EC8-2G

Il nuovo standard europeo per la progettazione sismica

EUCENTRE FOR YOUR SAFETY.

reluis

Materiali e tipologie costruttive

EN1998-1-2. Strutture metalliche e composte acciaio-cls

Raffaele Landolfo, Università degli Studi di Napoli Federico II

Pavia - 5 Giugno 2025

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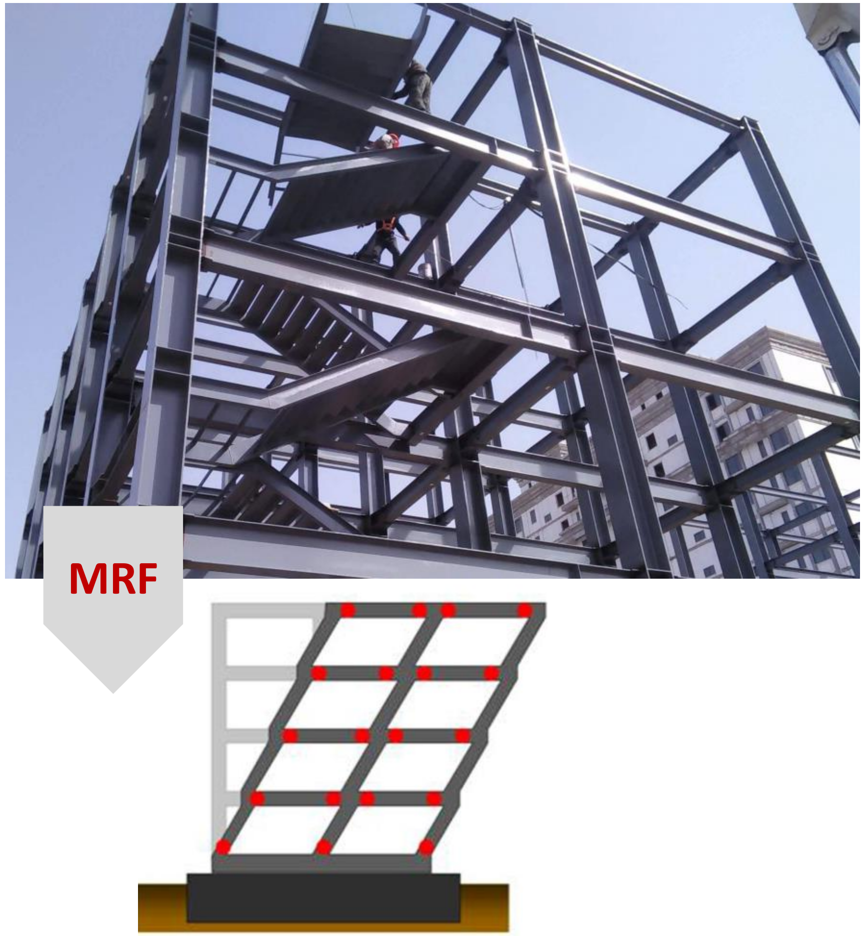
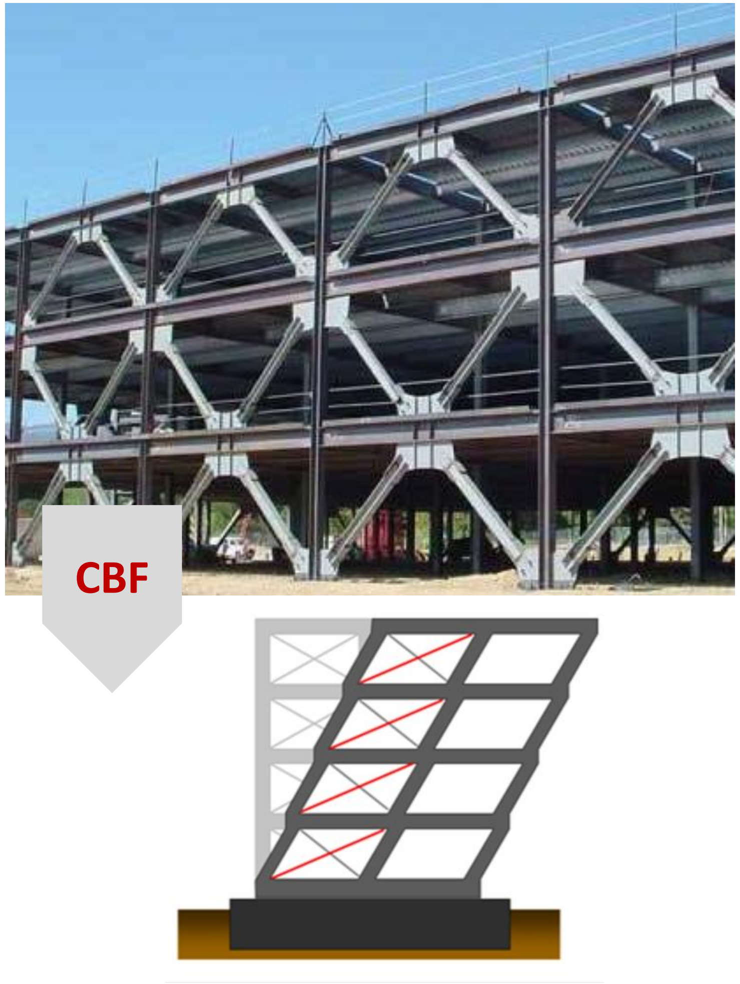
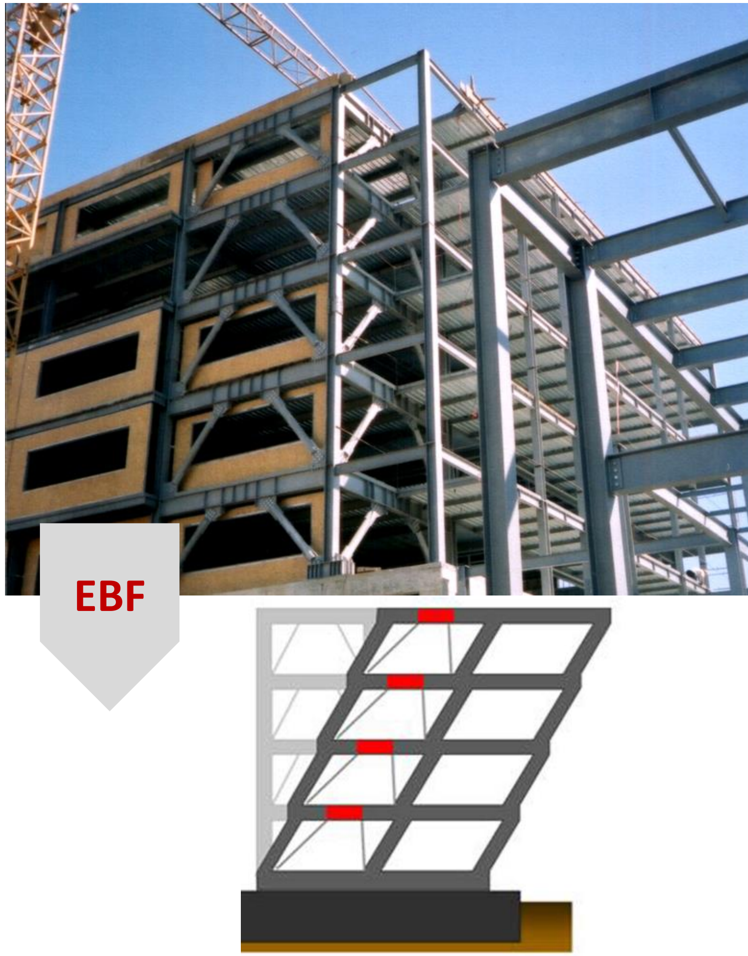
Introduction

Seismic-resistant steel structural typologies

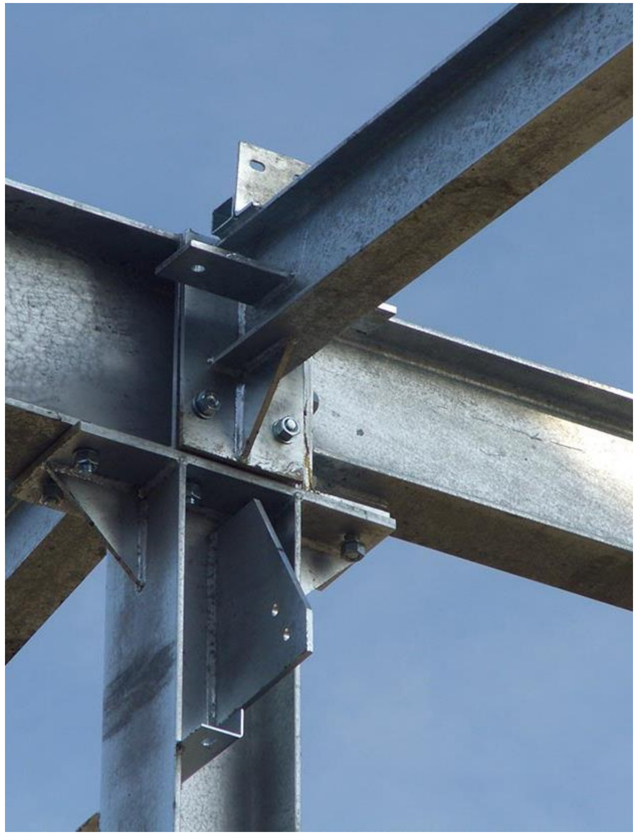






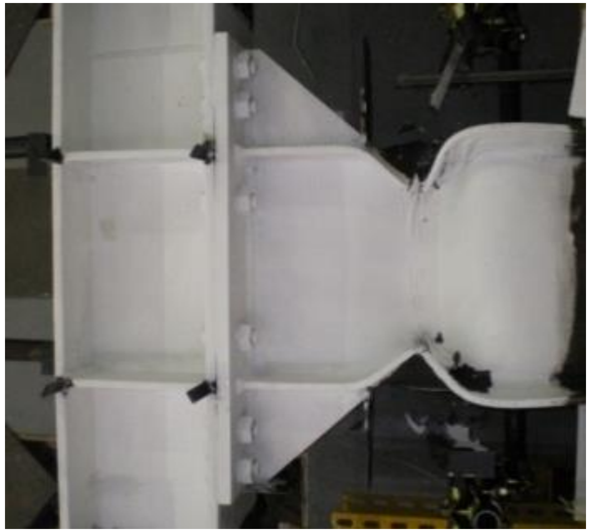
Introduction

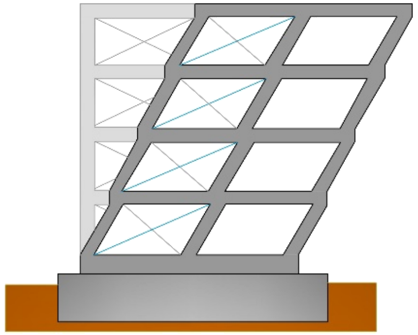
Steel connections

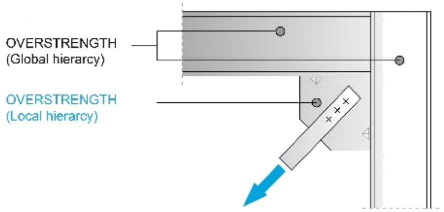


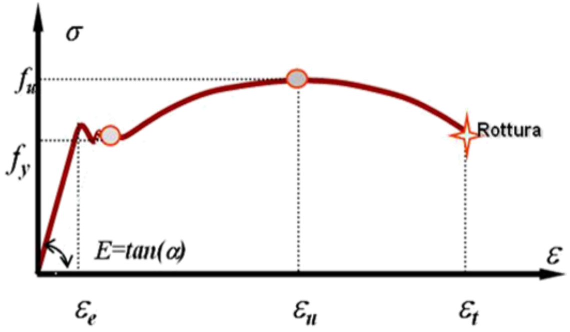
Introduction

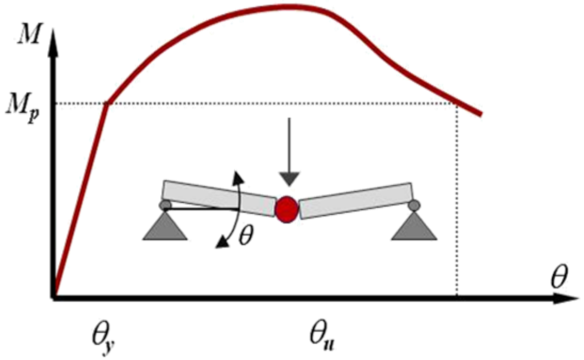
Benefits of steel in seismic design: *Ductility*

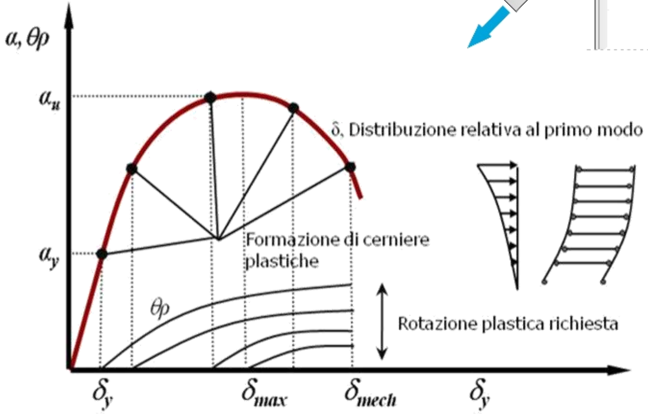










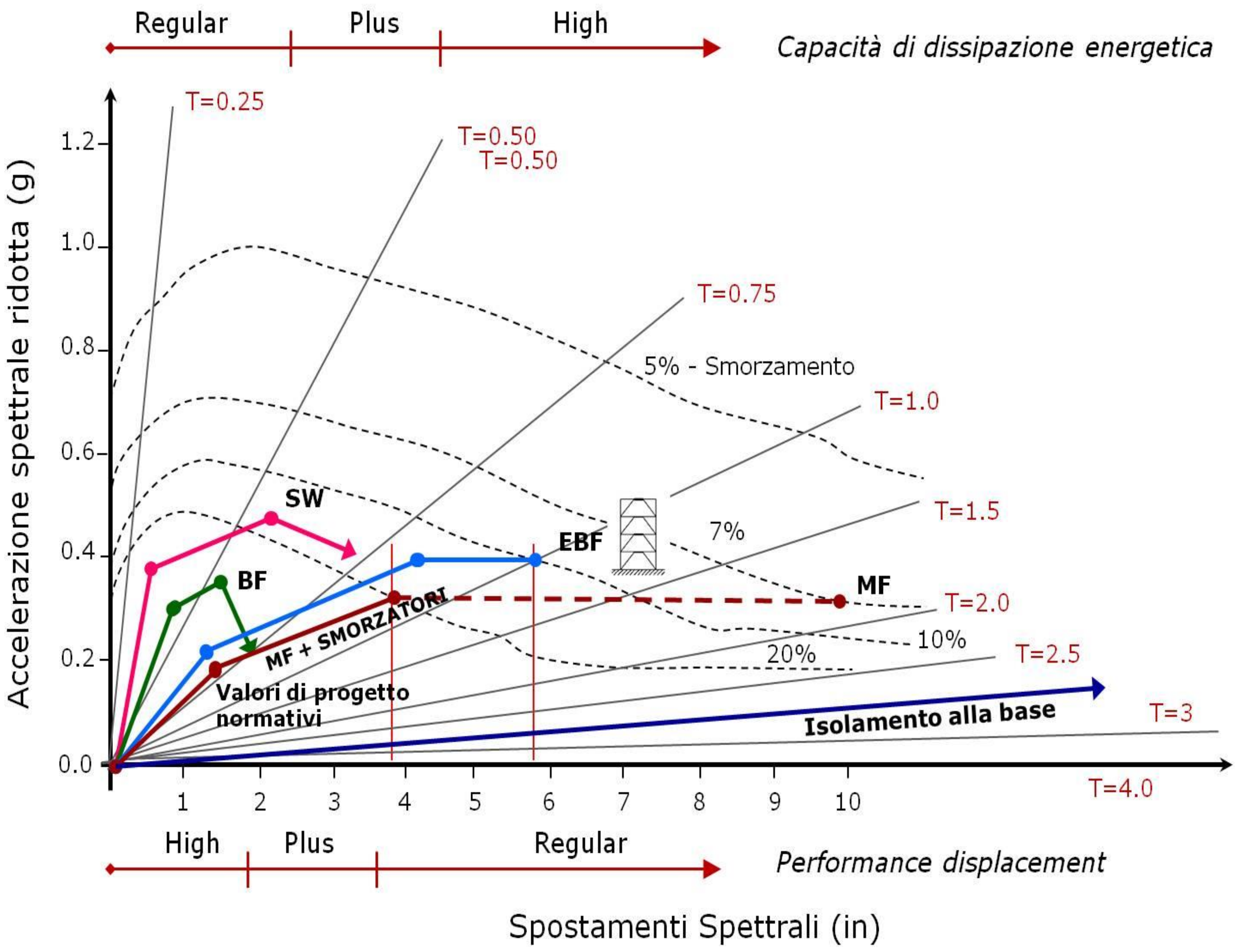


Material Ductility

Member Ductility

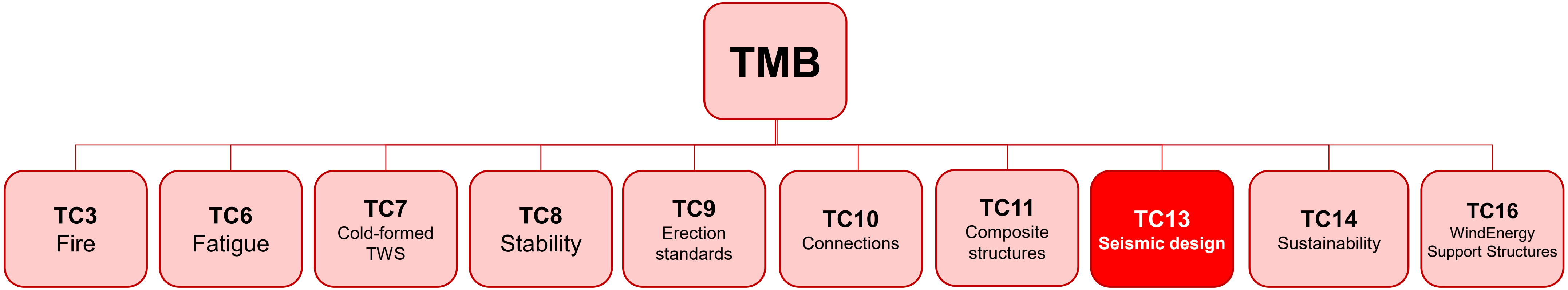
System Ductility

Seismic performance of steel structures in seismic areas



ECCS Technical Committes

- The expert forum that establishes **consensus on European practice** and provides the **undisputed background for normalization**;
- The expert forum that **identifies ongoing developments** in specific fields;
- The expert forum that **helps establishing priorities for R&DI**.



ECCS Technical Committees comprise over 200 experts

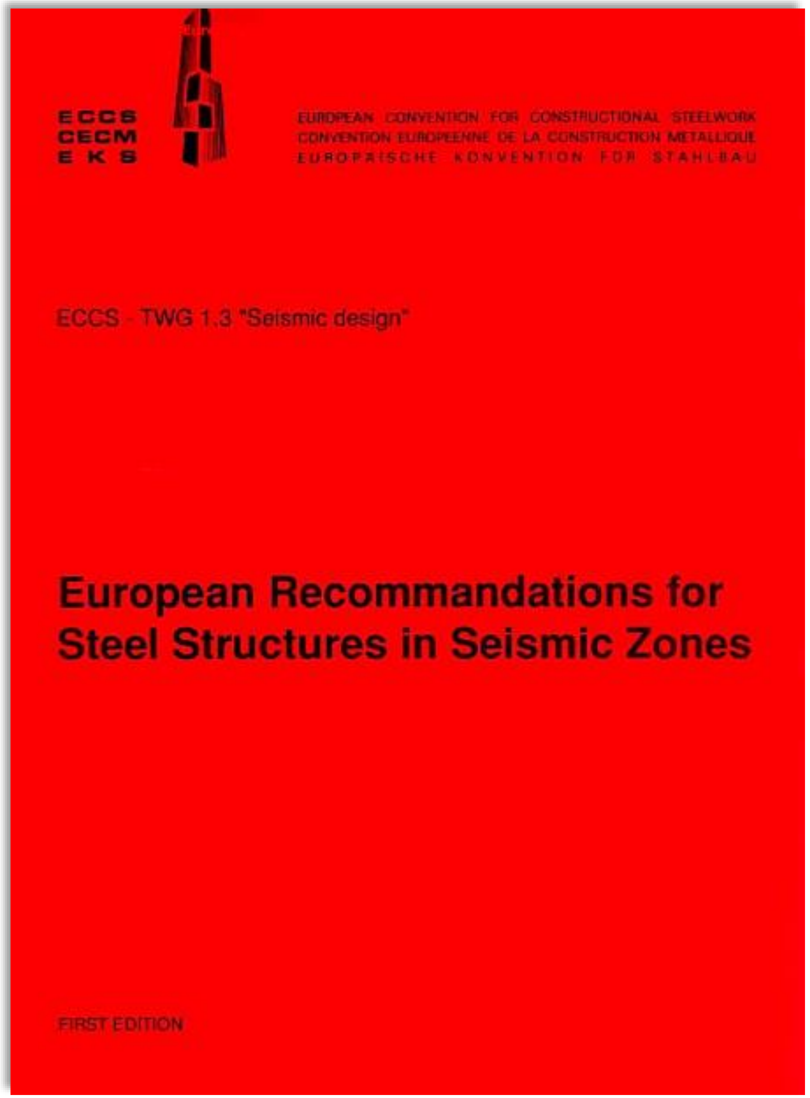
ECCS- TC13 Seismic Design Committee

Genesis of EU seismic codes

The development of seismic design provisions for steel structures is ongoing for over forty years in the framework of ECCS.

