EC8 Webinars
Second Generation of Eurocode 8

Overview of Part 3 and its main changes

Andreas Kappos
Member of SC8 Management Group
Former SC8-3 Leader

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The current code: EN 1998-3:2005 Eurocode 8 - Design of structures for earthquake resistance - Part 3: Assessment and retrofitting of buildings

Contents **Page**

Comments on current Eurocode 8 – Part 3

- Intended to be performance-based and displacement-based
- 'Flexibility' to accommodate the large variety of situations arising in practice, and in different countries
  - arguably major advantage, also major weakness!..
- Logically structured, *but* (on drafters' own admission, see Pinto 2011) missing the support from extended use
  - improvements to be expected from practical application (…)
- Normative part covering only material-independent concepts and rules; verification formulae are in *non-mandatory* Informative Annexes
- Very limited application, mainly in academic studies
  - national codes like the Greek CSI or the corresponding Italian Assessment Code have enjoyed much more extensive application

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1998-3

June 2005

ICS 91.120.25

Supersedes ENV 1998-1-4:1996
Incorporating corrigendum March 2010

English version

Eurocode 8: Design of structures for earthquake resistance -
Part 3: Assessment and retrofitting of buildings

Eurocode 8: Calcul des structures pour leur résistance aux séismes - Partie 3: Evaluation et renforcement des bâtiments

Eurocode 8: Auslegung von Bauwerken gegen Erdbeben - Teil 3: Beurteilung und Ertüchtigung von Gebäuden

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

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

Ref. No. EN 1998-3:2005: E

Structure of new EN1998-3 Assessment and retrofitting of structures

CEN/TC 250/SC 8 **N 1236**

CEN/TC 250/SC 8 "Eurocode 8: Earthquake resistance design of structures"
Secretariat: **IPQ**
Secretary: **Correia António Mr**

prEN_1998-3_2022_ENQ

1. Scope
2. Normative references
3. Terms, definitions, and symbols
4. Basis of design
5. Information for structural assessment
6. Modelling, structural analysis and verification
7. Design of structural intervention → from merging of 'old' 5 and 6
8. Specific rules for reinforced concrete structures
9. Specific rules for steel and composite structures
10. Specific rules for timber structures
11. Specific rules for masonry structures
12. Specific rules for bridges

(8–12) New clauses

Annex A: Preliminary analysis

Annex B: Supplementary information for concrete structures

Annex C: Supplementary information for timber structures

Annex D: Supplementary information for masonry structures

Annex E: Flowcharts for the application of this standard

(all annexes are informative)

CEN/TC 250

Date: 2022-11

prEN 1998-3:2022

Secretariat: BSI

Eurocode 8 — Design of structures for earthquake resistance — Part 3: Assessment and retrofitting of buildings and bridges

Einführendes Element — Haupt-Element — Ergänzendes Element

Élément introductif — Élément central — Élément complémentaire

ICS:

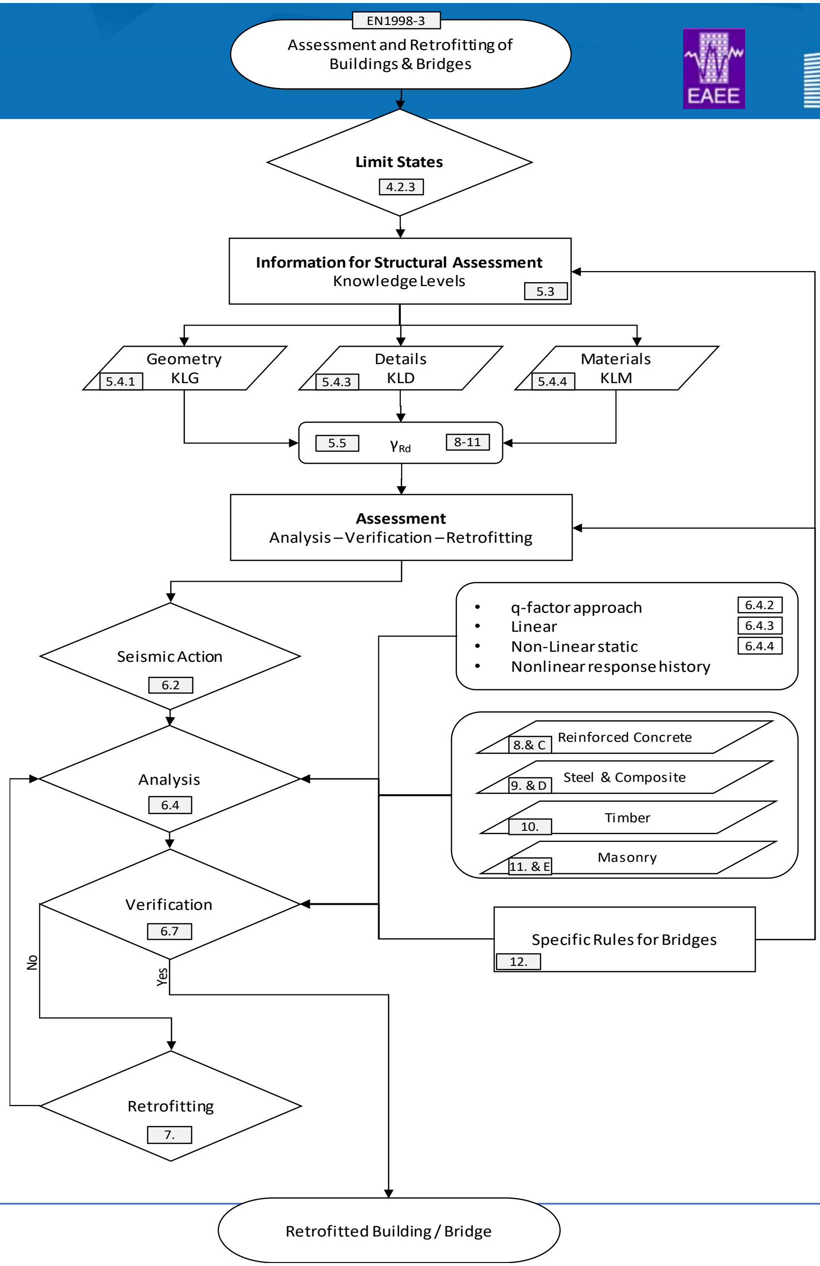
EC8-3 drafters - Composition of PT3 and allocation of work

