

Structure doesn't provide sufficient safety for normal use, only for temporary, **or**

Secondary or non-structural components seriously damaged, without, though, obstructing emergency use or causing life-threatening injuries; **or**

Structure on the verge of losing capacity, but retains sufficient load bearing capacity, residual strength & stiffness to protect life till repair is completed; **or**

Repair economically questionable - demolition may be preferable.

4. "Near-Collapse"

Structure heavily damaged, at the verge of collapse; **or**

Most non-structural components have collapsed; **or**

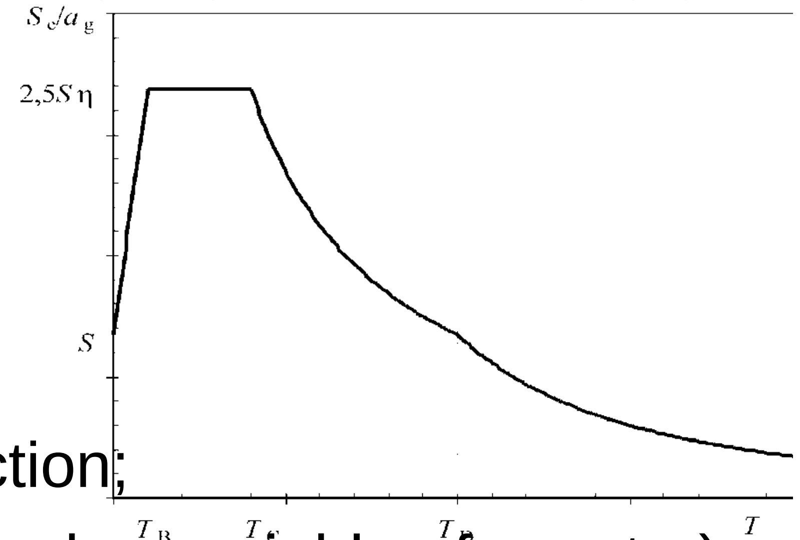
Life safety mostly ensured but not guaranteed during the event (falling debris); **or**

Structure unsafe even for emergency; it may not survive additional loading; **or**

Little residual strength & stiffness, but quasi-permanent loads supported.