- First activities started in 1980’s

- First EU seismic code:
ECCS code 1991 “*European for Recommendations for Steel Structures in Seismic Zones*”.

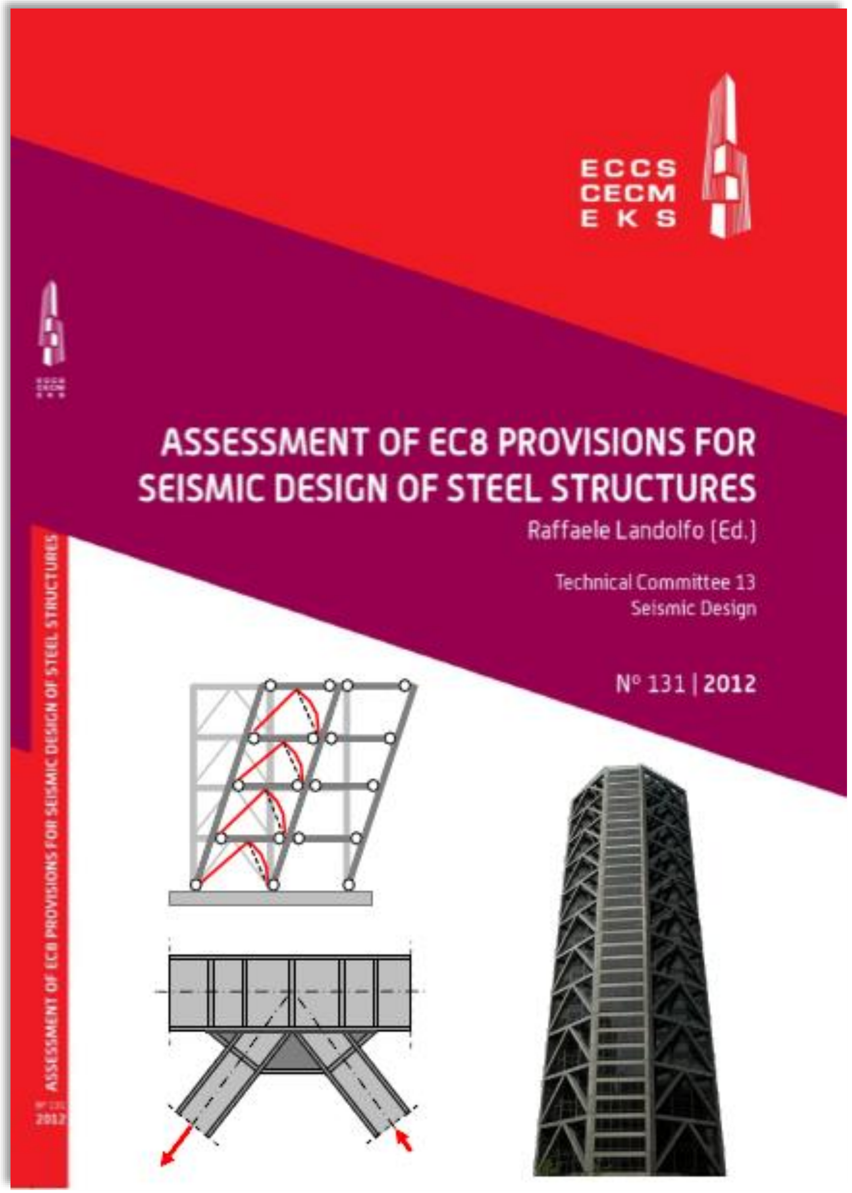


Introduction

The activity of TC13

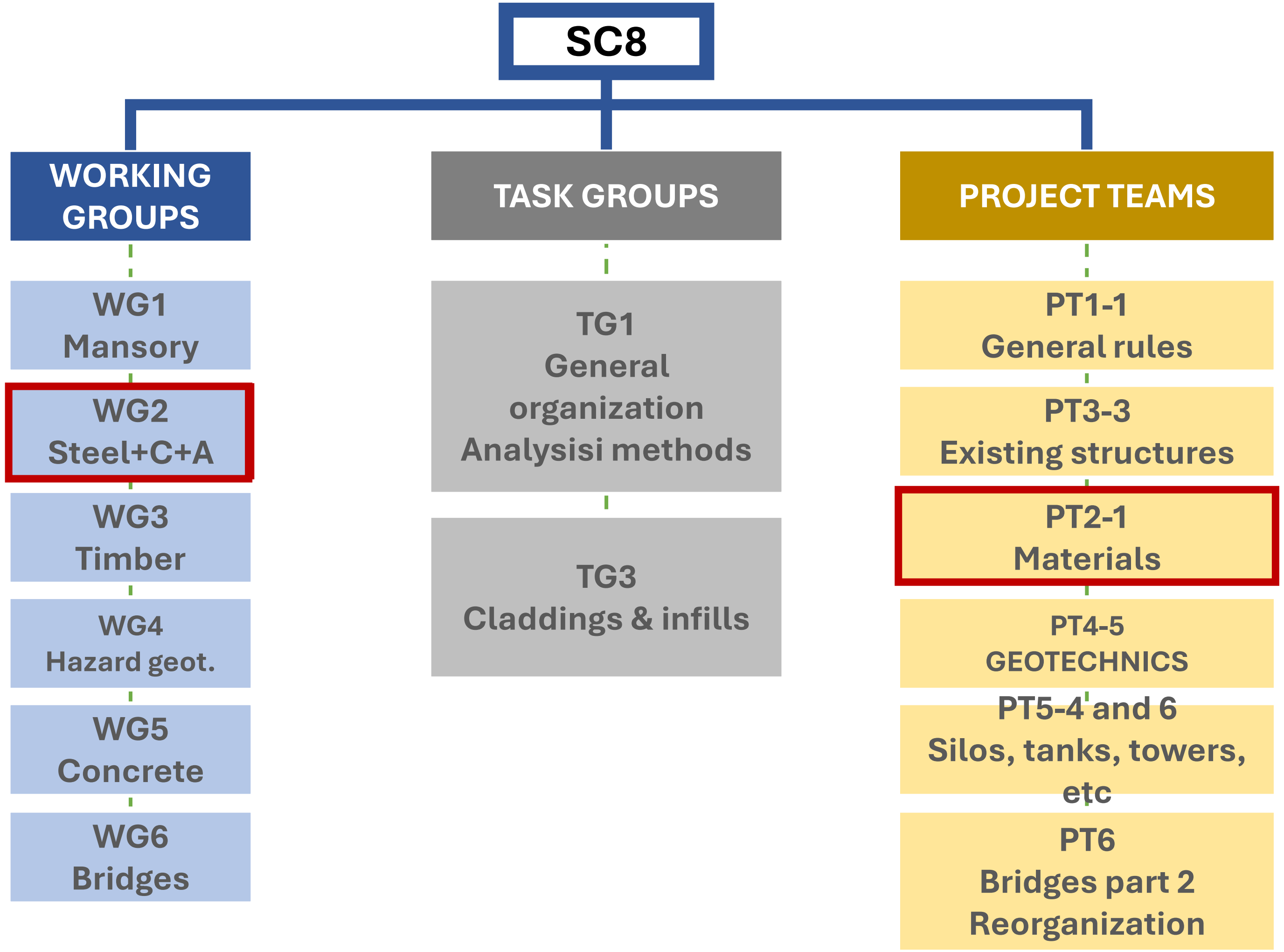
Since **2007** TC13 worked to **improve the rules on seismic design of steel structures.**
In 2013 **"Assessment of EC8 Provisions for Seismic Design of Steel Structures " was published,** containing a critical and systematic review of current EC8 and identifying main criticisms and issues needing revisions and/or upgrading.

- Material overstrength
- Selection of steel of toughness
- Local ductility
- Design rules for connections in dissipative zones
- New links in eccentrically braced frames
- Behaviour factors
- Capacity-design rules
- Design of concentrically braced frames
- Dual structures
- Drift limitations and second-order effects
- New structural types
- Low-dissipative structures



Introduction

Organisation of CEN/TC250/SC8



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Specific rules for steel buildings

Evolution of seismic rules

EC8 1ST GENERATION

VS

EC8 2ND GENERATION

EN1998-1 (2004)

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

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

Eurocode 8: Design of structures for earthquake resistance.

Part 1. General rules, seismic actions and rules for buildings

EN1998-1-2 (2025)

CEN/TC 250

Date: 2025-02-13

FprEN 1998-1-2:2025

Secretariat: BSI

Eurocode 8 — Design of structures for earthquake resistance — Part 1-2: Buildings

Eurocode 8 – Auslegung von Bauwerken gegen Erdbeben – Teil 1-2: Hochbauten

Eurocode 8 – Calcul des structures pour leur résistance au séisme – Part 1-2 : Bâtiments

ICS:

Eurocode 8: Design of structures for earthquake resistance.

Part 1-2: Buildings

Specific rules for steel buildings

EC8 1st Generation

CHAPTER 6:

SPECIFIC RULES FOR STEEL BUILDINGS

Specific rules for steel buildings

EC8 2nd Generation

CHAPTER 11:
SPECIFIC RULES FOR STEEL BULDINGS

11. SPECIFIC RULES FOR STEEL BUILDINGS

Specific rules for steel buildings

EN1998-1 (2004) – Chapter 6

Chapter 6 of EN1998-1 has 23 pages

EN1998-1-2 (2025) – Chapter 11

Chapter 11 of EN1998-1-2 has 49 pages

Specific rules for steel buildings

Evolution of seismic rules

STEEL CHAPTER	EC8 1ST GENERATION EN 1998-1 (2004) Chapter 6	VS	EC8 2ND GENERATION EN 1998-1-2 (2025) Chapter 11

MAIN NOVELTIES

- Introduction of new design rules for low-moderate/medium ductility (DC2);
- Introduction of new structural types;
- Improvement of seismic design rules for traditional types;
- New Annexes

Specific rules for steel buildings

EN1998-1 (2004) – Chapter 6

Structural systems:
MRFs
CBFs
EBFs
Dual Frames

EN1998-1-2 (2025) – Chapter 11

Structural systems:
MRFs
CBFs
EBFs
BRBFs
Dual Frames
Light weight structures

Specific rules for steel buildings

EN1998-1 (2004) – Chapter 6	**EN1998-1-2 (2025) – Chapter 11**
NO ANNEXES	**Annexes** **E - Seismic design of connections for steel buildings** **F - Steel light weight structures** **H – Seismic design of exposed and embedded steel and composite column base connections**

Specific rules for steel buildings

Addressed topics

General rules

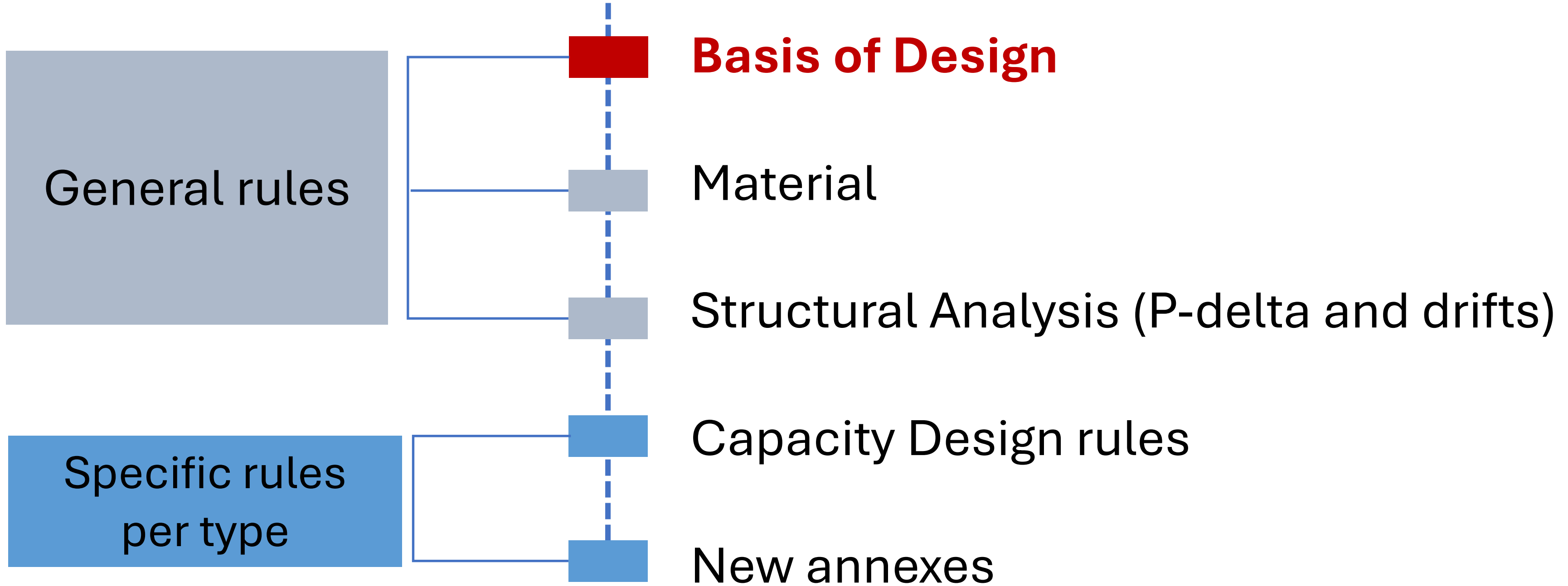
- Basis of Design
- Material
- Structural Analysis (P-delta and drifts)

Specific rules per type

- Capacity Design rules
- New Annexes

Specific rules for steel buildings

Addressed topics



Specific rules for steel buildings

Basis of Design: Structural Types

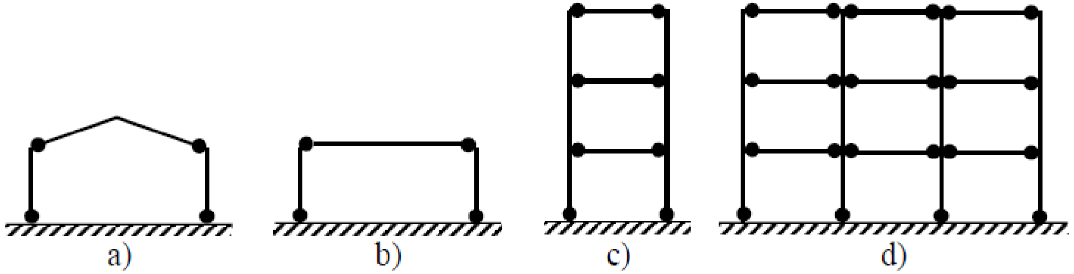


Figure 11.1 — Moment resisting frames (dissipative zones in beams and at bottom of columns): a) portal frame; b) single-storey MRF; c) single-span multi-storey MRF; d) multi-span multi-storey MRF

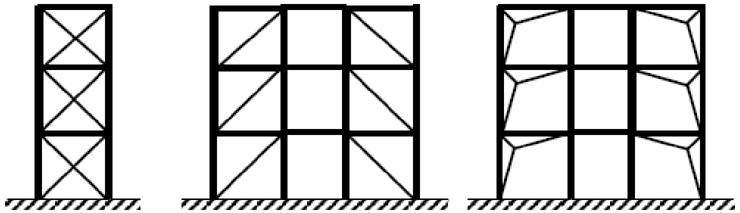


Figure 11.2 — Frames with concentric bracings where the concept of tension-only diagonals is allowed

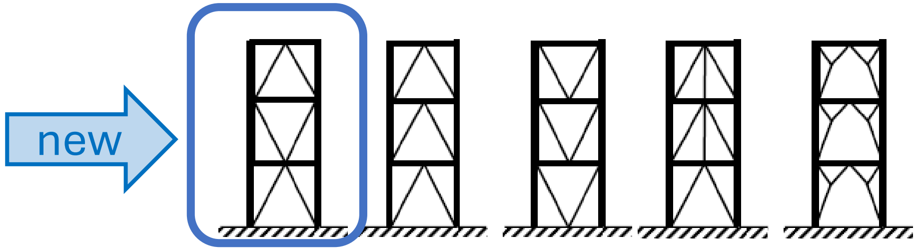


Figure 11.3 — Frames with concentric bracings where the concept of tension-compression diagonals is mandatory

Specific rules for steel buildings

Basis of Design: Structural Types

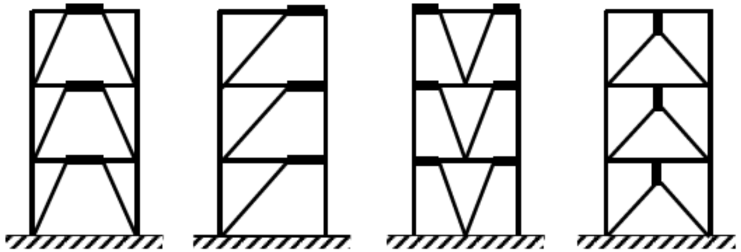


Figure 11.4 — Frames with eccentric bracings (dissipative zones in bending or shear links)

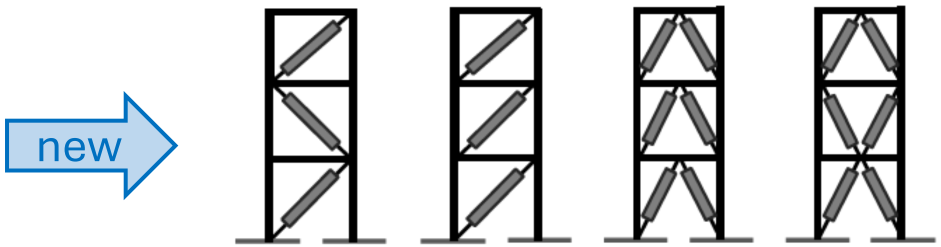


Figure 11.5 — Frames with buckling restrained bracings (dissipative zones in tension and compression diagonals)

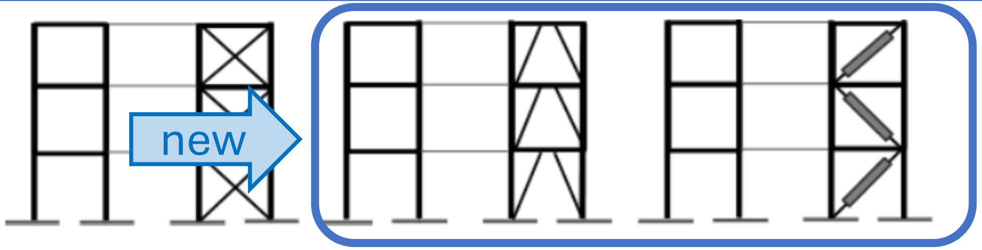


Figure 11.6 — Dual frames with moment resisting frame combined with either concentric, eccentric or buckling restrained bracing (dissipative zones in both moment and braced frames)

Basis of Design: Structural Types

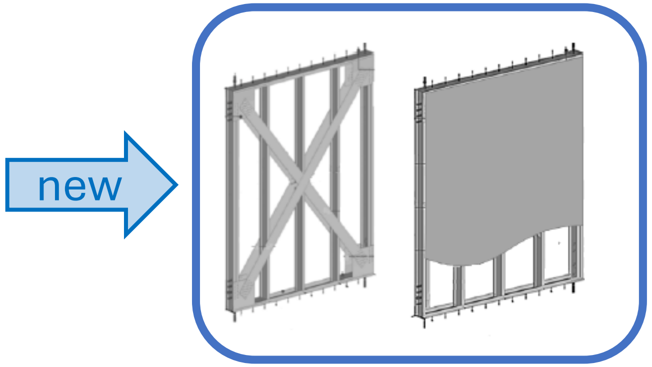
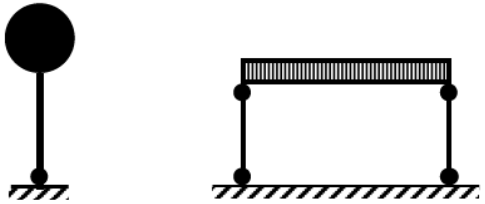


Figure 11.7 — Lightweight steel systems: a) Strap braced walls; b) Shear walls with steel sheet or wood sheathing or gypsum sheathing



a) b)

Figure 11.8 — Inverted pendulum: a) dissipative zones at the column base; b) dissipative zones in columns ($N_{Ed,G}/N_{pl,Rd} \geq 0{,}3$)