Name	Primary Chapter(s)	Secondary Chapter(s)
Kappos, Andreas	1, 7	11
Chrysostomou, Christis	8	6
Franchin, Paolo	4, 5	6, 12
Isaković, Tatjana	6	8
Lagomarsino, Sergio	11	4, 5
Panagiotakos, Telemachos	12	8

- SC8 chairman (P. Bisch) also regularly attended PT3 meetings and contributed to PT3 work
- Work on Part 3 continues until today within the Management Group; main contributors A. Kappos, P. Bisch, D. Lignos (Steel), WG3 (Timber)

Outline of the assessment and retrofit procedure according to EC8-3 (2022)

1. Scope
2. Normative references
3. Terms, definitions, and symbols
4. Basis of design
5. Information for structural assessment
6. Seismic action, methods of analysis and verification
7. Design of structural intervention
8. Specific rules for reinforced concrete structures
9. Specific rules for steel and composite structures
10. Specific rules for timber structures
11. Specific rules for masonry structures
12. Specific rules for bridges



Key changes in each chapter (clause)

Clauses **0 - 3**

- Scope extended to cover bridges
- Use by 'experienced personnel' only
  - ➢ need to clarify the definition of 'experienced'
- Terminology: instead of
  - ➢ capacity & demand

  use of:

  - ➢ resistance & action effects → Eurocode option!

    (but: displacement/deformation capacity/demand)
- Symbols still being harmonised among all Eurocodes

Clause 4 (Basis of design)

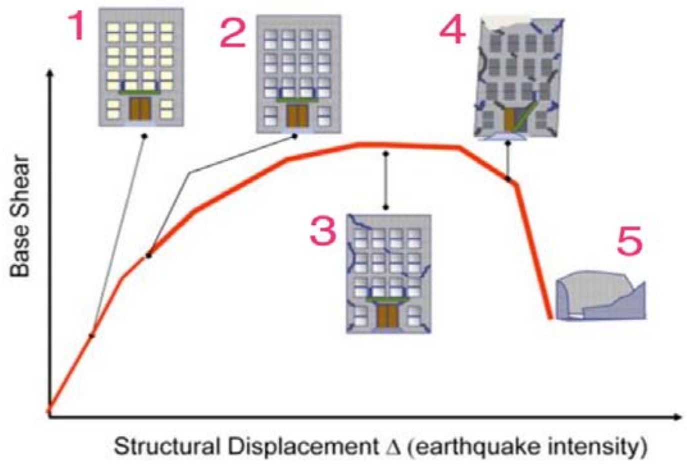
- Limit States:
  - Four LS (NC, SD, DL, OP) in lieu of the former three, harmonised with Part 1 ('Fully Operational' LS OP was added)
  - Verification for NC (as primary one) strongly encouraged

    NC: "When […] exceeded it should be always reported whether the loss of bearing capacity of an element has the potential to escalate into a global collapse or it is deemed to remain confined in a partial localised collapse […]"

    SD: If […] checked in lieu of the NC one, then the resistance for SD cannot exceed the resistance for NC divided by the ratio of the seismic action for the verification of NC to the seismic action for the verification of SD