Material-Independent Sections in EN1998-1

1. Harmonized Seismic Hazard

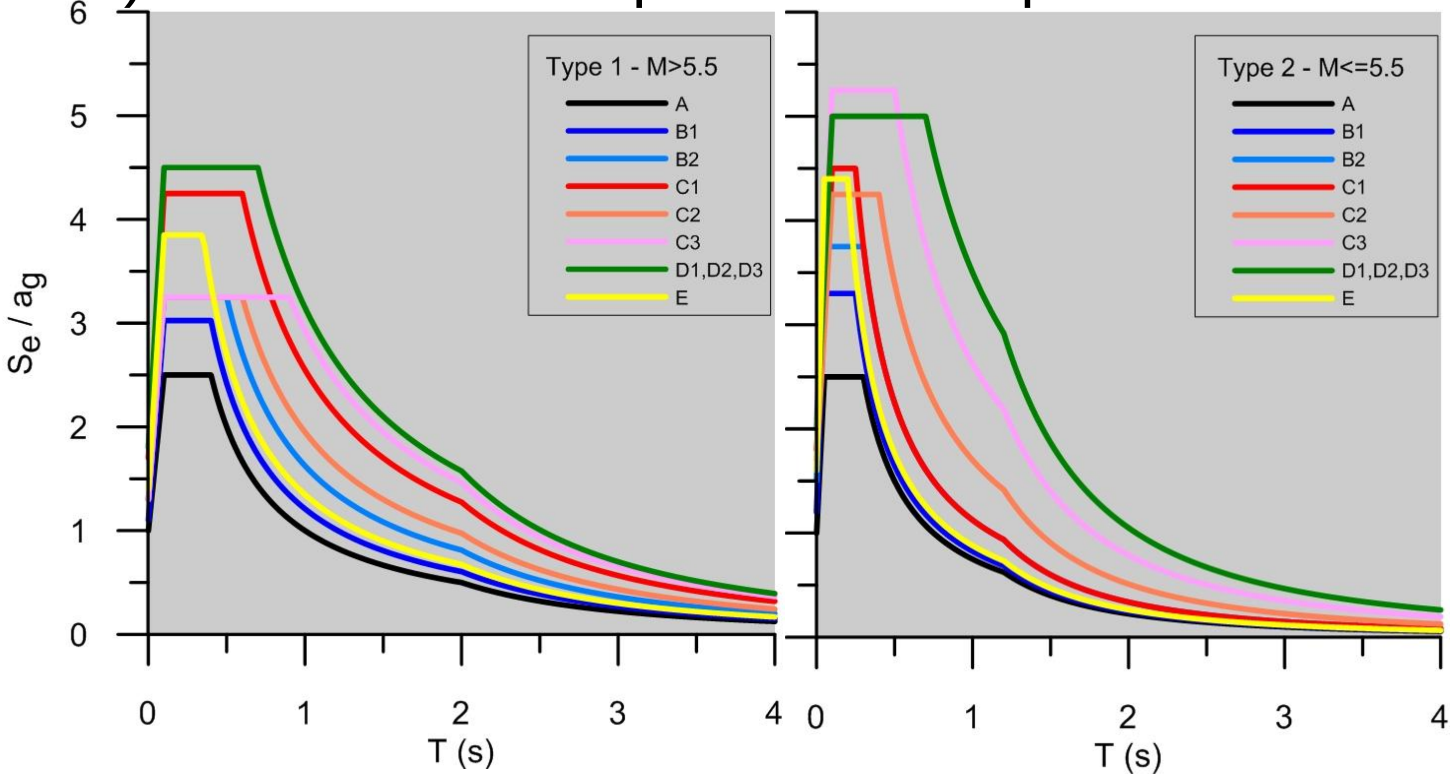


- EN 1998-1:2004:
  - Five “standard” soil types:
    Fixed
  - Return period of design seismic action;
  - Zonation maps for PGA on rock (anchor variable of spectra);
  - Exact spectral shape for each “standard” soil type:
    Nationally Determined Parameters (NDPs).
- 2nd generation EN 1998-1:
  - Return periods of seismic action (all performance levels): Nationally Determined Parameters (NDPs), but:
  - Uniform hazard spectrum on rock (or PGA & PGV & PGD, or $S_{a,1}$ & $S_{a,s}$) from online portals (eg 2013 European Seismic Hazard Model (ESHM2013) www.efehr.org)

Material-Independent Sections in EN1998-1 *(cont'd)*

2. "Standard" soil types & spectral shapes

- EN 1998-1:2004:
  - ➢ Five "standard" soil types: Fixed
- 2nd generation EN 1998-1:
  - ➢ Proposed: refined (sub-)classification of soil types (8 in lieu of 5) with different amplification of spectral values by the soil:



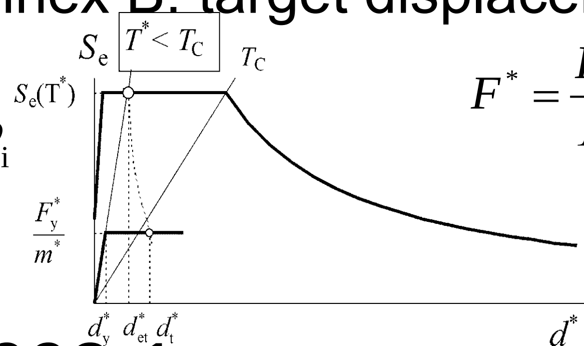
Material-Independent Sections in EN1998-1 *(cont'd)*

<u>3. Displacement based designs of new buildings</u>

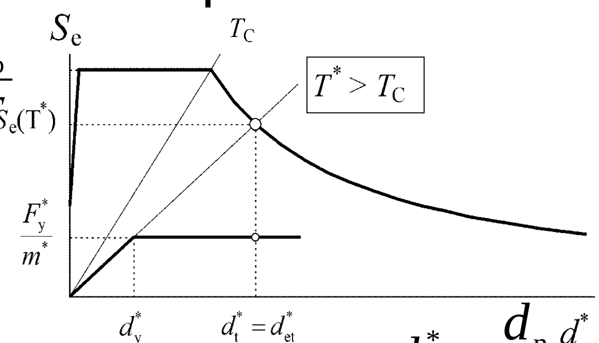
- EN1998-1:2004:
  - Foresees/allows Displacement-based design using nonlinear static (pushover) analysis; but
  - Safety checks in terms of deformations not fully presented.
  - "Supply":deformation capacity of elements/structures not included.
  - "Demand": Inform. Annex B: target displacement for pushover analysis

$$m^* = \sum m_i \Phi_i$$

$$\Gamma = \frac{m^*}{\sum m_i \Phi_i^2}$$



$$F^* = \frac{F_b}{\Gamma}$$



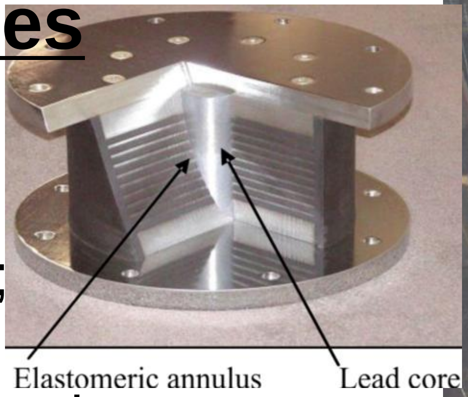
$$d^* = \frac{d_n}{\Gamma}$$

- 2nd generation EN1998-1:
  - Force-based methods with q-factor: still the reference;
  - Annex B on nonlinear static analysis updated/revised for practice.
  - Information on deformation capacity of structural elements in EN 1998-3 (existing buildings) will be considered/updated/included.
  - Profit will be taken from the checking criteria for the yielding and ultimate deformation of structural members in EN1998-3: 2005.