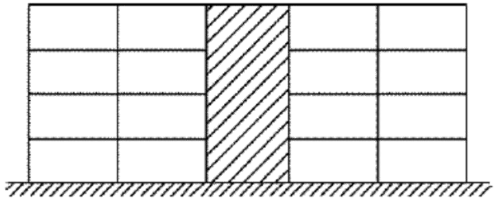
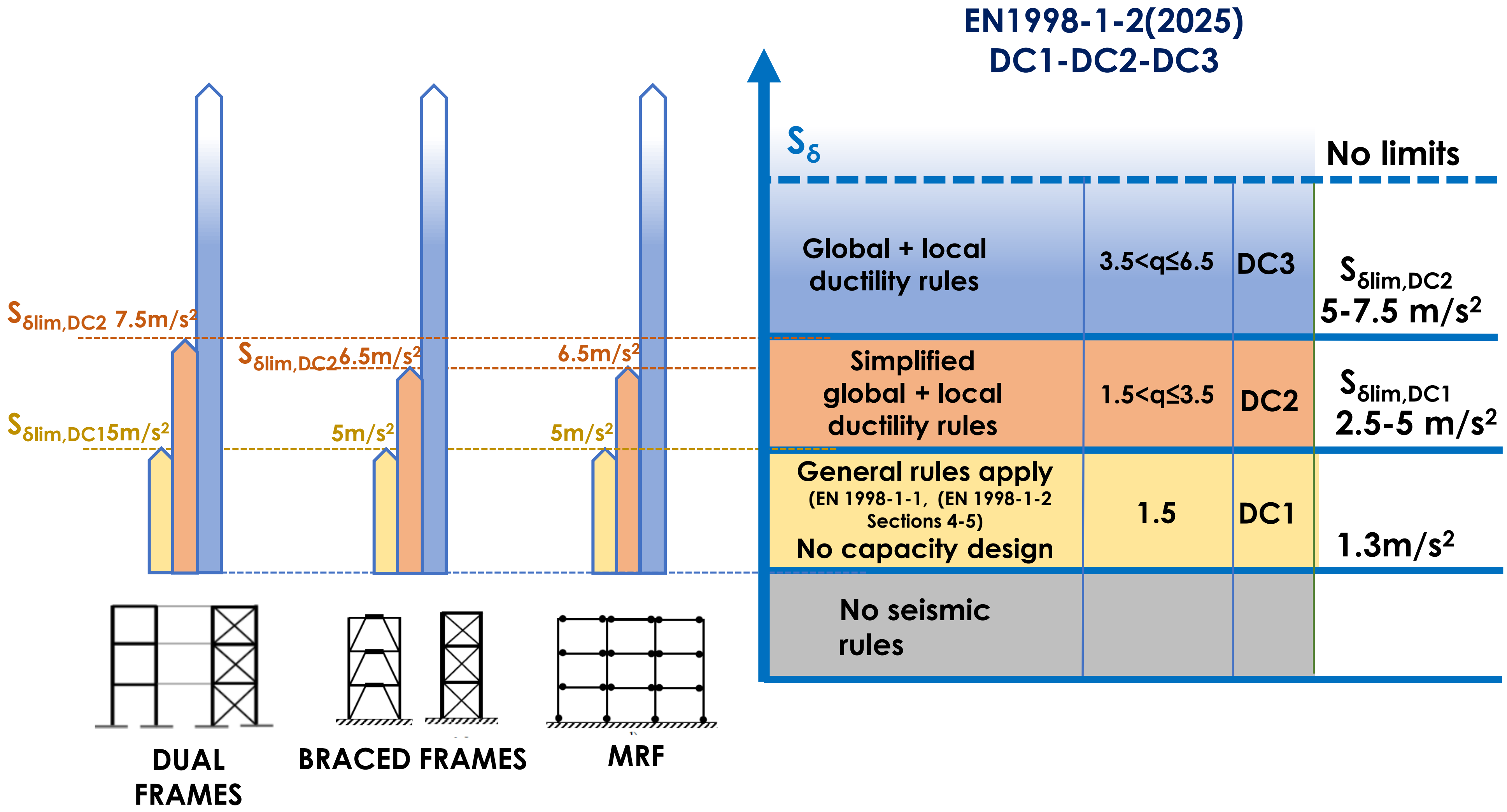


Figure 11.9 — Structures with concrete cores or concrete walls

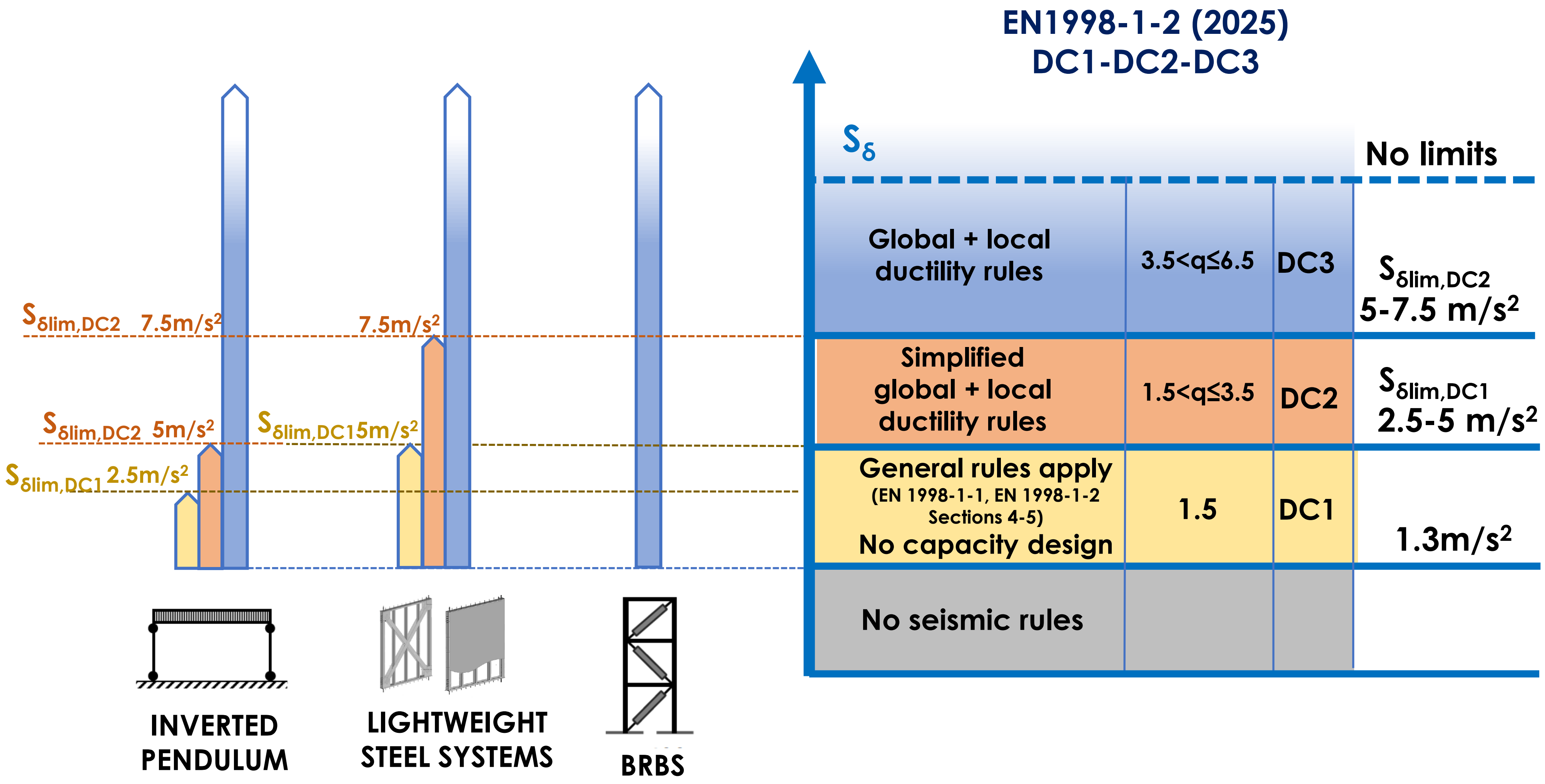
Specific rules for steel buildings

Basis of Design: limits of seismic action



Specific rules for steel buildings

Basis of Design: limits of seismic action



Specific rules for steel buildings

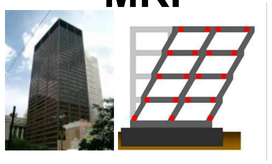
Basis of Design: behaviour factors

	Ductility Class					
STRUCTURAL TYPE	DC2			DC3		
	q_D	q_R	q	q_D	q_R	q
a) Moment resisting frames (MRFs)						
Portal frames and single-storey MRFs with class 3 and 4 cross sections	1,3	1	2	-	-	-
Portal frames and single-storey MRFs with class 1 and 2 cross sections	1,8	1,1	3	3,3	1,1	5,5
Multi-storey MRFs	1,8	1,3	3,5	3,3	1,3	6,5
b) Frames with concentric bracings Diagonal bracings V-bracings X-bracings on either single or two-storey	1,7	1	2,5	2,4	1,1	4
c) Frames with eccentric bracings	1,8	1,3	3,5	3,1	1,3	6
d) Frames with buckling restrained braces				3,3	1,2	6
e) Dual frames						
MRFs with concentric bracing	1,8	1,1	3	2,9	1,1	4,8
MRFs with eccentric bracing	2,1	1,3	4	3,3	1,3	6,5
MRFs with buckling restrained braces	-	-	-	3,3	1,3	6,5
f) Structures with concrete cores or concrete walls	See **10**					
g) Lightweight steel frame wall systems						
with flat strap bracing	1,3	1	2	1,7	1	2,5
with steel sheeting	1,3	1	2	1,7	1	2,5
with wood sheathing	1,3	1	2	1,7	1	2,5
with gypsum sheathing	1,1	1	1,7	1,3	1	2
h) Inverted pendulum	1,3	1	2	1,5	1	2,3
i) Moment resisting frames with infills						
Unconnected concrete or masonry infills, in contact with the frame	2	1	3			
Connected reinforced concrete infills	See **10**					
Infills isolated from moment frame	(see MRFs)					

Specific rules for steel buildings

Basis of Design: behaviour factors

MRF



EN-1998-1 (2004) VS EN 1998-1-2 (2025)

Current EN-1998-1

DCM → *q = 4*

DCH → *q = 5.5-6.5*

prEN 1998-1-2

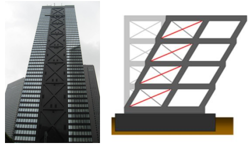
DC2
- *q = 2 for portal frame with class 3-4*
- *q = 3 for portal frame with class 1-2*
- *q = 3.5 for multi-storey MRF*

DC3
- *q = 5.5 for portal frame with class 1-2*
- *q = 6.5 for multi-storey MRF*

Specific rules for steel buildings

Basis of Design: behaviour factors

CBF



Current EN-1998-1 VS prEN 1998-1-2

Current EN-1998-1

- *DCM*
  - *q=2 VCBF*
  - *q=4 XCBF*
- *DCH*
  - *q=2.5 VCBF*
  - *q=4 XCBF*

prEN 1998-1-2

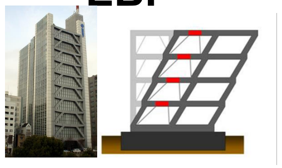
- *DC2* → *q = 2.5 for all types*
- *DC3* → *q=4 for all types*

Specific rules for steel buildings

Basis of Design: behaviour factors

EN-1998-1 (2004) VS EN 1998-1-2 (2025)

EBF



Current EN-1998-1	
DCM	*q=4*
DCH	*q=5-6*

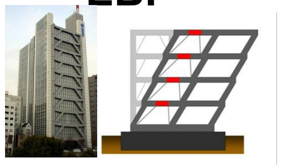
prEN 1998-1-2	
DC2	*q = 3.5*
DC3	*q=6*

Specific rules for steel buildings

Basis of Design: behaviour factors

EN-1998-1 (2004) VS EN 1998-1-2 (2025)

EBF



Current EN-1998-1	
DCM →	*q=4*
DCH →	*q=5-6*

prEN 1998-1-2	
DC2 →	*q = 3.5*
DC3 →	*q=6*

Specific rules for steel buildings

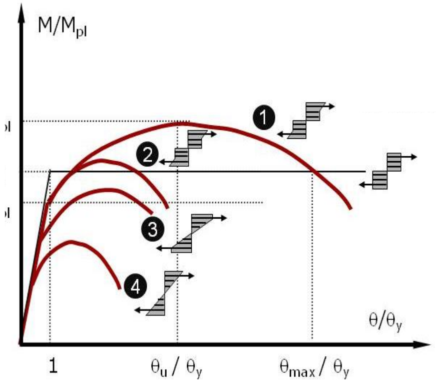
Basis of Design: required cross sectional classes

EN1998-1 (2004)

DCH	2.5<q≤6.5	Class 1
DCM	2<q≤3.5	Class 1, 2

EN1998-1-2 (2025)

DC3	q>3.5	Class 1
	2≤q≤2.5	Class 1, 2, **3 or 4** for lightweight systems
DC2	1.5<q≤2	Class 1, 2, **3 or 4** for portal frames, lightweight systems and single storey MRF
	1.5<q≤2	Class 1, 2 for inverted pendulum
	2<q≤3.5	Class 1, 2 for MRFs, CBFs, EBFs and Dual frames

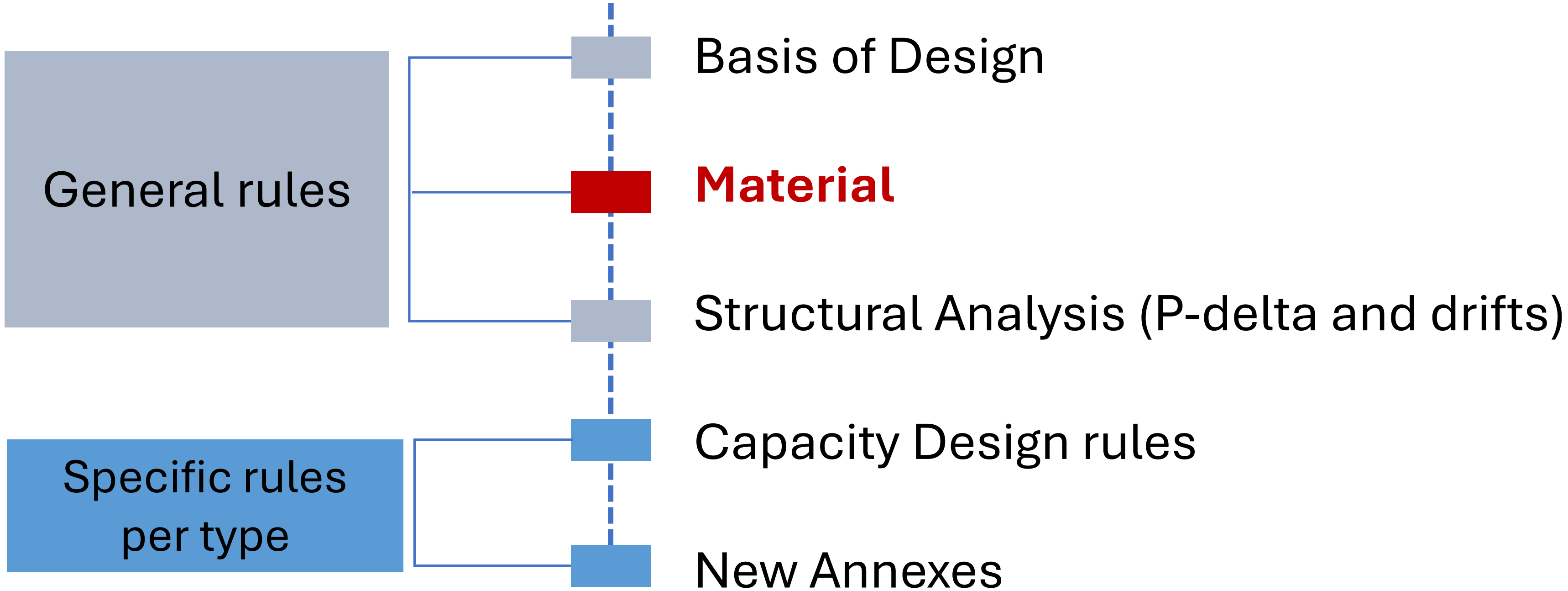


REQUIRED CROSS SECTIONAL CLASS DEPENDS ON STRUCTURAL TYPES

CLASSES 3 and 4 are allowed for certain structural typologies

Specific rules for steel buildings

Addressed topics



Specific rules for steel buildings

Material: random variability of steel strength

EN1998-1 (2004)

γ_{ov} is the material overstrength factor used in design

NPD-Recommended Value 1,25

EN1998-1-2 (2025)

ω_{rm} is the ratio between the expected (i.e. average) yield strength $f_{y,average}$ and the relevant f_y. This ratio is the material overstrength factor used in design, which depends on the steel grade

Steel grade	Material randomness coefficient ω_{rm}
S235	1.45
S275	1.35
S355	1.25
S420	1.25
S460	1.2

Specific rules for steel buildings

Addressed topics

General rules
- Basis of Design
- Material
- **Structural Analysis (P-delta and drifts)**

Specific rules per type
- Capacity Design rules
- New Annexes

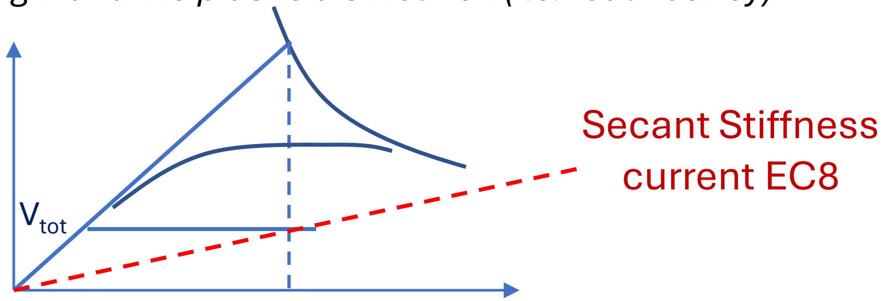
Specific rules for steel buildings

Structural analysis: second order effects

Current EN-1998 (2005)

Stability coefficient based on the secant stiffness of the idealized elastic-plastic response curve, which disregards the design overstrength and the plastic distribution (i.e. redundancy)

$$\theta = \frac{P_{tot} \cdot d_r}{V_{tot} \cdot h}$$



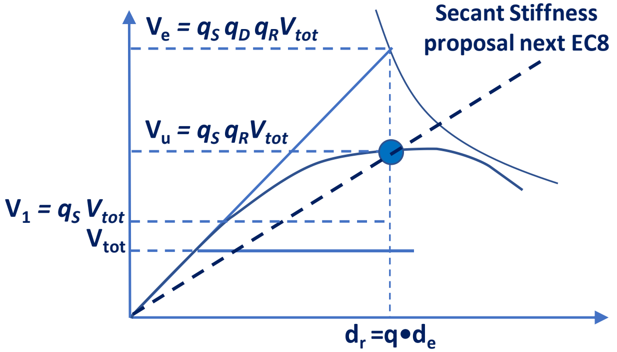
EN1998-1-2(2025)

Modified stability coefficient based, which account for design overstrength and the plastic distribution

$$\theta = \frac{P_{tot} \cdot d_{r,SD}}{q_s \cdot q_R \cdot V_{tot} \cdot h}$$

$$for\ DC2 \quad \rightarrow \quad q_s = 1.5$$

$$for\ DC3 \quad \rightarrow \quad q_s = \omega_{rm}\Omega_d$$



Specific rules for steel buildings

Structural analysis: drift limitation

Current EN-1998(2005)

At Damage Limitation state the interstorey drift should be verified as follows

$$d_r \leq \alpha h$$

where α = 0.05; 0.075; 0.01 depeding on the non−structural elements

New EN-1998-1-2

No mandatory check at Damage Limitation.
At Significant Damage limit state should be verified as follows:

$$d_r \leq \lambda h$$

λ depeds on the structural system: λ= 0.01 for ligthweight systems; λ= 0.015 for braced frames and inverted pendulum λ= 0.02 for dual and MRFs

Specific rules for steel buildings

Addressed topics

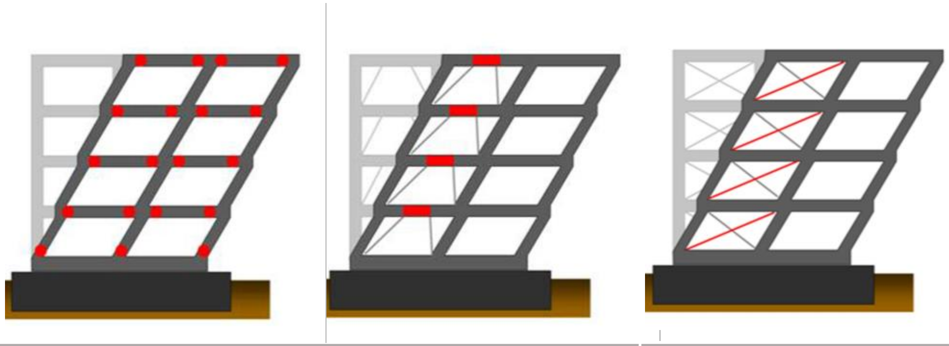
General rules

- Basis of Design
- Material
- Structural Analysis (P-delta and drifts)

Specific rules per type

- **Capacity Design rules**
- New annexes

Capacity design: general rules



Ductility Class	Capacity design rules	Current VS Next EC8
DC3	Capacity design rules	Improved as respect to current DCM and DCH
DC2	Simplified capacity design rules	Completely new as respect to current EC8
DC1	No capacity Design	Similar to current DCL

EC8-2G
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Specific rules for steel buildings