- Seismic action for each LS defined in Part 1-1, by $T_{LS,CC}$ (period associated with certain LS, for given Consequence Class)
  - Note: **I**mportance **C**lasses (used in current EC8) have been replaced by the **C**onsequence **C**lasses of EN1990

Nomenclature of limit states (performance levels) in different normative documents (before 2015)



Document	1	2	3	4	5
EN1998-1	-	Damage limitation	Ultimate (No-collapse)	-	-
EN1998-2	-	Minimisation of damage	Ultimate (No-collapse)	-	-
EN1998-3	-	Damage Limitation	Significant damage	Near collapse	-
US	Fully operational	Operational	Life safety	Near collapse	Collapse
fib MC2010	Operational	Immediate use	Life safety	Near collapse	

PT3 background document for EC8-3, Dec. 2015

Cl. 4 (cont'd)

Qualification of consequence classes in EN-1990 (2020)

Consequence class	Indicative qualification of consequences	
	Loss of human life or personal injury[a]	Economic, social or environmental consequences[a]
CC4 – Highest	Extreme	Huge
CC3 – Higher	High	Very great
CC2 – Normal	Medium	Considerable
CC1 – Lower	Low	Small
CC0 – Lowest	Very low	Insignificant

[a] The consequence class is chosen based on the more severe of these two columns.

Subdivision of CC3 allowed, e.g. in EN-1998-1-2 (Buildings):

CC3-a	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.
CC3-b	Buildings of installations of vital importance for civil protection, e.g. hospitals, fire stations, etc. and their equipment.

Return periods (yrs) of seismic action for each LS in EN-1998-1-2 (2021)

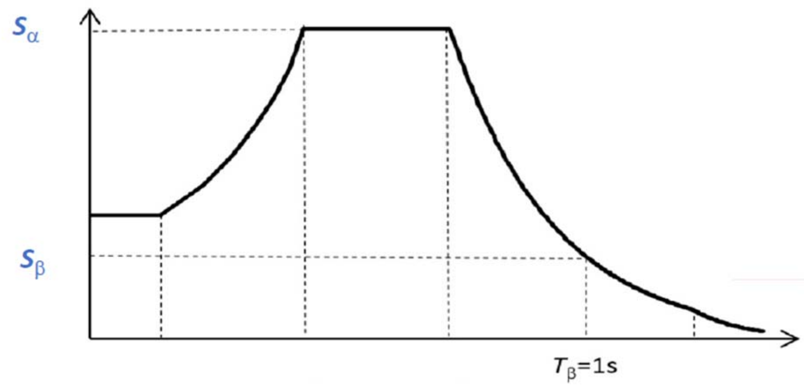
Limit state	Consequence class (CC)			
	CC1	**CC2**	CC3-a	CC3-b
NC	800	1600	2500	5000
SD	250	475	800	1600
DL	50	60	60	100

reference return period

Seismic action: $S_d = \delta\, F_a\, F_T\, S_{a,475}$

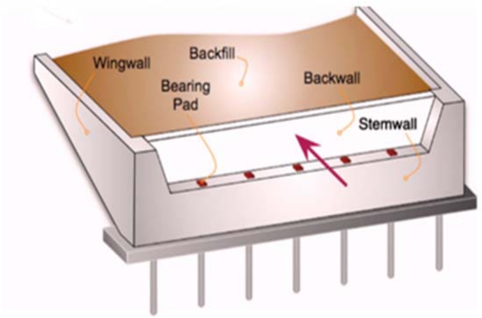
(F_a: site amplification factor; F_T: topography amplification factor)

	Consequence class (CC)			
	CC1	CC2	CC3-a	CC3-b
δ	0.60	1.0	1.25	1.60



Cl. 4 (cont'd)

- "Non-critical" elements added beside "secondary" elements of Part 1-1
  - Can be neglected in modelling and verification and be heavily damaged as long as they do not endanger primary elements and can be locally repaired (e.g. abutment backwalls, shear keys)



- Global verification added alongside conventional local, member-level, ones
  - Just an option, can be used only in conjunction with advanced nonlinear modelling (i.e. including strength deterioration)
  - Complemented by local verification for all non-simulated failure modes
  - Useful for masonry buildings, reflects current practice (in Southern Europe); also appropriate for RC/Steel frames with masonry infills when the latter dominate the behaviour

Clause **5** (Information for structural assessment)

- Knowledge Levels
  - New definitions, distinct KLs for Geometry, Details and Materials (KL**G**, KL**D**, KL**M**)
  - Need not to be unique over the entire structure
  - New % (p) of elements to be investigated, associated with each KL

$$p = p_1 - n^{-c} \leq 100$$

(*n*: total number of members of this type; p_1, c given in tables)