Material-Independent Sections in EN1998-1 *(cont'd)*

3. Base isolation, additional damping, new technologies

- EN1998-1:2004:
  - Considers only full isolation (:superstructure stays elastic);
  - Does not cover passive energy dissipation systems not arranged on a single interface, but distributed over several stories or levels.
- 2nd generation EN1998-1:
  - To encompass partial isolation (:inelasticity in superstructure) and distributed damping;
  - To liaise with the CEN Committee for the antiseismic devices product standard (EN15129) to remove inconsistencies and eliminate confusing overlaps.



Material-Dependent Sections in EN1998-1

1a. Concrete buildings: Ductility Classes

- EN1998-1:2004:
  - Three Ductility Classes (DC):
    - DC Low (L):
      - Design with q = 1.5 & ductile steel, using Eurocode 2 alone;
      - Recommended only for low seismicity - PGA on rock ≤ 0.08g
    - DC Medium (M) & High (H):
      - Use ~6 > q > 1.5, capacity design & detailing for local ductility;
      - DC M & H differ in degree, not substance with few exceptions:
        - explicit check of sliding shear in walls & short beams;
        - explicit verification of beam-column joints;
        - explicit calculation of inelastic shears in walls
- 2nd generation EN1998-1:
  - DC L+ (add some rules for ductility) for use in low & moderate seismicity;
  - Reconsider usefulness of DC H in Europe; possibly merge DC M and H into a DC M+.

Material-Dependent Sections in EN1998-1 *(cont'd)*

1b. RC buildings: Flat slab frames

- EN1998-1:2004:
  - Flat slab systems not covered:
    - Columns supporting flat slabs can only be considered as "secondary elements":
      - Their lateral stiffness ignored; must be < 15% of that of the lateral-load-resisting system;
      - Stay elastic under imposed lateral drifts (: ~designed with q=1/1.15)
- 2nd generation EN1998-1:
  - Design rules for flat slab frames:
    - Modeling of slab in seismic analysis;
    - Design & detailing of column-slab connection for cyclic bending & punching.

Material-Dependent Sections in EN1998-1 *(cont'd)*

2. Steel and Composite (steel-concrete) buildings

- EN1998-1:2004:
  - The European Convention for Constructional Steel Works (ECCS) prepared report "Assessment of EC8 Provisions for Seismic Design of Steel Structures": issues regarding EN 1998-1 which require clarification or further development.
- 2nd generation EN1998-1:
  - Evaluate ECCS's proposals to improve and update EN 1998-1, bringing it up to date with the more recent advances in seismic design of steel & composite buildings.

3. Aluminium structures

- EN1998-1:2004:
  - Not covered:
- 2nd generation EN1998-1:
  - Add Section for Aluminium buildings or extend Section 6 (Steel buildings) to encompass them also.

Material-Dependent Sections in EN1998-1 *(cont'd)*

4. Timber buildings

- EN1998-1:2004:
  - ➢Out-of-date concerning timber buildings.
- 2nd generation EN1998-1:
  - ➢Extend; bring up to date with advances in design & technology, eg:
    - Re-evaluate building typologies & values of behavior factor;
    - Capacity Design - overstrength factors of ductile connections;
    - Interstory drift limits for performance-based design;
    - New wood-based materials: cross-laminated panels (xlam), oriented strand boards (OSB) & new types of fasteners;
    - Timber shear walls & horizontal diaphragms;
    - Mixed lateral load resisting systems (eg timber with RC cores or steel bracings).

5. Masonry buildings

- EN1998-1:2004:
  - Provisions for masonry buildings disputable or out-of-date :
    - Values of behavior factor questioned;
    - Rules for "simple masonry buildings" disputed as inconsistent with experience from earthquakes;
    - Too many Nationally Determined Parameters (NDPs).

- 2nd generation EN1998-1:
  - Bring up-to-date with State-of-the-Art in seismic design of masonry buildings, (accounting for the large variability of masonry units & construction practice across Europe).

Material-Dependent Sections in EN1998-1 *(cont'd)*

6. Infilled frames and claddings

- EN1998-1:2004:
  - Rules to avoid any adverse effects of masonry infills on lateral-load-resisting system.
  - Damage Limitation under 40-50% of design earthquake via interstory drift limits:
    - 0.5% for brittle partitions;
    - 0.75% for "ductile" (?) ones.