Capacity design: general rules

EN1998-1 (2004) DCM

$$R_d \geq E_{Ed,G} + 1.1 \cdot \gamma_{ov} \cdot \Omega \cdot E_{Ed,E}$$

$$\Omega = \min\left(\frac{R_d}{E_{Ed,E}}\right)$$

EN1998-1-2 (2025) DC2

$$M_{Rd} \geq M_{Ed,G}" + "M_{Ed,E}$$

$$V_{Rd} \geq V_{Ed,G}" + "V_{Ed,E}$$

$$N_{Rd} \geq N_{Ed,G}" + "\Omega \cdot N_{Ed,E}$$

$\Omega =$ seismic action magnification factor (from the Table 11.7)

In current DCM all seismic induced effects are magnified
In new DC2 only axial forces are magnified

Specific rules for steel buildings

Table 11.7 — Members to which (1) or (2) apply. Values of seismic action magnification factor *Ω* in DC2

STRUCTURAL TYPE	*Ω*	Members to which (1) or (2) apply
Moment resisting frames (MRFs)		columns
Portal frames with class 3 and 4 cross sections	1,5	
Single-storey MRFs with class 3 and 4 cross sections	1,5	
Portal frames and single-storey MRFs with class 1 and 2 cross sections	1,7	
Multi-storey MRFs	2	
MRFs with friction connections	2	
Frames with concentric bracings	1,5	beams and columns
Diagonal bracings		
V-bracings		
X-bracings on either single or two-storey		
Frames with eccentric bracings	2	beams outside the link, braces and columns
Dual frames		
MRFs with concentric bracing	1,7	beams and columns of the concentric bracing; columns of the MRF;
MRFs with eccentric bracing	2	beams out of the link, braces and columns of the eccentric bracing; columns of the MRF
Structures with concrete cores or concrete walls	See **10**	
Lightweight steel frame wall systems		connections and framing: chord studs and tracks
with flat strap bracing	1,5	
with steel sheeting	1,5	
with wood sheathing	1,5	
with gypsum sheathing	1,3	
Inverted pendulum structures	1,5	columns
Moment resisting frames with infills		
with unconnected with non-interacting concrete or masonry infills	1,5	columns
with connected reinforced concrete infills	See **10**	See section **10**
with non-interacting infills	(see MRFs)	columns

Specific rules for steel buildings

Capacity design: general rules

EN1998-1 (2004) DCH	EN1998-1-2 (2025) DC3
$R_d \geq E_{Ed,G} + 1.1 \cdot \gamma_{ov} \cdot \Omega \cdot E_{Ed,E}$	$R_d \geq E_{Ed,G} + \omega_{rm} \cdot \omega_{sh} \cdot \Omega_d \cdot E_{Ed,E}$
Ω Design overstrength of dissipative members	Ω_d Design overstrength of dissipative members ω_{sh} hardening overstrength factor ω_{rm} material randomness coefficient

In new DC3 the hardening factor is specified per dissipative mechanism

Specific rules for steel buildings

Table 11.8 — Overstrength factor ω_{sh} accounting for hardening of the dissipative zones

Structural Type	Dissipative Zones	Plastic Mechanism	ω_{sh}
Moment resisting frames	beams yielding connections columns at base	bending	$\frac{(f_y + f_u)}{2f_y} \le 1{,}2$
	friction connections	friction	$1{,}3\omega_{sr}\,\omega_{\mu} \le 2{,}2$ ω_{sr} and ω_{μ} as defined in Annex E
Frames with concentric bracings (simple and dual)	diagonal members	axial	1,1
	all members	bending (see **11.10.5** and **11.10.6**)	1,1
	dissipative connections	axial	1,1
		bending	1,2
		shear	1,5
Frames with eccentric bracings (simple and dual)	short links	shear $e \le M_{p,link}/V_{p,link}$ (very short links)	1,8
		shear $M_{p,link}/V_{p,link} < e \le 1{,}6M_{p,link}/V_{p,link}$ (short links)	1,5
	intermediate links	bending and shear $e \le 2{,}6M_{p,link}/V_{p,link}$	1,5
		bending and shear $2{,}6M_{p,link}/V_{p,link} < e \le 3M_{p,link}/V_{p,link}$	1,35
	long links	Bending $3M_{p,link}/V_{p,link} < e \le 5M_{p,link}/V_{p,link}$	1,25
		Bending $e > 5M_{p,link}/V_{p,link}$	$\omega_{sh} = \frac{(f_y + f_u)}{2f_y} \le 1{,}2$
	beams - columns	bending (see **11.11.5**)	1,1
Frames with buckling restrained braces	diagonal members	axial	see 11.12.3(4)
	beams - columns	bending (see **11.12.6**)	1,2

Specific rules for steel buildings

SPECIFIC RULES FOR MOMENT RESISTING FRAMES

1ST VS 2ND GENERATION : main novelties

- Simplified hierarchy of resistances in DC2
- Expected location of plastic hinge is considered in calculations in DC3
- Specific rules for lateral-torsional stability in DC3
- Specific rules for columns in DC3
- Prequalification of beam-to-column joints

Specific rules for steel buildings

Capacity design

MRF - Summary

Design for DC2

q= [2; 3.5]

- **Beams**
  - Cross section class 1,2,3,4 (Portal frames)
  - Design shear force calculated from elastic analysis
  - Lateral-torsional stability according to EC3
- **Columns**
  - No Local hierarchy (no WB-SC criterion)
  - Simplified global hierarchy – assumed design overstrength factor for axial force
- **Joints**
  - Current EC8 rules are retained, additional rules in Annex E

Design for DC3

q= [5.5; 6.5]

- **Beams**
  - Cross section class 1,2
  - Design shear force calculated in the expected position of plastic hinge
  - Lateral torsional stability: specific rules for DC3
- **Columns**
  - Local hierarchy calculated for the expected position of plastic hinge (WB-SC criterion)
  - Simplified global hierarchy – assumed design overstrength factor for axial force, bending, shear
- **Joints**
  - Annex E: Prequalifed connections

Specific rules for steel buildings

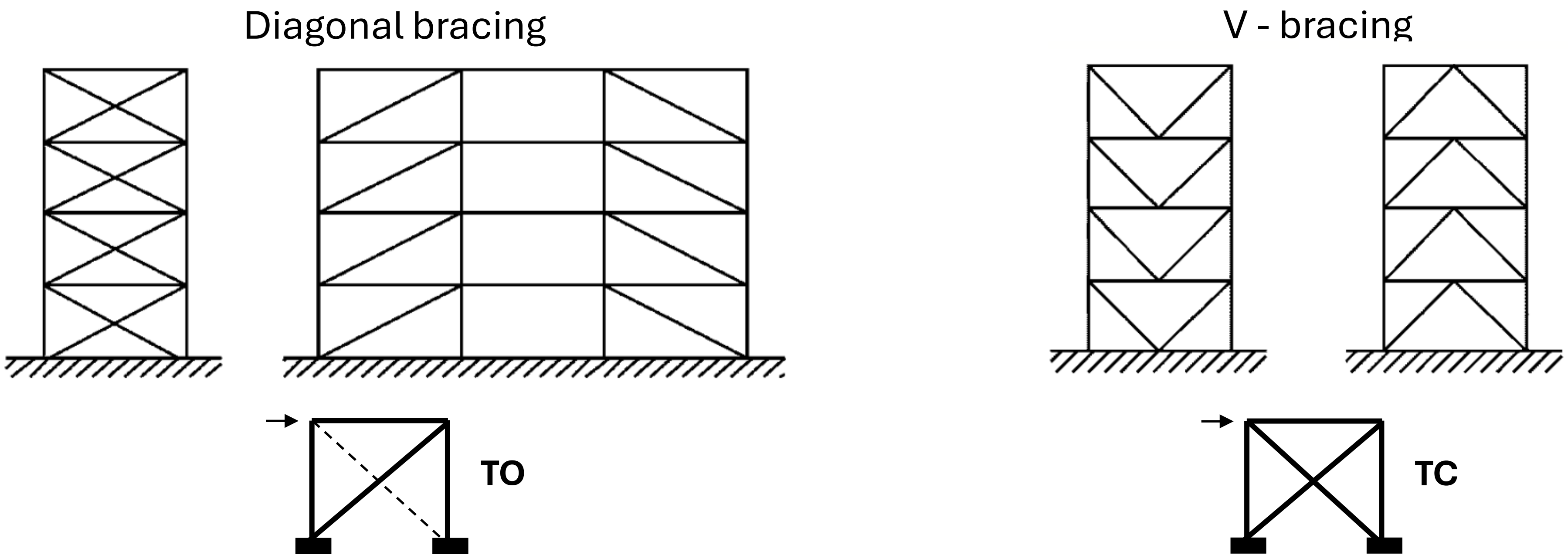
SPECIFIC RULES FOR CONCENTRICALLY BRACED FRAMES

1ST VS 2ND GENERATION : main novelties

- Simplified hierarchy of resistances in DC2
- Use of TC model for XCBFs
- New global slenderness limits
- Specific local slenderness limits for dissipative members in DC3
- Use of plastic mechanism analysis to determine required strength of non dissipative members in DC3
- Annex E for design of brace-to-frame connections in DC3

Specific rules for steel buildings

Frame with concentric bracing (CBF) in EN1998-1 (2004)



STRUCTURAL TYPE	Ductility Class	
	DCM	DCH
b) Frame with concentric bracings Diagonal bracings V-bracings	 4 2	 4 2,5

Specific rules for steel buildings

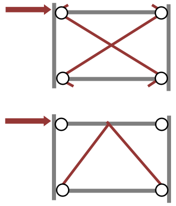
Capacity design

CBF - Summary

Design for DC2 ⟷ Diagonal CBF / X CBF / V CBF

q=2.5

T-C model
Elastic Analysis
Slenderness lower than 2,5



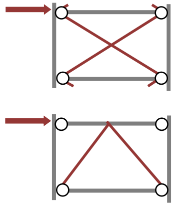
Joints (gusset connections)

Both DC2 and DC3 shall comply with the similar requirements for brace connections. Specific rules are given in Annex E

Design for DC3 ⟷ Diagonal CBF / X CBF / V CBF

q=4

T-C model
Plastic mechanism analysis
Slenderness lower than 2



Specific rules for steel buildings

SPECIFIC RULES FOR ECCENTRICALLY BRACED FRAMES

1ST VS 2ND GENERATION : main novelties

- BOX sections allowed for links
- Simplified hierarchy of resistances in DC2
- No overstrength variation limit in DC2
- Use of plastic mechanism analyses to determine required strength of non dissipative members in DC3

Specific rules for steel buildings

• Specific rules for steel buildings

Capacity design rules

EBF - Summary

Design for DC2 — *q= 3.5*

- Link — Elastic analysis
- Beams, braces, columns — Simplified global hiearchy (only axial force is magnified)

Joints — Both DC2 and DC3 shall comply with the similar requirements for connections
Specific rules are given in Annex E

Design for DC3 — *q=6*

- Link — Elastic analysis
- Beam, braces — Plastic mechanism analysis
- columns — Global hiearchy with magnification factor

Specific rules for steel buildings

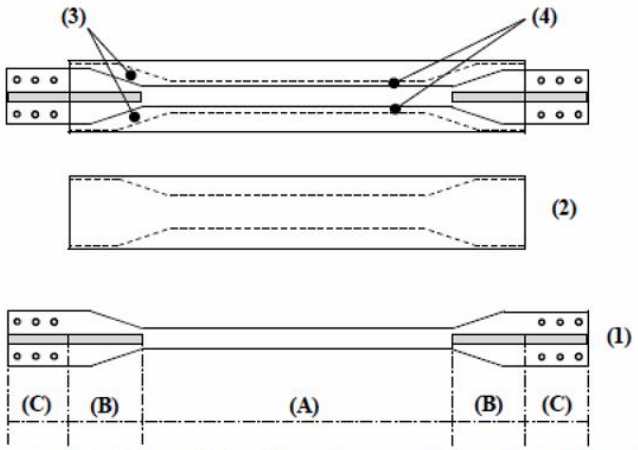
SPECIFIC RULES FOR BUCKLING RESTRAINED BRACES

1ST VS 2ND GENERATION : main novelties

- BRBs design rules are INTRODUCED
- BRBs shall be designed solely in DC3
- Capacity design rules are provided

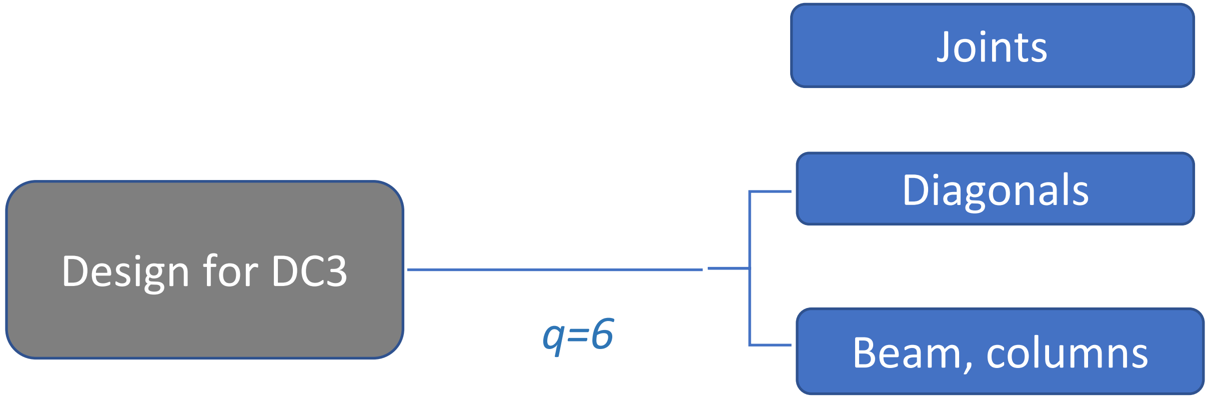
Specific rules for steel buildings

EBF - Summary



Key: (1) "core": bracing member; (2) "sleeve": buckling restraining system; (3) longitudinal "gap"; (4) transverse "clearance"; (A): yielding zone, (B) transition zones, (C) connection zones.

Figure 11.17 — Geometrical features and main components of a typical BRB



Specific rules are given in Annex E

Elastic analysis
Stability of sleeve

Plastic mechanism analysis

Specific rules for steel buildings

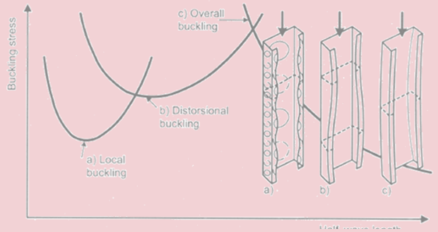
SPECIFIC RULES FOR LIGHTWEIGHT STEEL STRUCTURES

1ST VS 2ND GENERATION : main novelties

- LWSS design rules are INTRODUCED
- LWSS can be designed in all DC
- Capacity design rules are provided

Specific rules for steel buildings

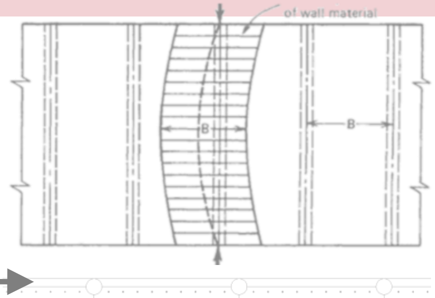
Lightweight steel structures: Design approaches



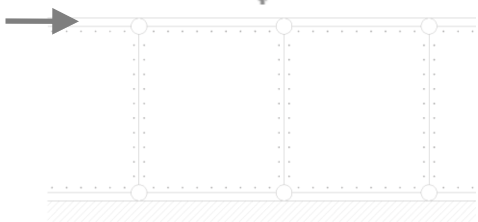
VERTICAL LOADS

HORIZONTAL LOADS

Strap braced walls design



VERTICAL LOADS

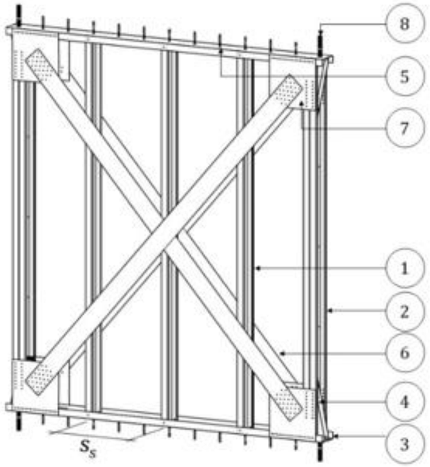


HORIZONTAL LOADS

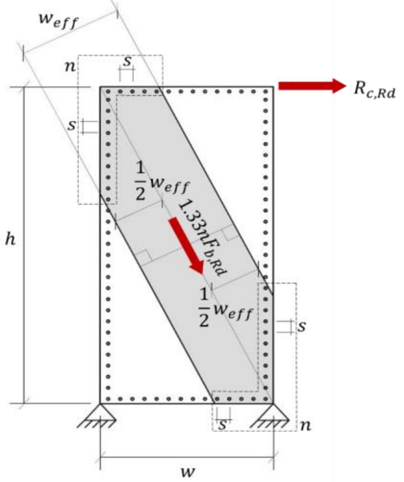
Shear walls with sheetings design

Specific rules for steel buildings

1. Strap-braced walls

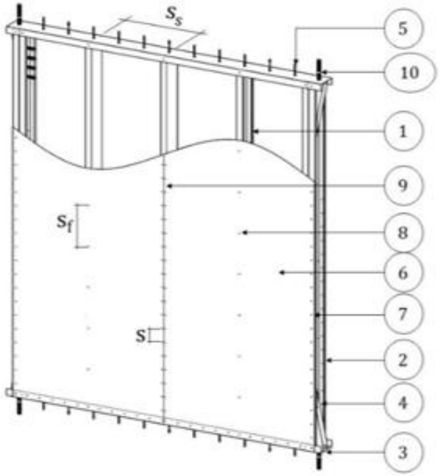


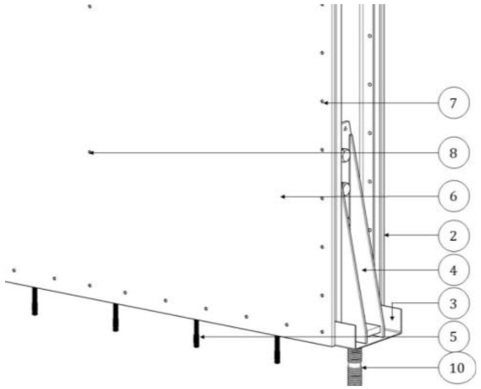
2. Shear walls with steel sheet sheathing



Shear walls with panels (wood, gypsum)

3. Shear walls with wood sheathing





4. Shear walls with gypsum sheathing

Specific rules for steel buildings

Seismic design criteria for CFS systems according to EN1998-1-2

All-steel structure

Tipologia strutturale	**DC2**	**DC3**	**Design approach**
	q	***q***	
Strutture con controventi a piatti	2	2.5	Dissipative

Shear walls with sheetings

Tipologia strutturale	**DC2**	**DC3**	**Design approach**
	q	***q***	
Strutture con lamiera d'acciaio	2	2.5	Dissipative
Strutture con pannelli di legno	2	2.5	Dissipative
Strutture con pannelli di cartongesso	1.7	2	Dissipative

Specific rules for steel buildings

Addressed topics

- General rules
  - Basis of Design
  - Material
  - Structural Analysis (P-delta and drifts)
- Specific rules per type
  - Capacity Design rules
  - **New Annexes**

ANNEX E
Seismic design of connections for steel buildings

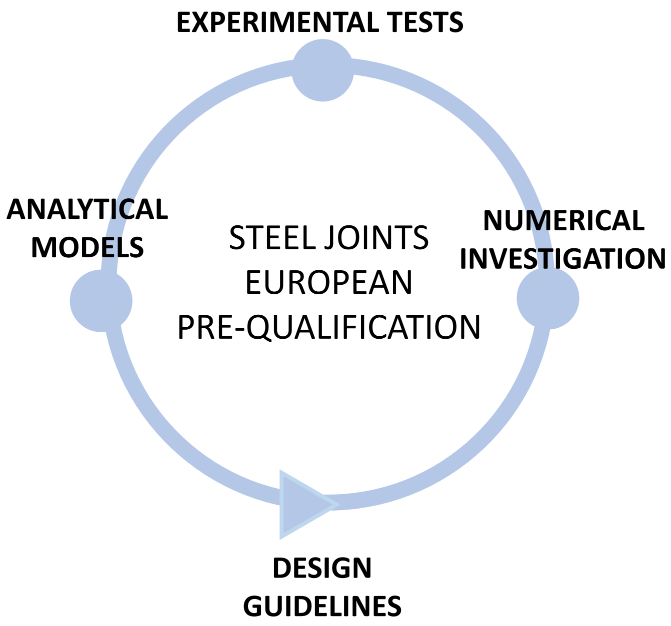
ANNEX E: Seismic design of connections for steel buildings

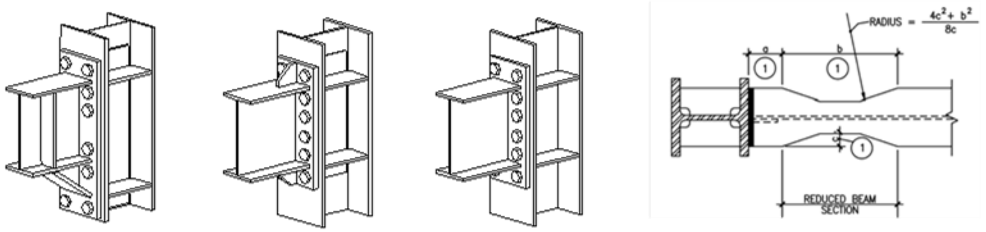
Background:

European Qualification of Seismic Resistant Steel Beam-to-column Joints

- The **EQUALJOINTS** research project aimed at providing **pre-qualification procedure** for a set of selected seismic resistant steel beam-to-column joints, introducing a **codified practice currently missing in Europe.**
- A large **experimental** programme supported by **theoretical** and **numerical** analyses has been performed
- The **guidelines** for the seismic design of joints developed within the Equaljoints project constitute the **scientific background** seismic rules given for beam.to-column joints in **the Annex E of EN 1998-1-2.**

European Commission
Research Fund for Coal & Steel





More details in:
R. Landolfo, European seismic prequalification of steel beam-to-column joints: EQUALJOINTS and EQUALJOINTS-Plus projects, Journal of Constructional Steel Research 192 (2025) 107238

ANNEX E: Seismic design of connections for steel buildings

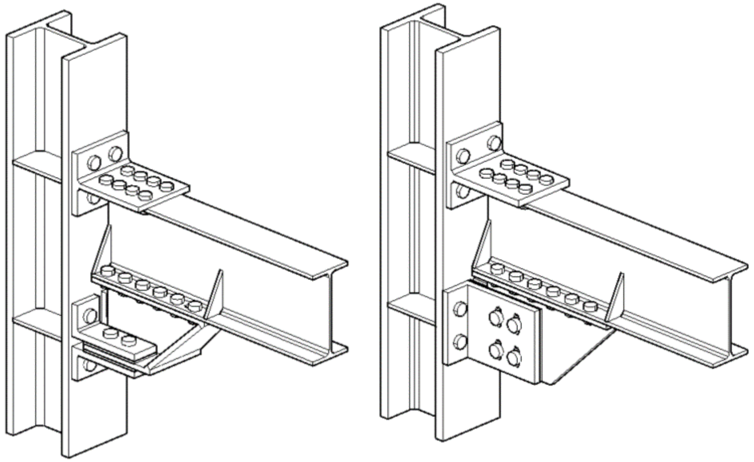
Background:

Introduction of partial-strength friction joints

This type of joints are widely used in New Zealand. Clifton and MacRae developed the so-called sliding hinge joints.