  - KLx1÷3 are now called: **M**inimum, **A**verage, **H**igh

Level of survey	Limited (L)	Extended (E)	Comprehensive (C)
p_1	200	250	300
c	0.8	0.6	0.5

Cl. 5 (cont'd)

- Preliminary analysis introduced (Annex A):
  - not mandatory, but encouraged: it allows focusing tests and inspections on specific areas
- Confidence factor abandoned!
  - safety factors for uncertainty in resistance (γ_{Rd}) depend on KL
- Mean values used for existing and added materials
  - may be different in different areas of the structure
  - for KLM 'L' mean values may be obtained from standards in force at the time of construction (reinforcing steel and timber), or from cl. 9 for steel and Annex D for masonry
  - recommended values for standard deviation given for each material
- Characteristic values may be used for new materials if a new structure is built to resist all seismic action effects (force-based approach)
  - in all other cases mean values are used: combination of new & existing materials, or new structure verified by displacement-based approach

Clause 6 (Modelling, structural analysis and verification)

- The structure of Chapter 6 has been modified to ensure ease of use and to harmonize the chapter with EN 1998 Part 1-1
- Focuses on differences in analysis of new and existing structures
- Structural modelling
  - mean values of material properties should be used
  - emphasis on nonlinear behaviour - envelopes of hysteretic curves should be defined based on the relevant material-related clauses (8 to 11)
- Force-based approach (q-factor method)

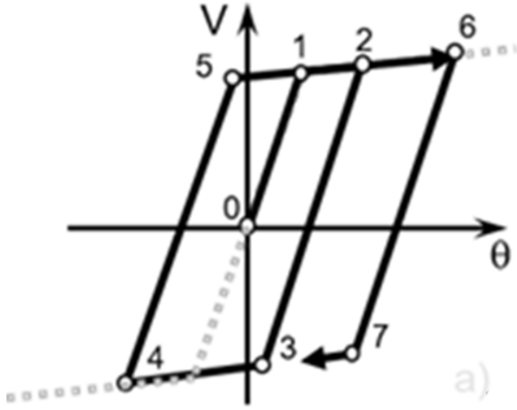
Conservative q should be used (due to non-uniform deformation demands, resulting from absence of capacity design)

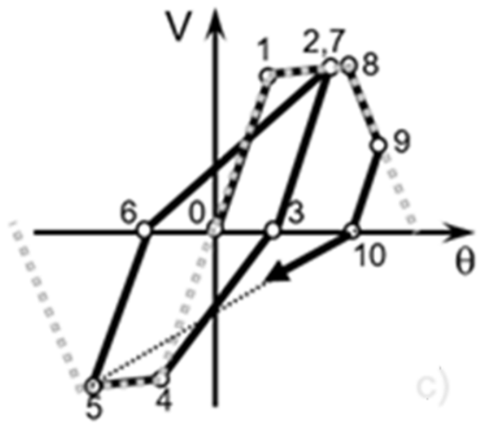
Prevailing material of the structure	q-factor
Reinforced concrete	1.5
Steel	2.0
Timber	1.5
Masonry	1.5

for the vertical component:
q_v = 1.5 for buildings
q_v = 1.0 for bridges

Cl. 6 (cont'd)

- Displacement-based approach
  - Linear elastic analysis: applicability based on ratio of action effect (demand) to resistance (capacity) $\rho_i = E_d / R_d$ at the critical zones (design values)
    - E_d is calculated from elastic response spectrum (q=1)
    - linear analysis allowed if maxρ_i/minρ_i < 2.5 (buildings) or <2 (bridges)
      - verifications are based on deformations (flexure), or forces (shear)
  - Nonlinear static analysis: As for new buildings (with 'modal' pattern), but:
    - if soft storey is expected, 'uniform' load pattern should also be used
    - if predominant mode mass <0.7M_{tot}, modal pattern should be replaced by triangular pattern or modal combination of load patterns from relevant modes
    - in buildings without rigid diaphragms (e.g. URM buildings), lateral load should be applied at the location of, and proportionally to, the masses of the model
  - Nonlinear response history analysis: As for new buildings (Part 1-1, §6.6)
- Verifications
  - NC verifications should be carried out in local or global terms; force-based approach should *only* be used in low seismic action class structures
  - Global verifications are based on nonlinear static analysis, using the resistance (pushover) curve and a strength drop criterion





Clause 7 (Design of structural intervention)

- Scope extended to cover bridges
- Detail was deliberately left out, to allow flexibility
  - the code should specify in detail how the (strengthened) structure is verified, not how the strengthening is made
  - → but principles are included!
- Option of reducing demand given (passive systems, treated only in Parts 1-1 and 1-2)
- Still not properly covered the case that all seismic action is carried by new lateral system (existing system: classified as secondary elements)

Steps in Retrofit Design:

- Conceptual design
- Analysis
- Verifications

- Will see in more detail later (lecture on Cl. 7)

Clause 8 (and Annex B) – R/C structures

- Resistance models for assessment (§8.4)
  - Beams, columns and walls under flexure with / without axial force:
    New physical and empirical models (with/without FRP wrapping) for the calculation of yield rotation, θ_y, and ultimate rotation, θ_u, for
    - concrete members with continuous ribbed bars
    - concrete members with ribbed longitudinal bars, lap-spliced at the end section
    - concrete columns with smooth bars lap-spliced at floor levels
    - Definition of ultimate strains (before and after spalling of the concrete cover, and before and after rupture of the FRP) for the calculation of ultimate curvature, ϕ_u, and definition of plastic hinge length, L_{pl} (with/without FRP wrapping)
    - Definition of minimum lap length
    - Definition of the plastic part of the ultimate chord rotation, θ_p, for the case of lap splicing
  - Beams, columns and walls under Shear (§8.4.3)
    - Sliding shear resistance at the base of a wall
    - Shear resistance of “squat” walls

Cl. 8 (cont'd)

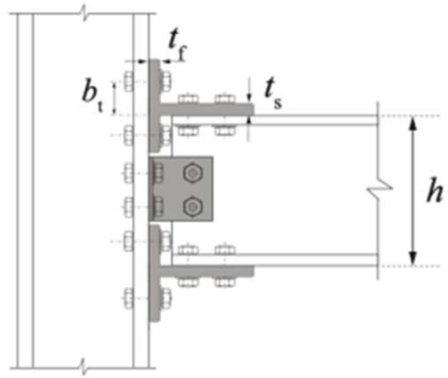
- Verification of limit states (§8.5)
  - New section for the verification of limit states (expanded to cover both 'existing' and strengthened members); e.g. $\theta_{NC} = \theta_u/\gamma_{Rd}$
- Resistance models for strengthening (§8.6)
  - Modified equations for R/C jacketed members
  - FRP plating and wrapping shear strength (§8.6.4.2)
    - New equations have been introduced

Annex B

- Prediction of ultimate chord rotation at the end of a column with section consisting of rectangular parts, without or with lap-splices and/or FRP
  - Equations for calculating less conservative estimates of ultimate chord rotation for members with smooth bars lap-spliced at floor levels

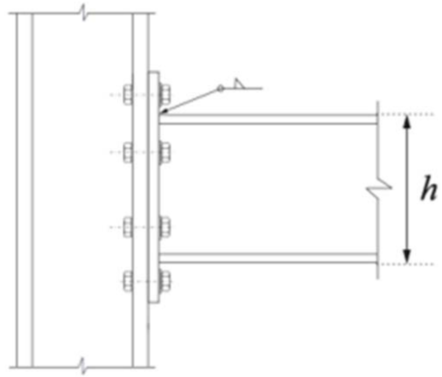
Clause 9 (Steel & composite structures)

- Developed after the end of the PT3 work, by TG5 of WG2 (primarily D. Lignos), revised by PT6 and SC8 Chair (Ph. Bisch)
- Structure same as reinforced concrete and other material-specific clauses, but no informative annex!..
- Overall, different, much more in line with current state of the art (on both sides of the Atlantic) than the existing (2005) chapter
- Not much detail on retrofit design…



T-stub joint

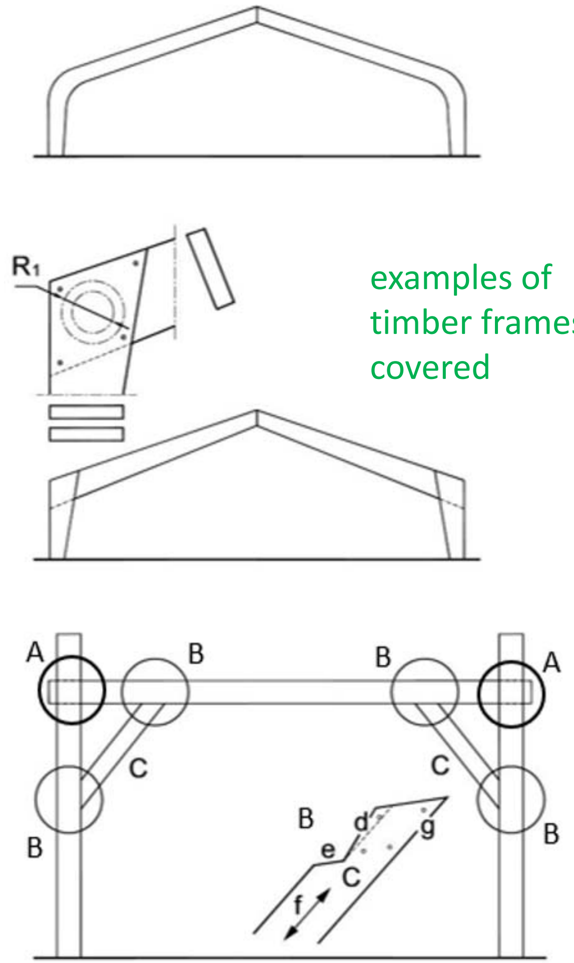
Strength and stiffness of steel members & connections