- 2nd generation EN1998-1:
  - Account for beneficial effects of infills (over-strength, energy dissipation); consider impact on design & quality assurance in construction.
  - Cover cladding elements & panels & other types of enclosures (out-of-plane collapse?).
  - Modeling & design checks for infills & claddings with or without openings (strength, stiffness, deformation capacity, connection to the structure).

EN 1998-3 “Seismic retrofitting of structures”

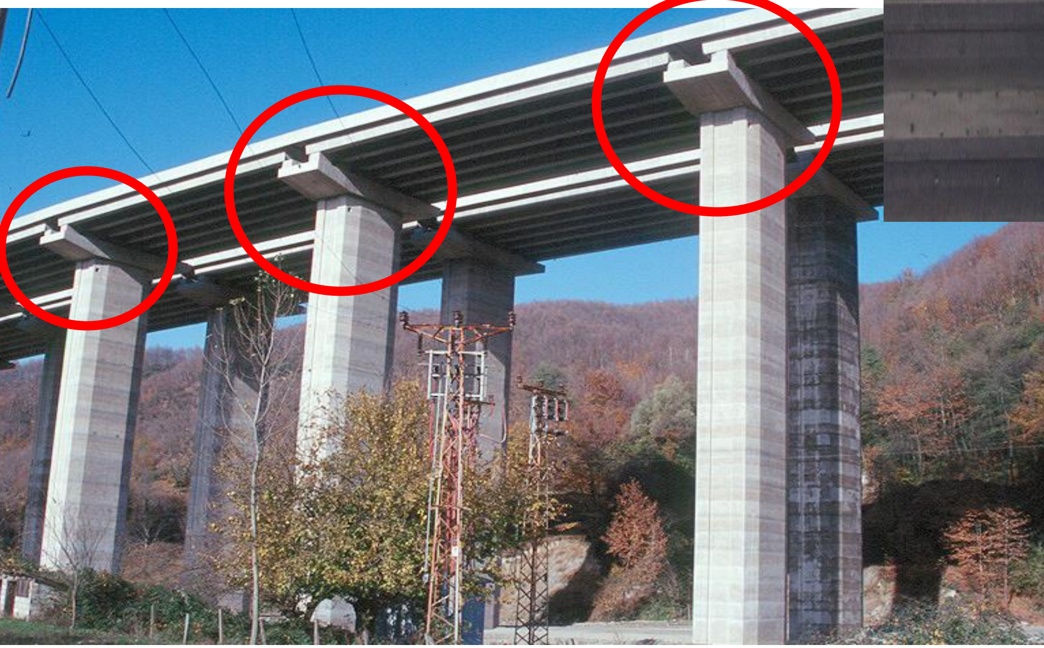
1. Buildings

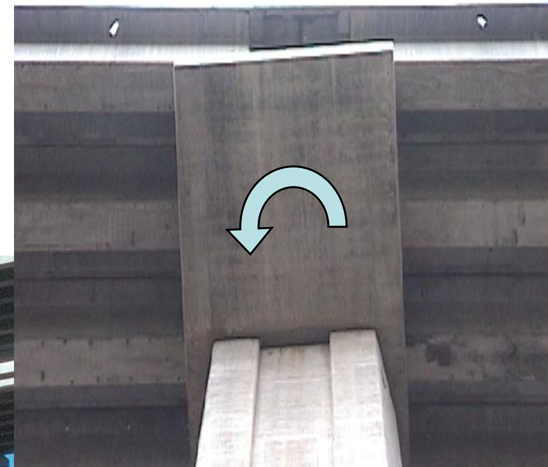
- EN1998-3:2005:
  - Normative Part: Short, contains only material-independent rules;
  - Inform. Annexes A, B, C: for concrete, steel, masonry buildings
  - Criticisms:
    - It addresses concrete buildings; masonry ones poorly covered;
    - “Confidence factor” (function of “Knowledge Level”) modifying mean material properties: poor representation of uncertainties;
    - Performance requirements expressed for the structure as a whole, but compliance criteria refer to members only;
    - Non-structural elements not addressed;
    - Shear failure of concrete & masonry elements needs revisiting.
- 2^{nd} generation EN1998-1:
  - Revisit “Confidence factors” and reliability format;
  - Develop criteria for ultimate condition of the structural system;
  - Drastically strengthen/improve provisions for masonry buildings;
  - Advance/update nonlinear (static) analysis, as reference method.

EN 1998-3 Seismic retrofitting of structures *(cont'd)*

2. Bridges

- EN1998-3:2005:
  - Not covered.





- 2nd generation EN1998-1:
  - Cover seismic assessment & retrofitting of:
    - concrete & steel/composite bridges;
    - bridge foundations and bearings.
  - Seismic isolation or dissipation devices: means for retrofitting.

Teşekkür ederim!