In Europe, these types of joints have been recently prequalified in the **RFCS FREEDAM** project.

Thanks to the ongoing dissemination project **FREEDAM Plus**, all rules and requirements are available.



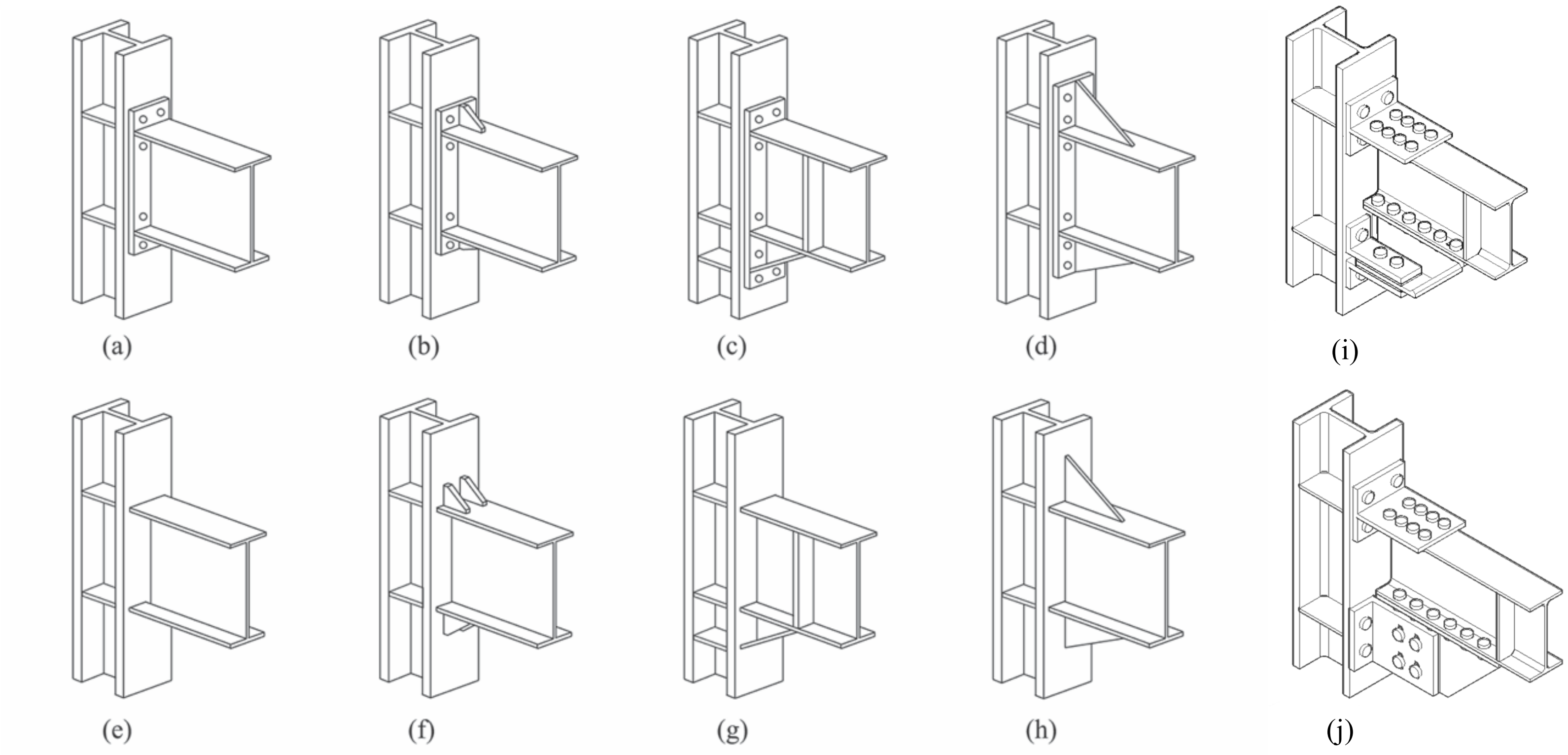
Research Fund for Coal & Steel

FREEDAM PROJECT

PARTNERS	• Leader: **University of Salerno** • University of Naples "Federico II" • University of Liege • University of Coimbra • FIP • O FELIZ

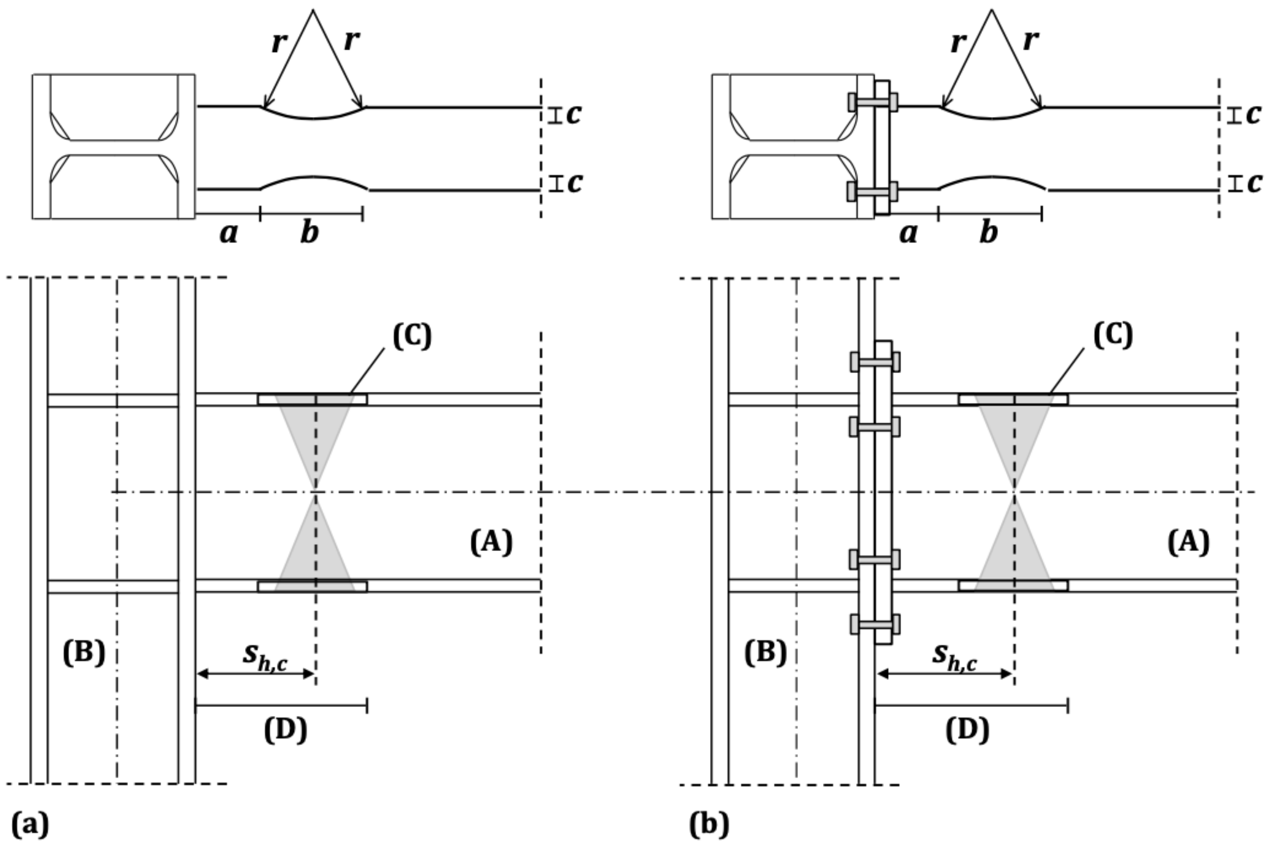
O FELIZ PRECISÃO
FIP INDUSTRIALE

Types of beam-to-column joints covered by Annex E



unstiffened (a, e), stiffened wth ribs (b, d, f, h), stiffened with haunches (c, g), friction joint parallel to the beam flange (i) friction joint parallel to the beam web (j)

Types of beam-to-column joints covered by Annex E

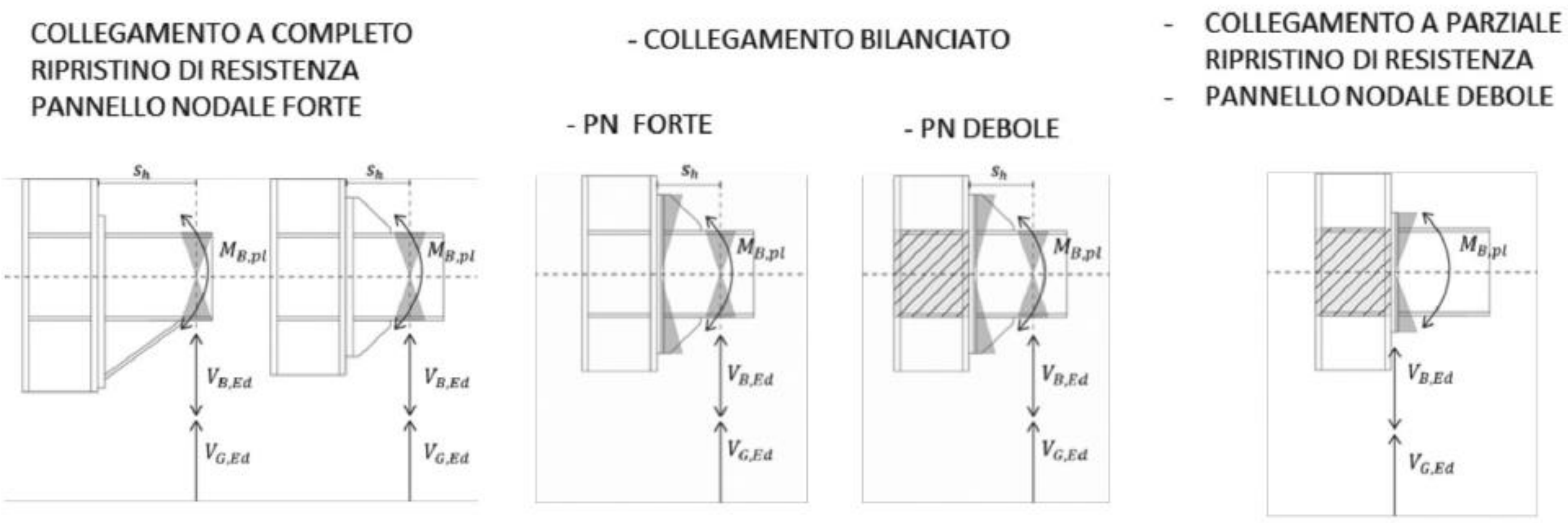


Joints with reduced beam section

Moment resisting beam-to-column joints

Classification by localization of dissipative mechanism in the joint:

The categories of the connections are classified on the basis of the localization of the dissipative mechanism in the joint:



Gusset plate connections in concentrically bracings

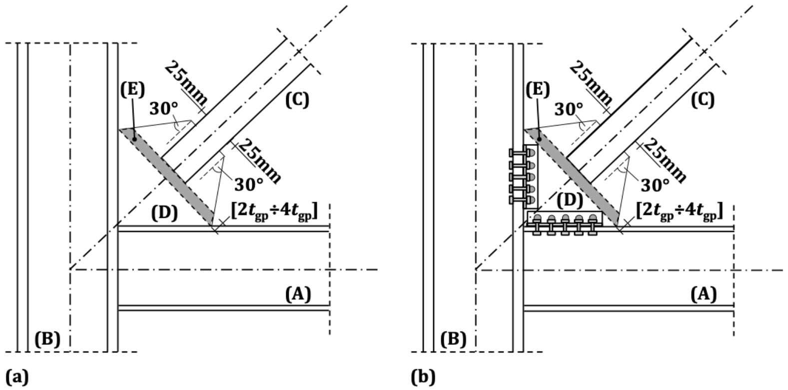


Figure E.18 — Configurations of gusset plate connections for out-of-plane buckling: a) welded connection; (b) bolted connection; (b) bolted connection; (A) beam; (B) column; (C) diagonal brace; (D) gusset plate; (E) linear clearance

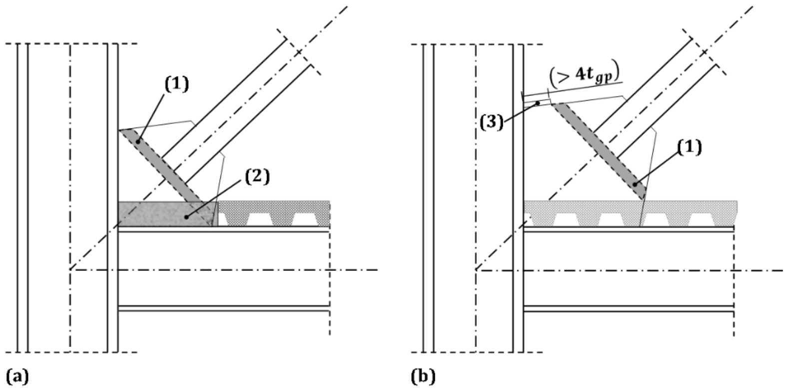


Figure E.19 — slab-to-gusset details: a) isolated from the slab; (b) restrained by the slab; (1) linear clearance; (2) compressible material; (3) edge stiffener

ANNEX E: Seismic design of connections for steel buildings

Brace connections in eccentric bracings

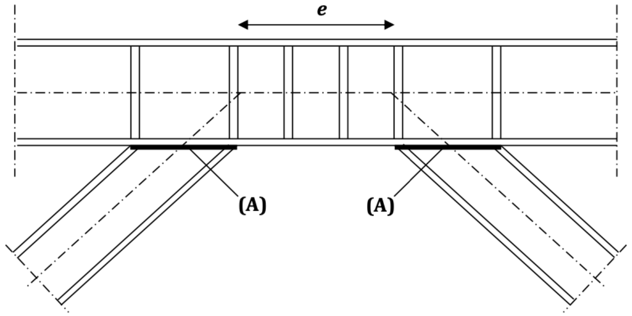
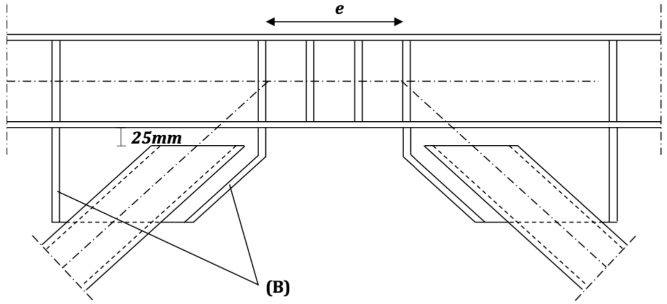
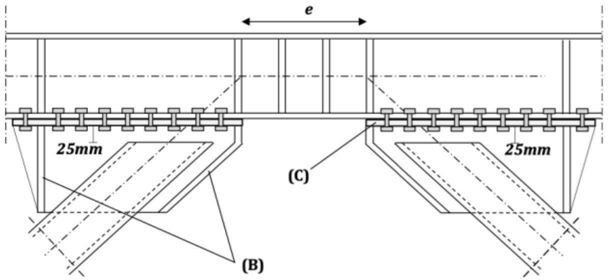


Figure E.25 — Welded brace connections of EBF: (A) full penetration groove welds in accordance with E.3.3.3(6)



a)

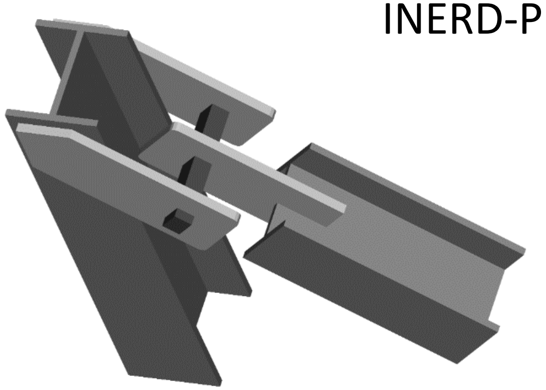


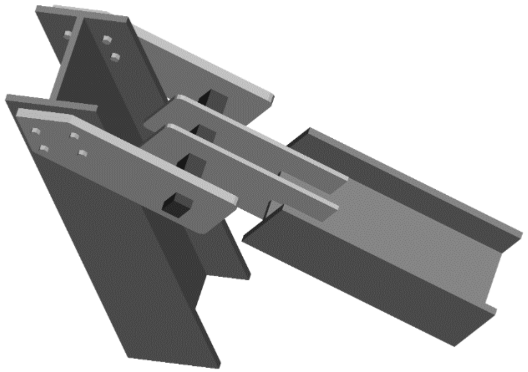
b)

Figure E.26 — Gusset plate connections of diagonal braces of EBF: (B) stiffeners of the free edge of the gusset; (C) end-plate connection in bolted gusset plates

Partial strength connections in concentrically bracings

INERD-PIN



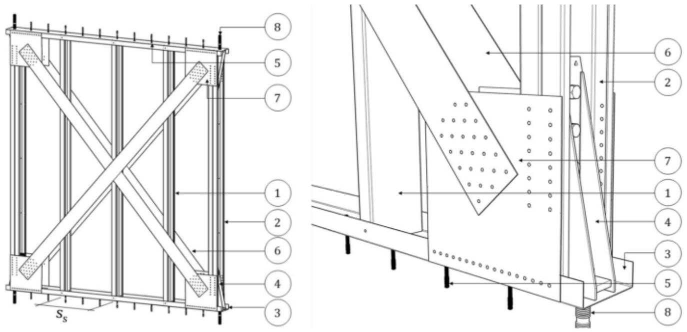


- The INERD-PIN connection is made of a pin that crosses two external plates connected to the frame columns/beams, and one or two internal plates connected to the brace
- Limits for beams and columns (geometry and material)
- Rules for welds, bolts, stiffeners, gussets (geometry and material)
- Rules for calculation of strength and modelling

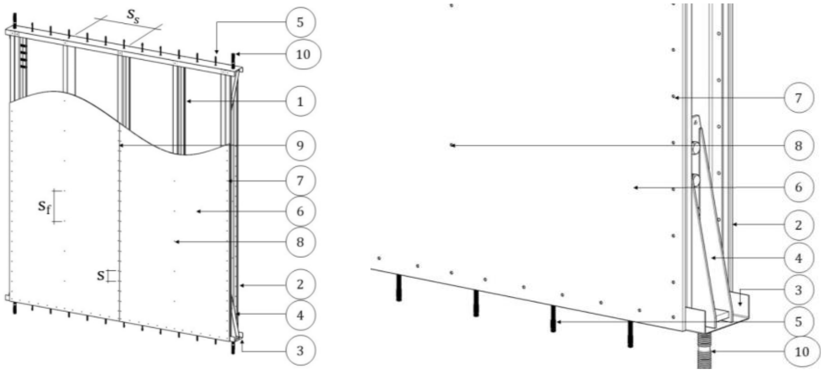
ANNEX F
Complementary design rules for Lightweight steel structures