bolted end plate unstiffened joint

Clause **10** (Timber structures) and Annex C

- New clause, written by WG3, revised by Ph. Bisch
  - still work to be done on Annex C and to harmonise with new EC5
- Brand new material (timber not covered in current EN1998-3)
- Structure a bit different from that of other material-related clauses
  - emphasis on condition assessment ↔ ϕ factor
  - classification of timber structural elements (diaphragms, frames)
- Force-based elastic analysis is the preferred method
  - special emphasis on modelling of timber diaphragms
- Detailed resistance models for diaphragms, carpentry joints (accounting for the different failure modes) and dowel-type joints
- Verification based on either strength or drift criteria



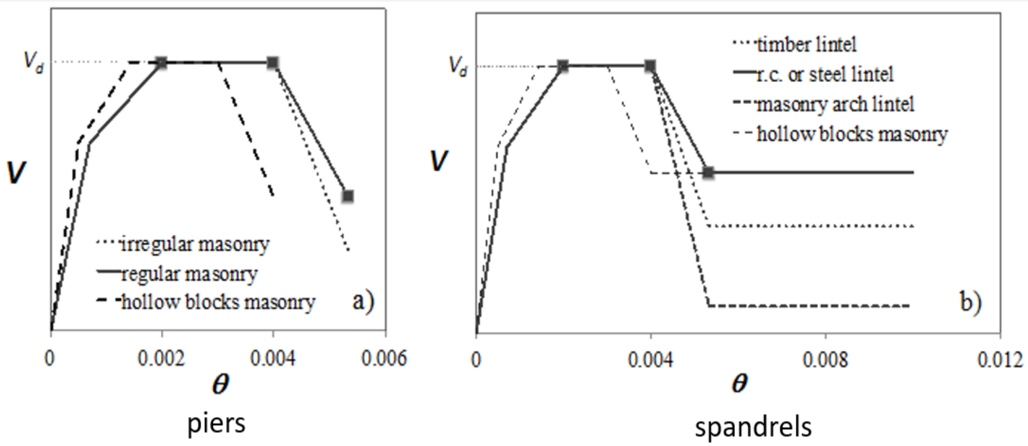
examples of timber frames covered

Clause **11** (and Annex D) – Masonry structures

- **Modelling** (§11.3):
  - Both in-plane and out-of-plane response of masonry walls are considered
  - In-plane behaviour of a masonry wall is modelled as equivalent frame (piers, spandrels)
  - Piece-wise linear force-deformation relations are adopted, with limited deformation
  - Horizontal diaphragms should be defined as rigid, stiff, or flexible
  - Global model is defined when diaphragms are rigid or stiff; in the case of flexible diaphragms each wall is analysed independently
  - Local out-of-plane mechanisms are considered using equilibrium limit analysis

- **Nonlinear static (pushover) analysis**

  Ultimate displacement capacity δ_u by checking global strength degradation
  - If horizontal diaphragms are not rigid, it is also to be checked that the NC limit state is not reached in all piers at the same level of any masonry wall considered relevant



Cl. 11 (cont'd)

- Resistance models for in-plane loaded masonry elements (§11.4.1)
  - Shear resistance of masonry elements (piers-spandrels) is the minimum among 3 possible alternative failure modes: flexure, shear sliding, diagonal cracking
  - Failure criteria are provided by considering the different behaviour of piers and spandrels
  - Masonry classification: i) regular masonry (arranged through horizontal layers and stair-stepped mortar joints); ii) irregular masonry
  - Drift limits are provided for all the above-mentioned cases, for damage levels of SD and NC

- Verification of local mechanisms (§11.4.2)
  - Out-of-plane failure of portions of masonry walls not well connected to orthogonal walls and horizontal diaphragms is modelled by a kinematic mechanism of rigid blocks
  - Limit analysis provides the peak ground (or peak floor) acceleration that activates the rocking behaviour (DL limit state) – application of the principle of virtual work
  - By considering the evolution of the mechanism (geometric nonlinearity), the pushover curve is obtained, and SD and NC limit states are defined
  - Safety verification is made in terms of displacements

Annex D

Cl. 11 (cont'd)

- Reference values for the material properties of masonry types
  - Median value and dispersion of mechanical parameters suggested for using in failure criteria
  - Corrective factors for considering quality of mortar, interlocking and transversal connection
  - Bayesian updating of the a-priori distribution by means of results from in-situ tests
  - Corrective factors for the effect of strengthening intervention