Annex F: Complementary rules for lightweight structures

Types of systems covered by Annex F

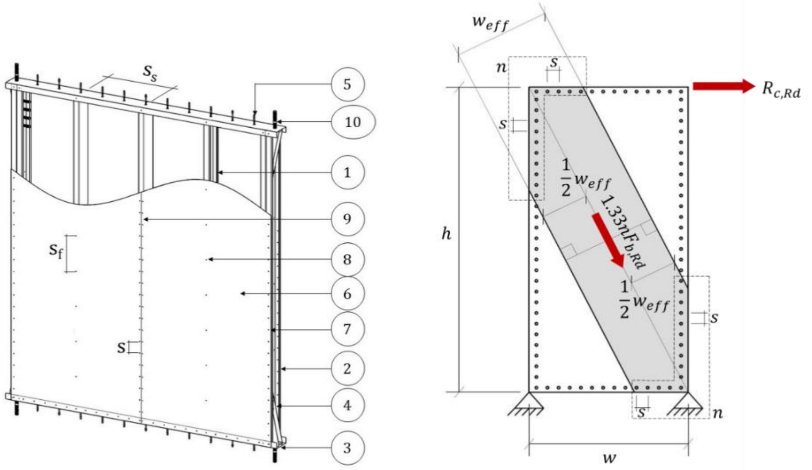


Strap braced walls



Shear walls with wood or gypsum sheathing

- Limits for elements (geometry and material)
- Rules for fasteners (geometry and material)
- Rules for calculation of strength and modelling



Shear walls with steel sheet sheathing

Design of non-dissipative components for DC2 dissipative lightweight steel systems

(1) In DC2, non-dissipative components should be designed to resist the action effect E_{Ed} calculated with Formula (11.54) :

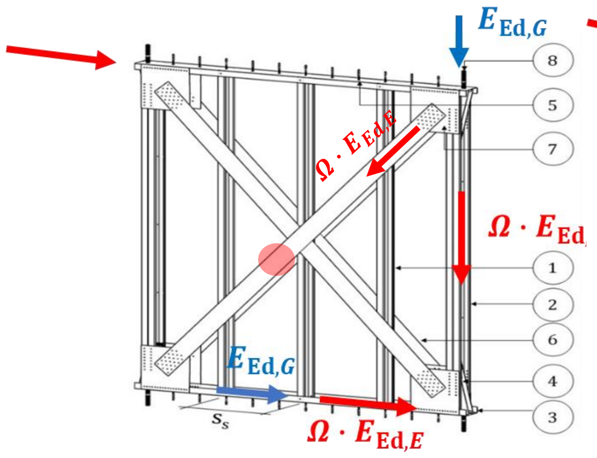
$$E_{Ed} = E_{Ed,G} \text{ "+" } \Omega \, E_{Ed,E} \qquad (11.54)$$

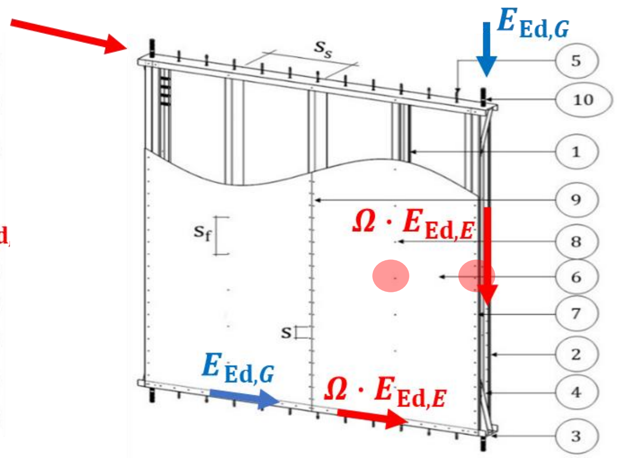
where:

$E_{Ed,G}$ is the action effect due to the non-seismic actions in the seismic design situation;

$E_{Ed,E}$ is the seismic action effect due to the design seismic action;

Ω is the seismic action magnification factor, see Table 11.6.

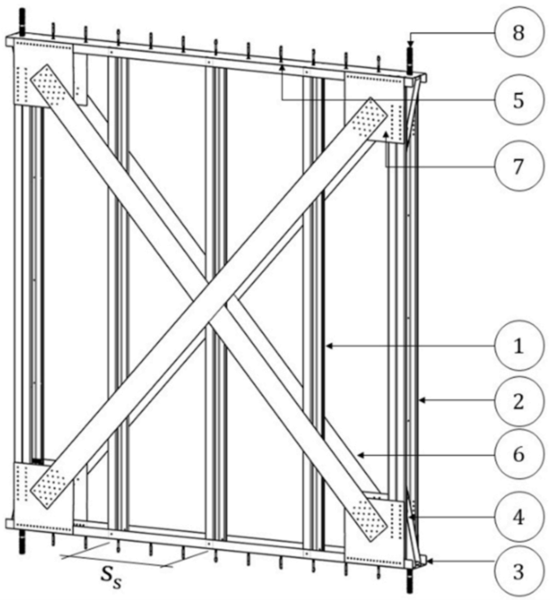




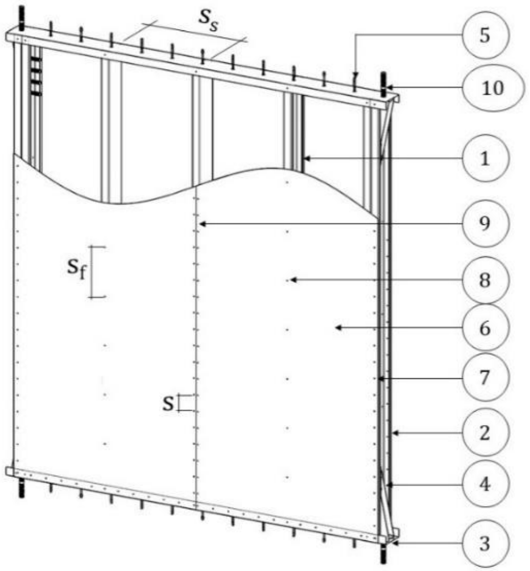
Dissipative component in DC2 and DC3 structures

LFRS	DC2
	Ω
Strap-braced walls	1.5
Shear walls with steel sheet sheathing;	1.5
Shear walls with wood sheathing	1.5
Shear walls with gypsum sheathing	1.3

Design of non-dissipative components for DC3 dissipative lightweight steel systems



$$E_{Ed} = E_{Ed,G} \text{ “}+\text{” } 1{,}1 \cdot \omega_{rm} \cdot E_{Nfy}$$



$$E_{Ed} = E_{Ed,G} \text{ “}+\text{” } k \cdot E_{Rc,Rd}$$

Design of non-dissipative component in Strap braced wall and Shear wall in **DC3**

ANNEX H
Seismic design of exposed and embedded steel and composite column base connections

Annex H: Seismic design of exposed and embedded steel and composite column base connections

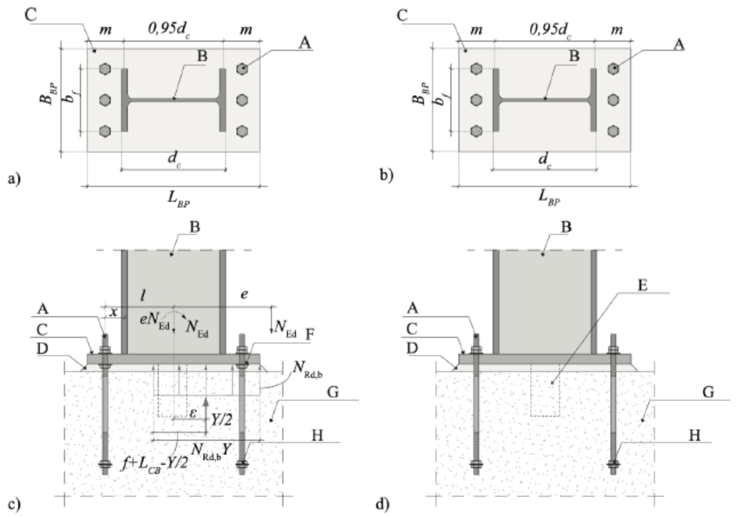
Use of this informative Annex

This Informative Annex provides complementary / supplementary guidance to 11 and 12.

Scope

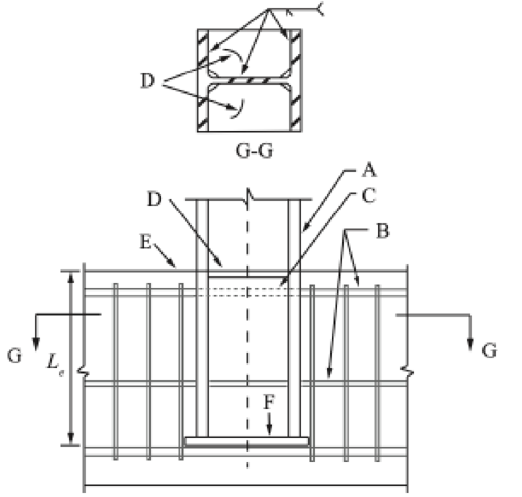
This annex can be used for the design of column base connections retaining moment in steel and/or composite steel - concrete buildings.

NOTE : Free to rotate column bases are not covered by this Annex.



A Anchor rods;
B Column;
C Base plate;
D Grout layer;
E Shear lug;
F Levelling nuts;
G Concrete footin
H Anchoring poin..

Figure H.1 — Schematic representation of exposed column base connection



Key

A Column;
B Horizontal reinforcement;
C Line of horizontal reinforcement;
D Face bearing plates;
E Concrete footing;
F Steel base plate.

Figure H.3 — Typical embedded column base connection detail

Contents

- Introduction
- Specific rules for steel buildings
- **Specific rules for composite steel-concrete buildings**
- Specific rules for aluminum buildings
- Conclusions

Specific rules for composite steel-concrete buildings

EC8 1st Generation

CHAPTER 7:

SPECIFIC RULES FOR COMPOSITE STEEL-CONCRETE BULDINGS

Specific rules for composite steel-concrete buildings

EC8 2nd Generation

CHAPTER 12:
SPECIFIC RULES FOR COMPOSITE STEEL-CONCRETE BULDINGS

Specific rules for composite steel-concrete buildings

EN1998-1 (2004) – Chapter 7

Chapter 7 of EN1998-1 has 26 pages

EN1998-1-2 (2025) – Chapter 12

Chapter 12 of EN1998-1-2 has 27 pages

Evolution of seismic rules

STEEL CHAPTER

EC8 1ST GENERATION
EN 1998-1 (2005) Chapter 7

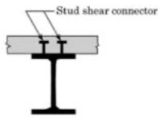
VS

EC8 2ND GENERATION
EN 1998-1-2 (2025) Chapter 12

- Introduction of new design rules for low-moderate/medium ductility (DC2);
- Introduction of new structural types;
- Improvement of seismic design rules for traditional types;
- New Annexes

MAIN NOVELTIES

Specific rules for composite steel-concrete buildings



EN1998-1 (2004) – Chapter 7

Annex C - DESIGN OF THE SLAB OF STEEL-CONCRETE COMPOSITE BEAMS AT BEAM-COLUMN JOINTS IN MOMENT RESISTING FRAMES

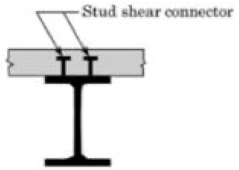
EN 1998-1-2 (2025) Chapter 12

I - DESIGN OF THE SLAB OF STEEL-CONCRETE COMPOSITE BEAMS AT BEAM-COLUMN JOINTS IN MOMENT RESISTING FRAMES

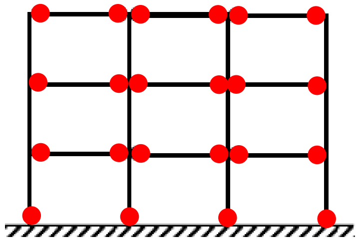
G - DESIGN OF COMPOSITE CONNECTIONS IN DISSIPATIVE COMPOSITE STEEL-CONCRETE MOMENT RESISTING FRAMES

H - SEISMIC DESIGN OF EXPOSED AND EMBEDDED STEEL AND COMPOSITE COLUMN BASE CONNECTIONS

Basis of Design: Structural Types

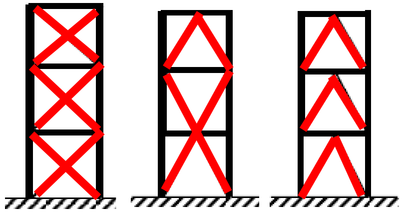


Frames with composite members



Composite MRF

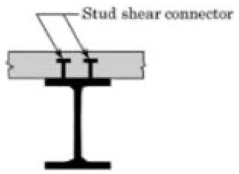
- Steel or composite beams and/or columns
- Full or partial strength connections
- Plastic hinges can form at the ends of the beams and at the bases of the ground columns or in the connections.
- Steel dissipative beams: chapter 11
- Composite dissipative beams: chapter 12
- Steel joints: Annex E to Ch. 11
- Composite joints: annex G to Ch. 12



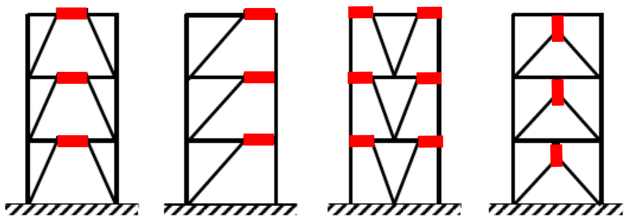
Composite CBF

- Steel or composite beams and/or columns
- Braced steel of filled composite
- Dissipative zones are located in the diagonal members
- Steel dissipative braces: chapter 11
- Composite dissipative braces: chapter 12

Basis of Design: Structural Types

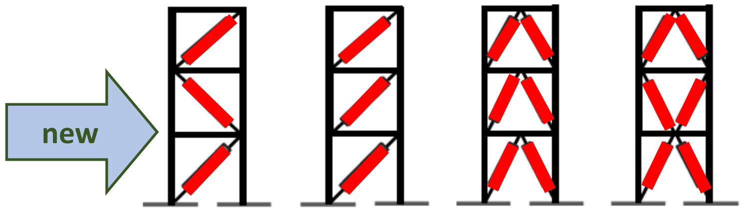


Frames with composite members



Composite EBF

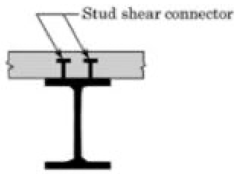
- **Members not containing seismic links may be steel or composite**
- **Dissipative zone are located in the link**
- **Steel dissipative links: chapter 11**



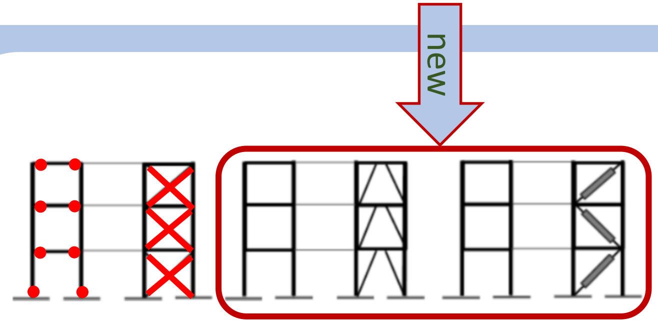
Composite frames with BRB

- **Steel or composite beams and/or columns**
- **Dissipation energy takes place in the BRBs**
- **Design of BRBs: chapter 11**

Basis of Design: Structural Types

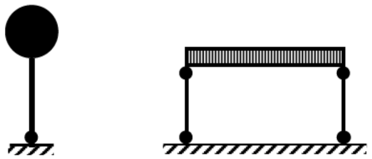


Frames with composite members



Composite Dual frames

- Beams and/or columns may be steel or composite
- Bracings may be steel or filled composite
- Dissipatation energy takes place both in the bracings and MRF part
- Steel dissipative members: chapter 11
- Composite dissipative members: chapter 12



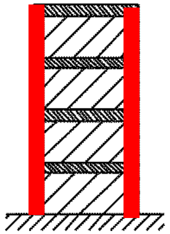
Inverted pendulum

- Steel or composite beams and/or columns
- Dissipation of energy takes place mainly at the base of a single building element or at the bases of columns.
- Steel dissipative members: chapter 11
- Composite dissipative members: chapter 12

Specific rules for composite steel-concrete buildings

Basis of Design: Structural Types

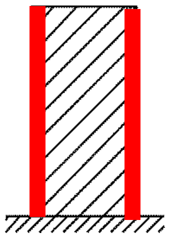
Composite structural wall systems



Type 1

Steel or composite moment frames with connected concrete infill panels

- **Dissipatation energy takes place in the vertical steel sections and in the vertical reinforcement**
- **Composite dissipative vertical members: chapter 12**



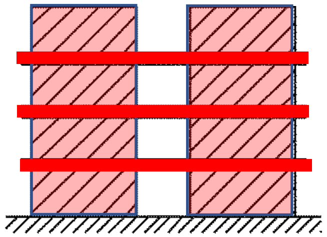
Type 2

Composite walls reinforced by connected encased steel sections

- **Dissipatation energy takes place in the vertical steel sections and in the vertical reinforcement**
- **Composite dissipative vertical members: chapter 12**

Basis of Design: Structural Types

<u>Composite structural wall systems</u>



Type 3

Composite of concrete walls coupled by steel or composite beams

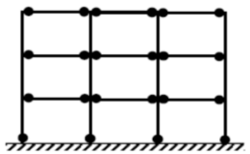
- **Type 3 composite structural wall systems should be designed to dissipate energy in the shear walls and in the coupling beams.**

- **Steel dissipative coupling beams: chapter 11**
- **Composite dissipative coupling beams: chapter 12**
- **Concrete shear walls: chapter 10**

Basis of Design: Structural Types

Frames with dissipative composite members:

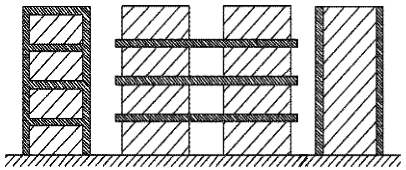
- Composite MRF
- Composite braced frames
- Composite frames with BRBs
- Composite Dual systems
- Composite inverted pendulum



- **Design objectives and global rules are common to those for steel systems, and they are given in Chapter 11**
- **Local rules and technological requirements for composite members are given in Chapter 12**

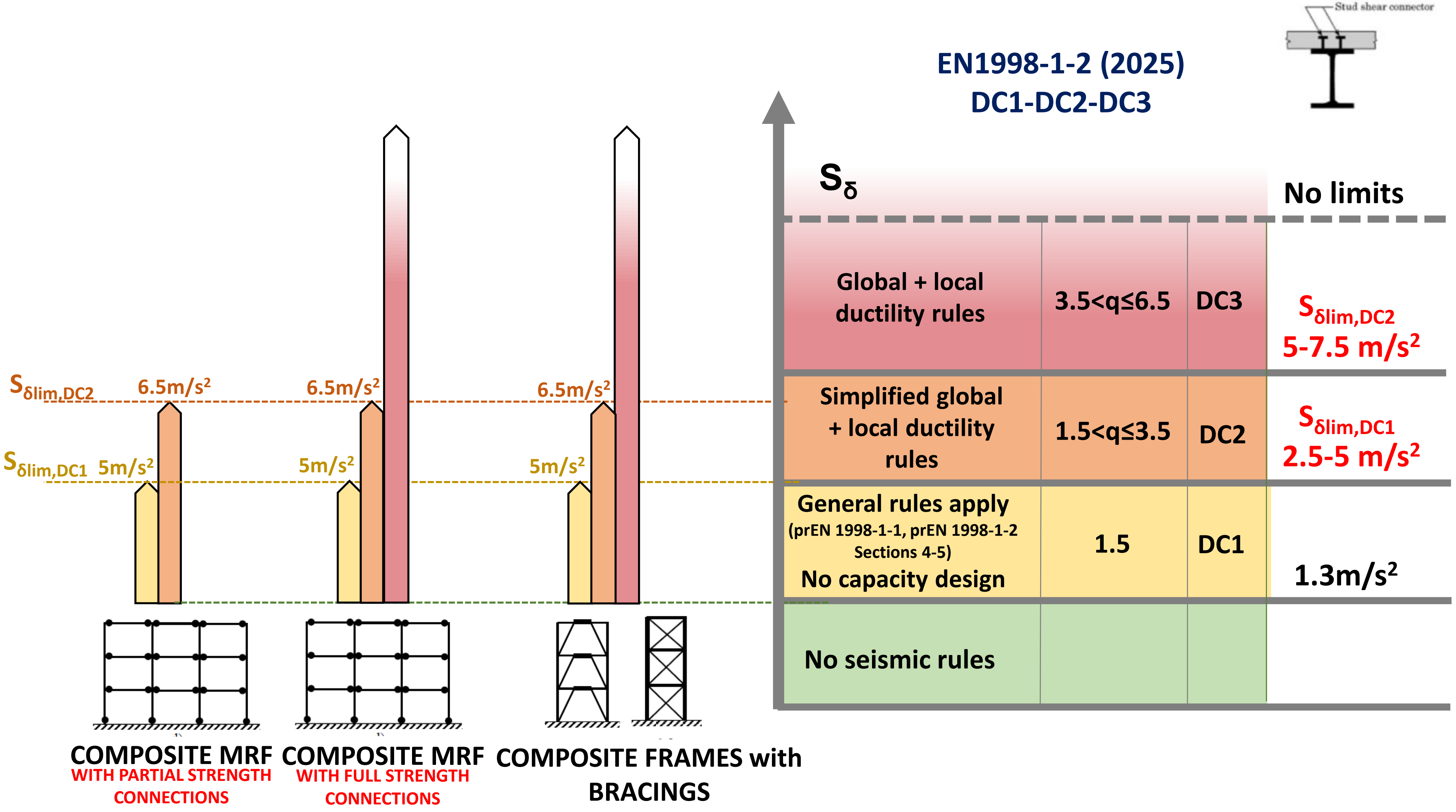
Composite structural wall systems

- Steel or composite moment frames with connected conrete infill panels
- Composite walls reinforced by connected encased steel sections
- Composite of concrete walls coupled by steel or composite beams