- Floor response spectra for the verification of local mechanisms
  - For verification of local mechanisms and of ancillary elements → method prescribed in Part 1-2, §7
  - for local out-of-plane mechanisms, the floor acceleration

$$S_{an,j} = \Gamma_1 \frac{Z_i}{H} S_e(T_1) \geq S_e(T_1)$$

Type of masonry		f [MPa]	f_t [MPa]	f_{v0} [MPa]	E [MPa]	G [MPa]	w [kN/m
Irregular stone masonry	mean	1,5	0,039	-	870	290	19
	c.o.v.	0,29	0,24	-	0,21	0,21	
Roughly cut stone masonry, with wythes of irregular thickness	mean	2,5	0,065	-	1230	410	20
	c.o.v.	0,20	0,19	-	0,17	0,17	
Uncut stonework with good texture	mean	3,2	0,097	-	1740	580	21
	c.o.v.	0,19	0,14	-	0,14	0,14	

Clause12 (Bridges)

Cl. 12 (cont'd)

- New section for bridges because the design of bridges is a separate part for all Eurocodes
- Bridges are particular structures, quite different from buildings, and require special consideration
  - more convenient for the user to have separate provisions for buildings and bridges regarding both assessment and retrofit
- The new section contains only those provisions that, in addition to other relevant sections or parts of Eurocodes, should be applied for the assessment and retrofitting of existing bridges
- Since the design of earthquake resistant bridges is covered by EN1998-2, same limitations also apply in the case of EN1998-3

- Intervention types for Bridges:

Type	Objective	Means
1	Durability	Local Repairs
2	Structural 'Non-seismic'	Various
3	Seismic Upgrading-1	Seismic Upgrading through **Seismic Isolation** (combined with additional Damping)
4	Seismic Upgrading-2	Seismic Upgrading through **Strengthening**
5	New Bridge	Replacement by a new bridge

EN1998-3 (Types 3 and 4)

New elements / Innovations:

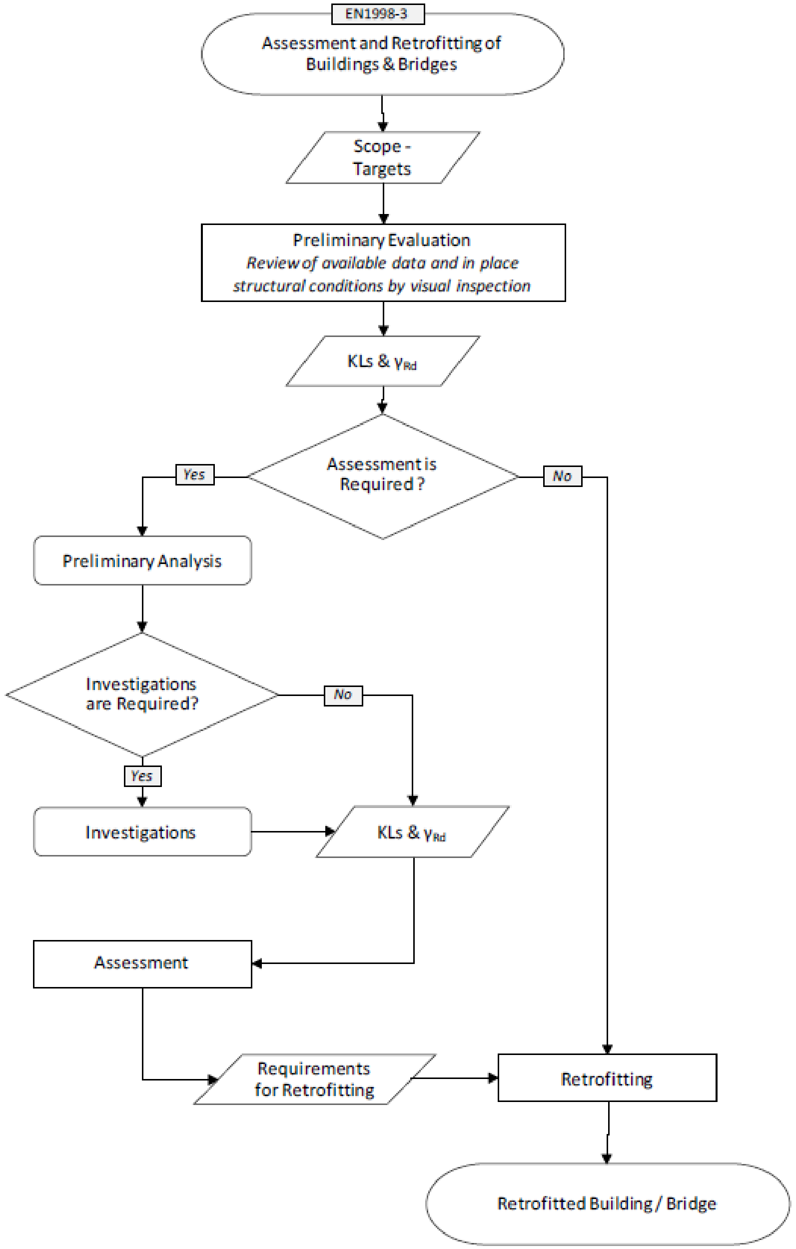
- Identification of five Bridge Components (with different Knowledge Level):
  - Deck, Piers, Foundation, Abutments, Bearings, Connections
- A general 3-step approach for Information for Structural Assessment:
  - Step 1: Collection of information and first inspection
  - Step 2: Simulated design (or reliable construction drawings)
  - Step 3: Detailed Survey and Investigation

- Different approach for:
  - Single-Span Framed or Box-type Bridges ↔ the main part of the seismic action comes from earth pressures acting on their abutments that are in contact with the embankment,

    the seismic design should be based on a *deformation compatibility approach* instead of limit equilibrium conditions (Mononobe-Okabe), or linear elastic solution for undeformable walls
  - Bridges with two or more spans
- The general procedure for the design of interventions defined in other chapters (for concrete & steel) is also applicable to bridges
- The strategy for the intervention on each bridge component is also defined

Treatment of NDPs in EN1998-3

Clause	Description	Relevant Note (or paragraph)
4.1 (2)	Limit States to be verified	The choice of the Limit States to be verified in a country for each type of existing structure may be found in the National Annex or may be elsewhere provided by the relevant Authorities. They can be different from those used for new structures. In the absence of such requirements, the choice of Limit States to be verified can be agreed for a specific project by the parties involved.
4.1(5)	Return periods or performance factors	The minimum values to be ascribed to $T_{LS,IC}$ or, alternatively, to $T_{LS,IC}$, for each type of existing structure, for use in a country, can be found in the National Annex or can be elsewhere provided by the relevant Authorities. They can be lower than those used for new structures. In the absence of such requirements, the choice of the corresponding value can be agreed for a specific project by the relevant parties.
4.2(8)	Value of k_2 to determine γ_{Rd} values	γ_{Rd} values corresponding to k_1 are given as appropriate in 8 to 11. Values of k_2 different from k_1 may be given in the National Annex.
4.2.3.5 (1)	Description of OP	For a specific project, the relevant parties can specify all non-structural components of interest in the verification, together with a description of relevant damage states for each component and the associated requirements.
5.4.4.(1)	Reference values for regional masonry types for KLM	In the case of masonry structures, direct testing may be avoided and reference values of predefined masonry types (if specified in the National Annex, otherwise consider Annex E).



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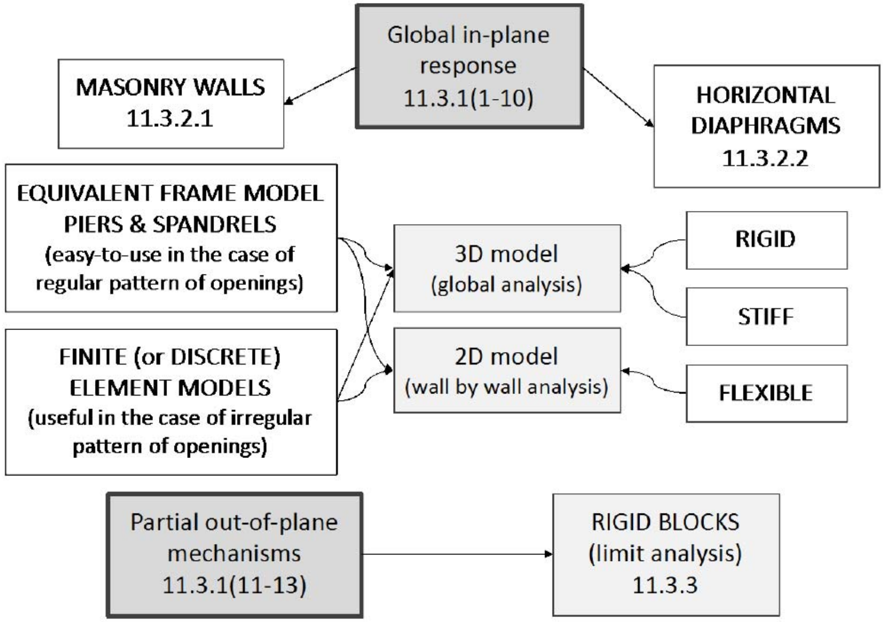
Annex **E: Flowcharts**



Thank you for your kind attention

A. Kappos Websites:

@ Khalifa University   Google Scholar   @ City University