- **Design objectives and global rules are given in Chapter 12**
- **Local rules and technological requirements for composite members are given in Chapter 12**

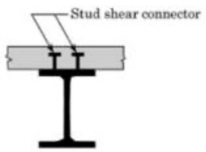
Basis of Design: limits of seismic action

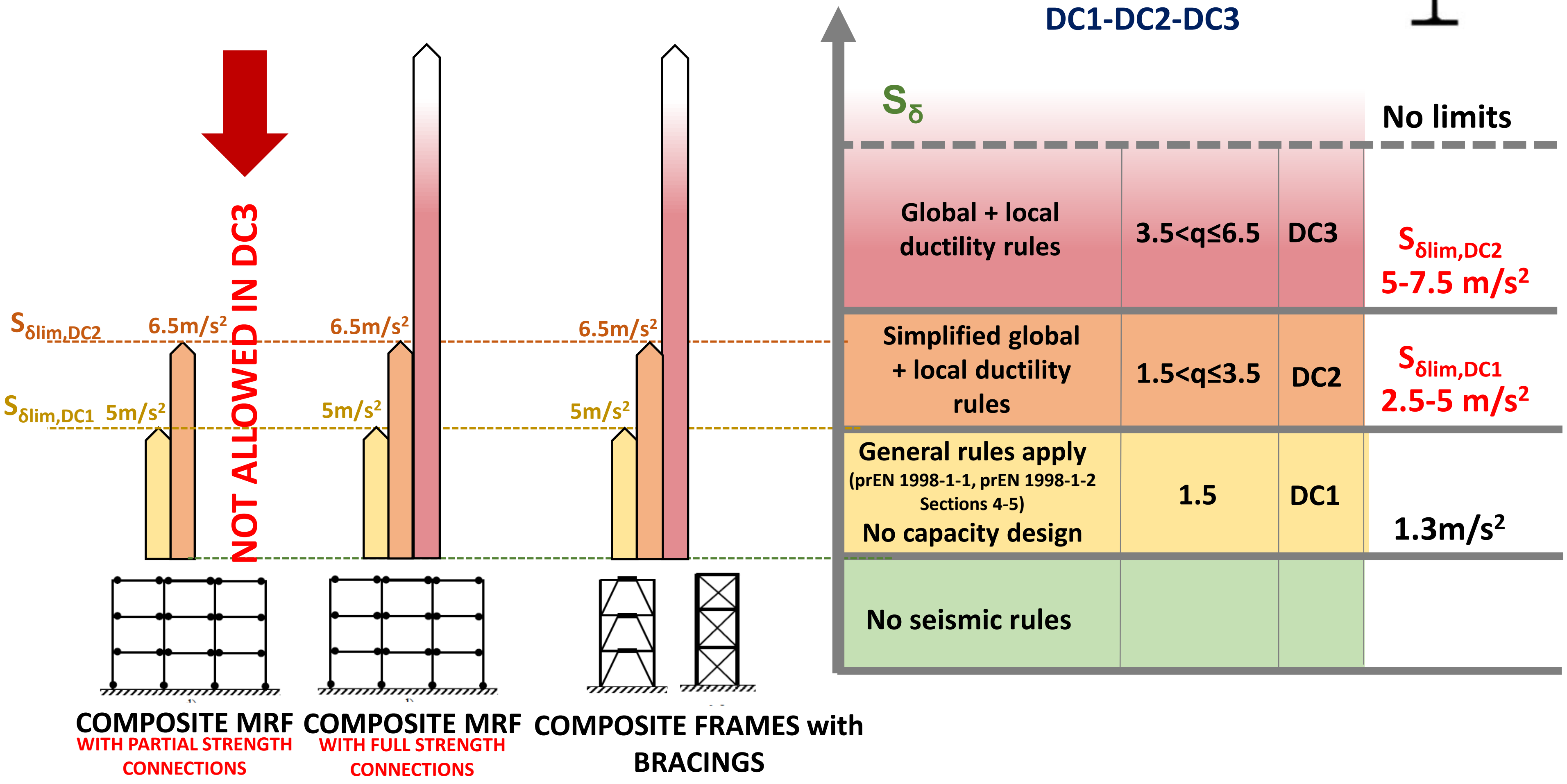


Specific rules for composite steel-concrete buildings

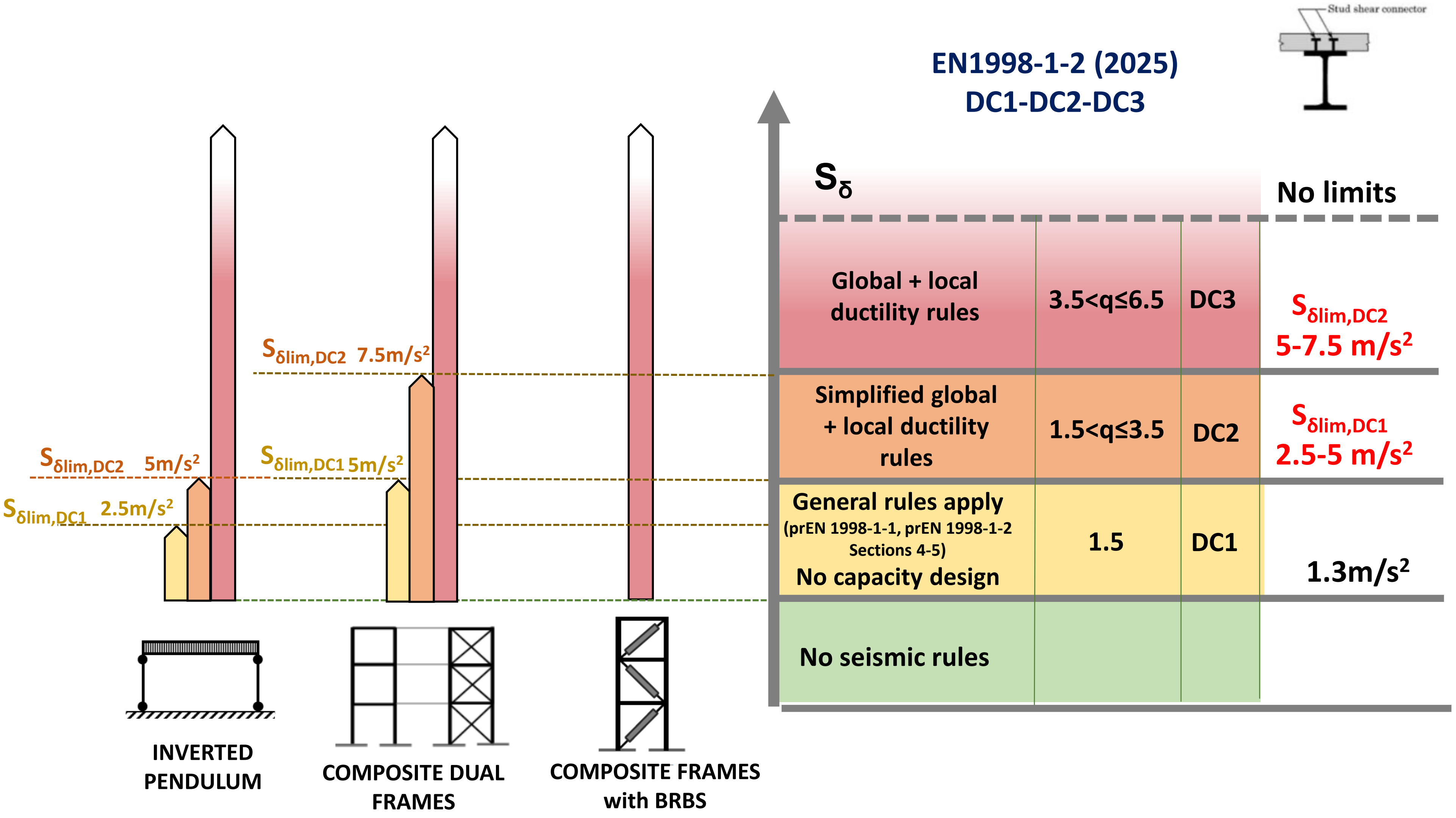
Basis of Design: limits of seismic action

EN1998-1-2 (2025)
DC1-DC2-DC3

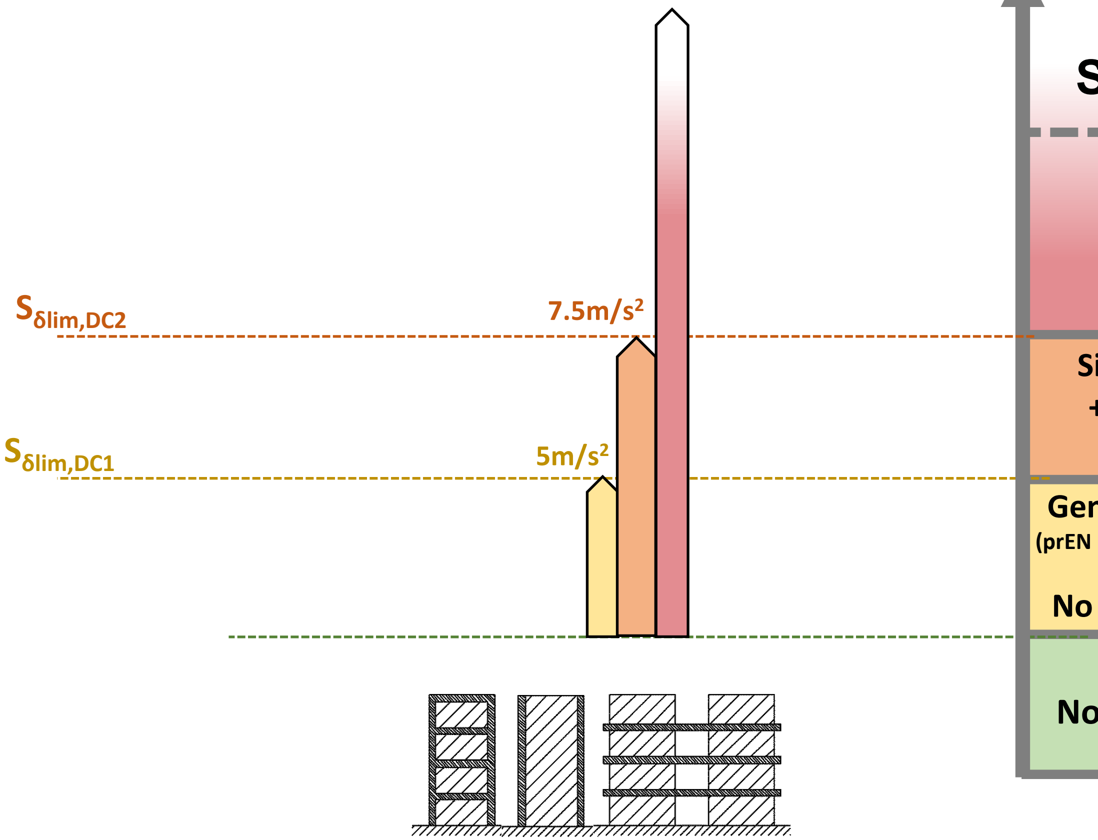




Basis of Design: limits of seismic action

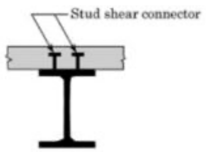


Basis of Design: limits of seismic action



COMPOSITE WALL SYSTEMS

EN1998-1-2 (2025)
DC1-DC2-DC3

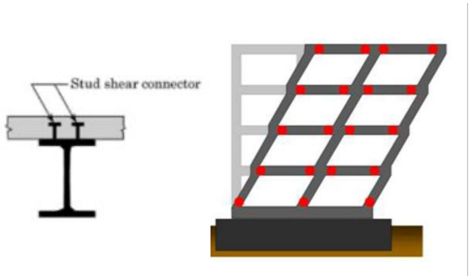


S_δ

			No limits
Global + local ductility rules	$3.5<q\leq6.5$	DC3	$S_{\delta lim,DC2}$ 5-7.5 m/s^2
Simplified global + local ductility rules	$1.5<q\leq3.5$	DC2	$S_{\delta lim,DC1}$ 2.5-5 m/s^2
General rules apply (prEN 1998-1-1, prEN 1998-1-2 Sections 4-5) No capacity design	1.5	DC1	1.3 m/s^2
No seismic rules			

Basis of Design: behaviour factors

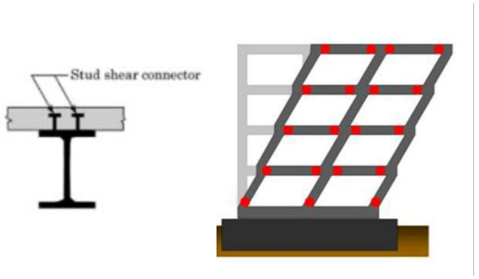
COMPOSITE MRF
FULL STRENGTH CONNECTIONS



EN1998-1		EN1998-1-2	
DCL	*q ≤ 1.5*	*DC1*	*$q = q_s = 1.5$*
DCM	*q = 4*	*DC2*	*q = 2 for portal frame with class 3-4* *q = 3 for portal frame with class 1-2* *q = 3.5 for multi-storey MRF*
DCH	*q = 5.5-6.5*	*DC3*	*q = 5.5 for portal frame with class 1-2* *q = 6.5 for multi-storey MRF*

Basis of Design: behaviour factors

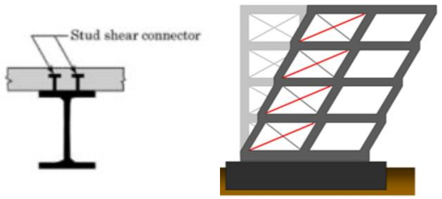
COMPOSITE MRF
PARTIAL STRENGTH CONNECTIONS



EN1998-1			EN1998-1-2	
DCL	*q ≤ 1.5*	→	*DC1*	$q = q_s = 1.5$
DCM	*q = 4*	→	*DC2*	*q = 3.5*
DCH	*q = 5.5-6.5*	→	*DC3*	NOT ALLOWED

Basis of Design: behaviour factors

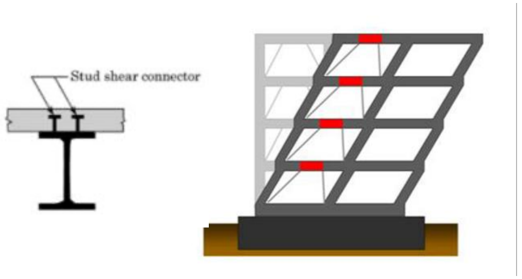
CBF



EN1998-1		EN1998-1-2	
DCL	*q ≤ 1.5*	*DC1*	*$q = q_S = 1.5$*
DCM	*q=2 VCBF* *q=4 XCBF*	*DC2*	*q = 2.5 for all types*
DCH	*q=2.5 VCBF* *q=4 XCBF*	*DC3*	*q=4 for all types*

Basis of Design: behaviour factors

EBF



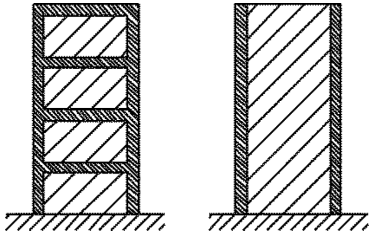
EN1998-1		EN1998-1-2	
DCL	*q ≤ 1.5*	*DC1*	$q = q_S = 1.5$
DCM	*q=4*	*DC2*	$q = 3.5$
DCH	*q=5-6*	*DC3*	$q = 6$

Basis of Design: behaviour factors

EN1998-1			EN1998-1-2	
DCL	$q \leq 1.5$	→	*DC1*	$q = q_S = 1.5$
DCM	$q=3.3$	→	*DC2*	$q = 3.5$
DCH	$q=4.4$	→	*DC3*	$q=4.5$

$*\alpha_u/\alpha_1=1.1$

Composite structural Systems

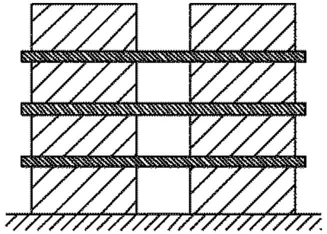


type 1 and 2

Basis of Design: behaviour factors

EN1998-1			EN1998-1-2	
DCL	*q ≤ 1.5*	→	*DC1*	$q = q_S = 1.5$
DCM	*q=3.3*	→	*DC2*	$q = 3.5$
DCH	*q=4.95*	→	*DC3*	$q=5$

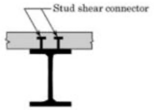
Composite structural Systems



type 3

$^*\alpha_u/\alpha_1=1.1$

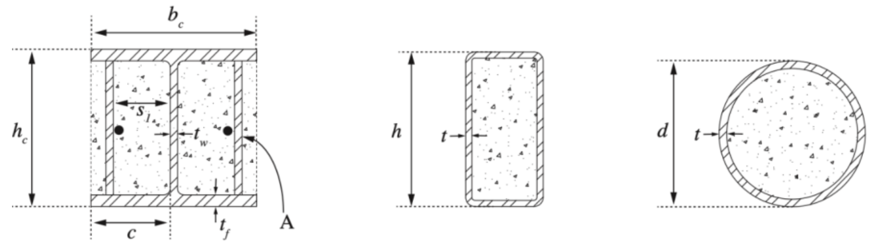
Basis of Design: local slenderness limit



Local slenderness limits for composite members

EN-1998-1 (2004)

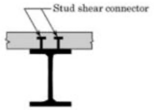
$$\varepsilon = (235/f_y)^{0,5}$$



(a) (b) (c)

Ductility class	DCM		DCH
Reference value of behaviour factor	q = 1,5-2	1,5 −2 < $q \leq 4$	$q > 4$
Partially or fully encased H- or I-cross section: c/t_f limits:	20ε	14ε	9ε
Filled rectangular cross section: h/t limits:	52ε	38ε	24ε
Filled circular cross section: d/t limits:	$90\varepsilon^2$	$85\varepsilon^2$	$80\varepsilon^2$

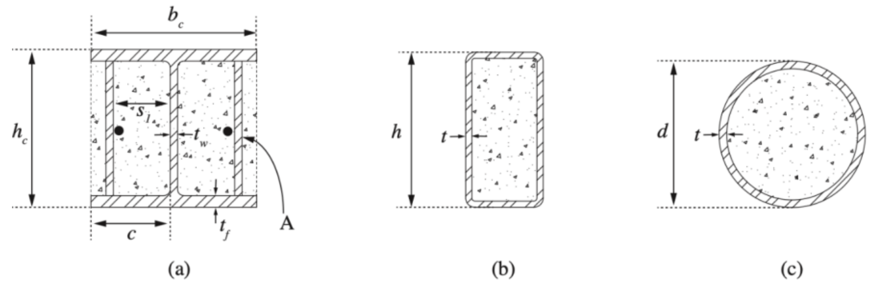
Basis of Design: required cross sectional classes



Local slenderness limits for composite members

EN 1998-1-2 (2025)

$$\varepsilon = (235/f_y)^{0,5}$$



Ductility class	DC2		DC3
Reference value of behaviour factor	$q = 1,5$	$1,5 < q \leq 3,5$	$q > 3,5$
Partially or fully encased H- or I-cross section: c/t_f limits:	20ε	14ε	9ε
Filled rectangular cross section: h/t limits:	**70ε**	**52ε**	**35ε**
Filled circular cross section: d/t limits:	**$125\varepsilon^2$**	**$90\varepsilon^2$**	$80\varepsilon^2$

SLIGHTLY LESS STRINGENT

Structural analysis: drift limitation

Verification of drift

EN-1998-1 (2004)

At Damage Limitation state the interstorey drift should be verified as follows

$$d_r \leq \alpha h$$

where α = 0.005; 0.0075; 0.01 depeding on the non−structural elements

EN-1998-1-2 (2025)

No mandatory check at Damage Limitation.
At Significant Damage limit state should be verified as follows:

$$d_r \leq \lambda h$$

where λ= 0.01; 0.015; 0.017; 0.02 depeding on the structural system

Capacity design: general rules

Capacity design rules: DCM VS DC2

EN-1998-1 (2004) DCM and DCH	**EN-1998-1-2 (2025) DC2**
$R_d \geq E_{Ed,G} + 1.1 \cdot \gamma_{ov} \cdot \Omega \cdot E_{Ed,E}$ $\Omega = \min\left(\frac{R_d}{E_{Ed}}\right)$	$M_{Rd} \geq M_{Ed,G}" + "M_{Ed,E}$ $V_{Rd} \geq V_{Ed,G}" + "V_{Ed,E}$ $N_{Rd} \geq N_{Ed,G}" + "\Omega \cdot N_{Ed,E}$ $\Omega =$ from the Table 12.5

In current DCM all seismic induced effects are magnified
In new DC2 only axial forces are magnified

Specific rules for composite steel-concrete buildings

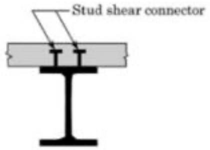


Table 12.5 — Members to which (1) or (2) should be applied. Values of seismic action magnification factor Ω for structural types in DC2

Structural types	Ω	Members
Composite moment resisting frames (CMRFs): With full-strength connections	See Table 11.7	Columns
With partial-strength connections	2,0	Columns
Composite frames with concentric bracings	See Table 11.7	Beams and columns
Composite frames with eccentric bracings	See Table 11.7	Beams outside the link, braces and columns
Composite inverted pendulum structures	See Table 11.7	Columns
Composite dual frames CMRFs with concentric bracings CMRFs with eccentric bracings	See Table 11.7	Beams and columns of the concentric bracing; columns of the CMRF Beams outside the link, braces and oclumns of the eccentricl bracing; columns of the CMRF
Composite structural wall systems	2,0	None
Types 1, 2 and 3		None

Capacity design: general rules

Capacity design rules: DCH VS DC3

EN1998-1 (2004) DCM and DCH	EN1998-1-2 (2025) DC3
$R_d \geq E_{Ed,G} + 1.1 \cdot \gamma_{ov} \cdot \Omega \cdot E_{Ed,E}$	$R_d \geq E_{Ed,G} + \omega_{rm} \cdot \omega_{sh} \cdot \Omega_d \cdot E_{Ed,E}$
$\Omega = \min\left(\frac{R_d}{E_{Ed}}\right)$	$\Omega_d = \min\left(\frac{R_d}{E_{Ed,E}}\right)$
	ω_{sh} From Table 11.8
	ω_{rm} material randomness coefficient

In new DC3 the hardening factor is specified per dissipative mechanism

Specific rules for composite steel-concrete buildings

Table 11.8 — Overstrength factor ω_{sh} accounting for hardening of the dissipative zones

Structural Type	Dissipative Zones	Plastic Mechanism	ω_{sh}
Moment resisting frames	beams	bending	$\frac{(f_y + f_u)}{2f_y} \leq 1{,}2$
	yielding connections		
	columns at base		
	friction connections	friction	$1{,}3\omega_{sr}\omega_{\mu} \leq 2{,}2$ ω_{sr} and ω_{μ} as defined in Annex E
Frames with concentric bracings (simple and dual)	diagonal members	axial	1,1
	all members	bending (see **11.10.5** and **11.10.6**)	1,1
	dissipative connections	axial	1,1
		bending	1,2
		shear	1,5
Frames with eccentric bracings (simple and dual)	short links	shear $e \leq M_{p,link}/V_{p,link}$ (very short links)	1,8
		shear $M_{p,link}/V_{p,link} < e \leq 1{,}6M_{p,link}/V_{p,link}$ (short links)	1,5
	intermediate links	bending and shear $e \leq 2{,}6M_{p,link}/V_{p,link}$	1,5
		bending and shear $2{,}6M_{p,link}/V_{p,link} < e \leq 3M_{p,link}/V_{p,link}$	1,35
	long links	Bending $3M_{p,link}/V_{p,link} < e \leq 5M_{p,link}/V_{p,link}$	1,25
		Bending $e > 5M_{p,link}/V_{p,link}$	$\omega_{sh} = \frac{(f_y + f_u)}{2f_y} \leq 1{,}2$
	beams - columns	bending (see **11.11.5**)	1,1
Frames with buckling restrained braces	diagonal members	axial	see 11.12.3(4)
	beams - columns	bending (see **11.12.6**)	1,2

Additional rules and technological requirement for composite members

BEAM

- **Composite steel Beams with slab**
- Lateral torsional restraint
- Shear connection grade
- Slab effective width for plastic reistance (b_{eff})
- Ductility of composite beam with slab (zc/dc)
- Seismic rebar
- Condition for disregarding the composite action of beams with slab

COLUMN

- **Encased columns**
- Length and location of critical regions
- Spacing s of confining hoops within critical regions
- Diameter of the hoop
- Distance between consecutive longitudinal bars
- **Partially-encased columns**
- Detail of welding of longitudinal bars to straigth links
- Diameter of straigth links
- Clear concrete cover of straigth links
- **Filled columns**
- Reinfocing steel contribution ratio
- Shear resistance of dissipative and non-dissipative filled composite columns.

Small differences between EN 1998-1 (2004) and EN 1998-1-2 (2025)

- **Connections NEW ANNEXES G, H**

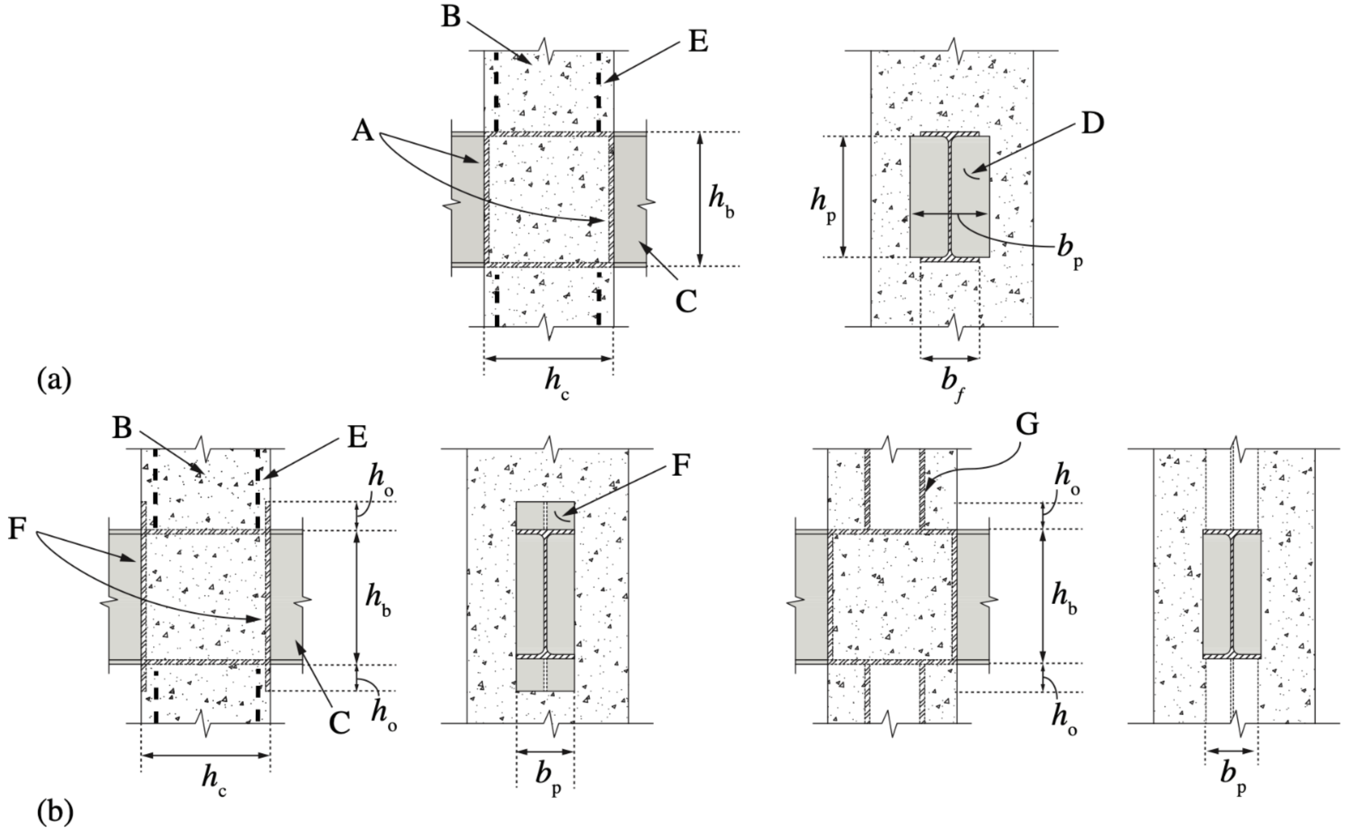
Annex G
DESIGN OF COMPOSITE CONNECTIONS IN DISSIPATIVE COMPOSITE STEEL-CONCRETE MOMENT RESISTING FRAMES

Scope

This annex should be used for the design, fabrication and quality criteria of **full-strength composite connections** of dissipative composite steel or steel beams to composite or concrete columns in composite steel - concrete moment resisting frames designed to DC2 and DC3.

Annex G: Design of composite connections in dissipative composite steel-concrete moment resisting frames

Joints between steel beams and reinforced concrete or composite columns

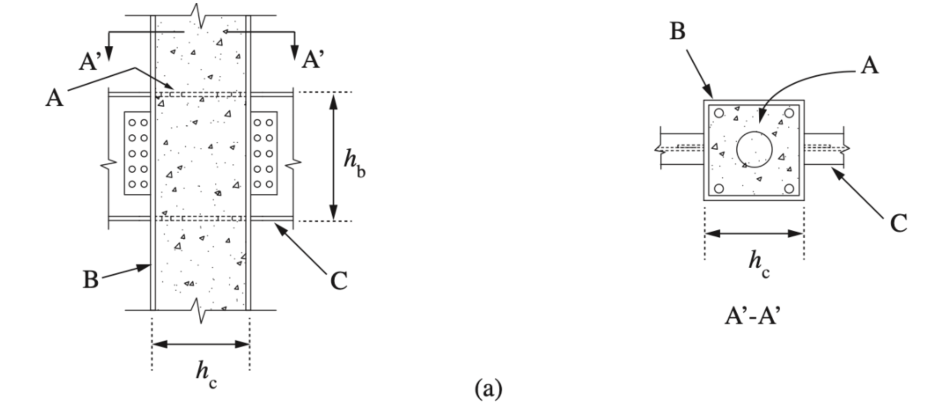


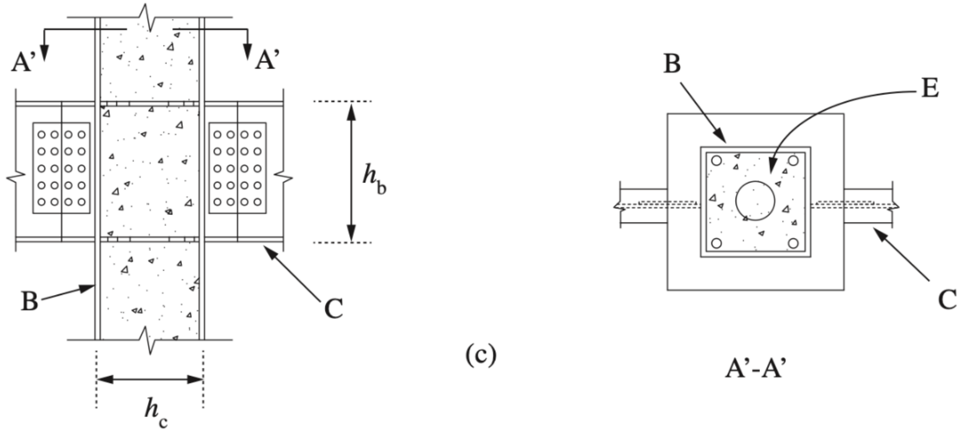
Key

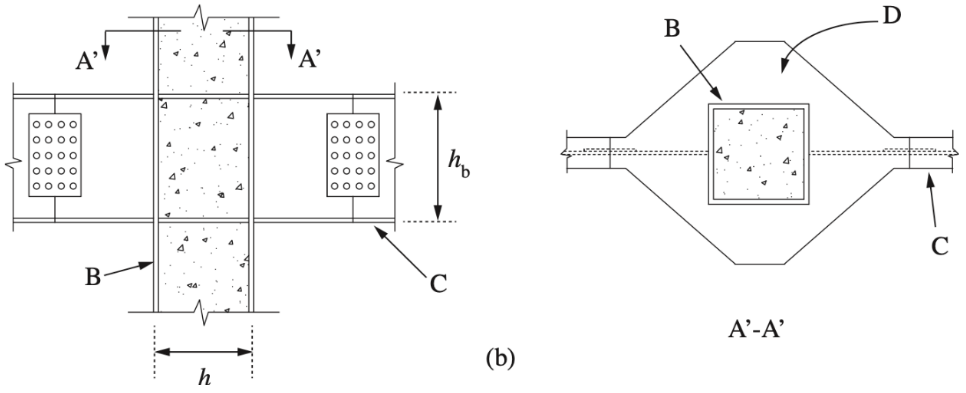
A	Face bearing plates;
B	Column;
C	Steel or composite beam;
D	Wide face bearing plate;
E	Vertical reinforcement bars;
F	Extended face bearing plates;
G	Structural steel profile;

Annex G: Design of composite connections in dissipative composite steel-concrete moment resisting frames

Composite joints using diaphragm plates





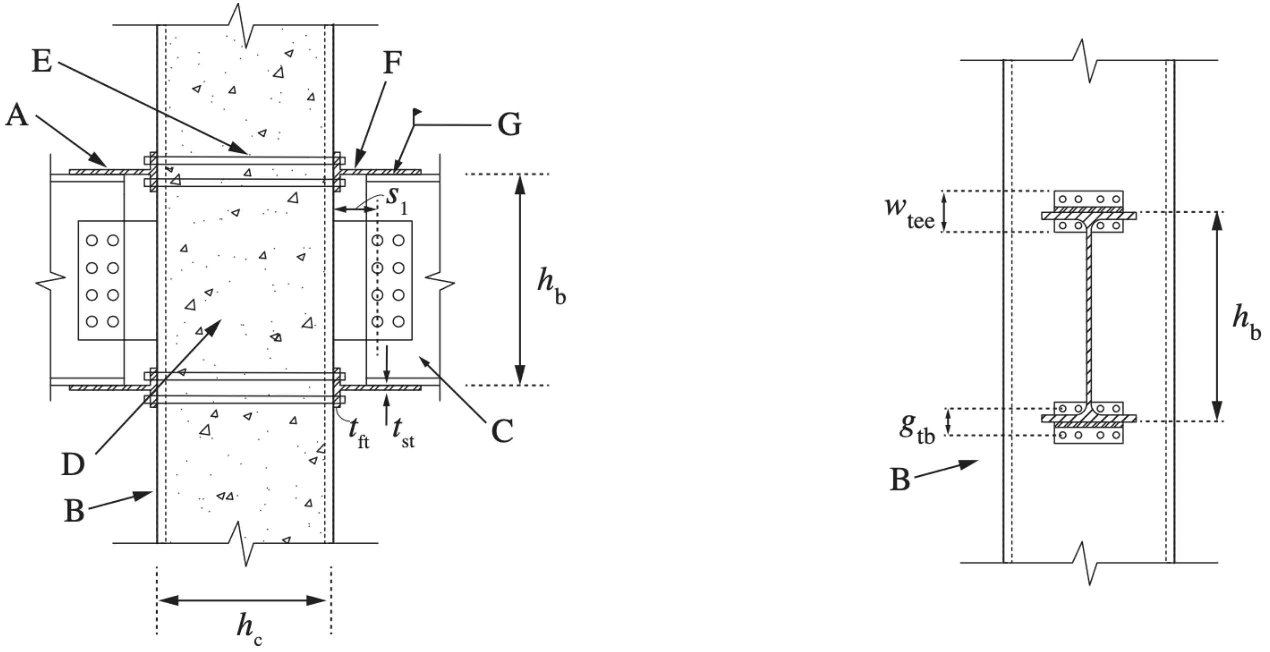


Key

A	Internal diaphragm plate;
B	Concrete-filled tube;
C	I-shape beam;
D	External diaphragm plate;
E	Through diaphragm plate.

Annex G: Design of composite connections in dissipative composite steel-concrete moment resisting frames

Full-strength composite joints with double-split tee connections in concrete filled tube columns



(a) (b)

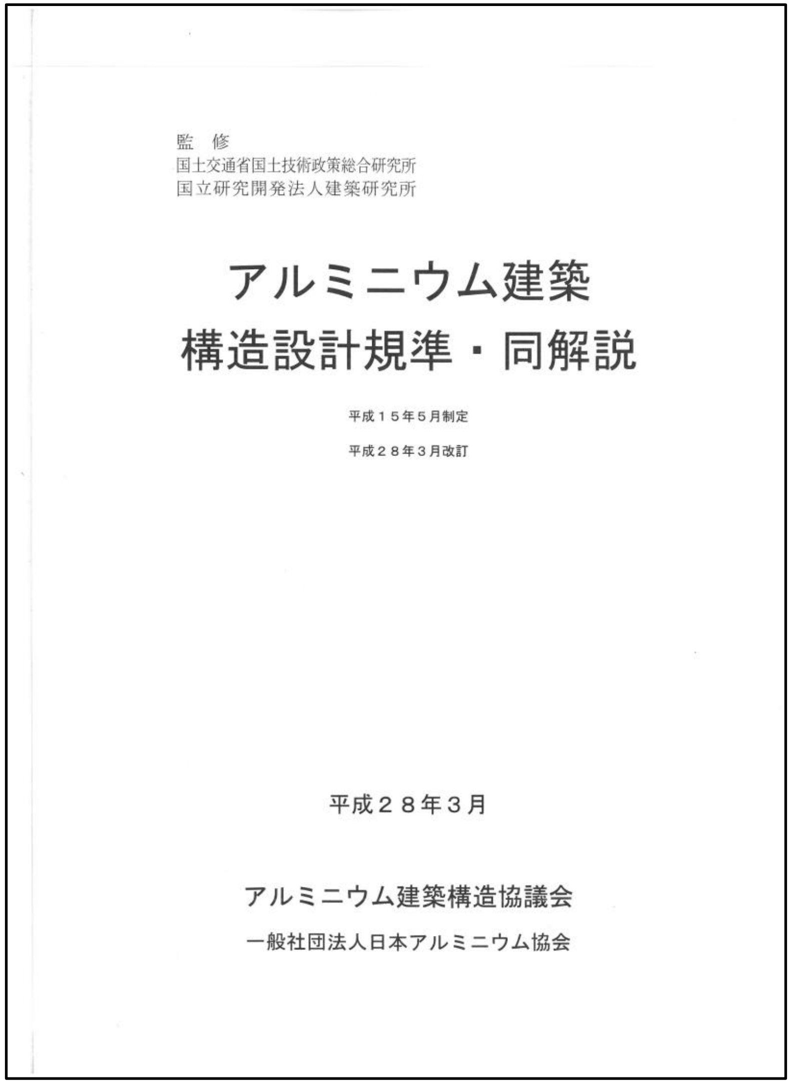
A Tee-stub;
B Concrete-filled tube;
C Steel beam;
D Web panel joint;
E Structural bolt;
F Compressive length of tee-stub;
G Fillet weld of tee-stub to the steel beam flange.

Contents

Specific rules for aluminium buildings

Background

The most of rules about materials, connections and hiearchy are derived from Japanese seismic recommendantions on Aluminum structures



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アルミニウム建築
構造設計規準・同解説

平成１５年５月制定
平成２８年３月改訂

平成２８年３月

アルミニウム建築構造協議会
一般社団法人日本アルミニウム協会

Specific rules for aluminium buildings

Evolution of seismic rules

ALUMINUM CHAPTER

EC8 1ST GENERATION
NO SEISMIC RULES

VS

EC8 2ND GENERATION
EN 1998-1-2 (2025) Chapter 15

MAIN NOVELTIES

- Introduction of new seismic design rules for aluminum structures missing in the previous EC8
- Japanese seismic code constituted the background for new seismic design procedure
- Design rules solely for DC2 are provided.

Specific rules for aluminium buildings

EC8 2nd Generation

CHAPTER 15:

SPECIFIC RULES FOR ALUMINIUM BULDINGS

Specific rules for steel buildings

EN1998-1 (2004)

No Aluminium Structures

EN1998-1-2 (2025) – Chapter 15

Chapter 15 of EN1998-1-2 has 10 pages

Specific rules for aluminium buildings

Basis of Design: Structural Types

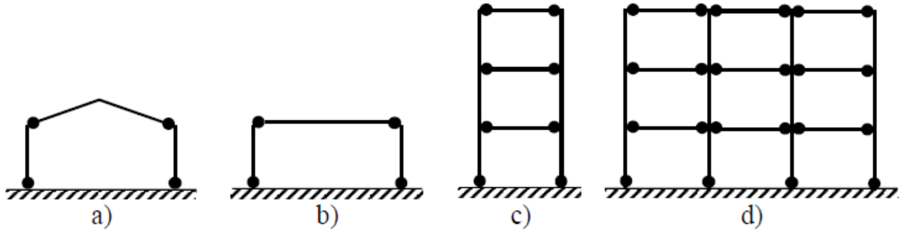


Figure 11.1 — Moment resisting frames (dissipative zones in beams and at bottom of columns): a) portal frame; b) single-storey MRF; c) single-span multi-storey MRF; d) multi-span multi-storey MRF

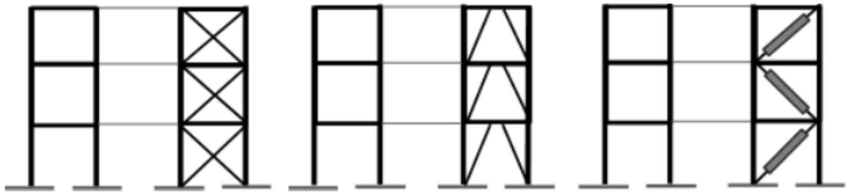


Figure 11.6 — Dual frames with moment resisting frame combined with either concentric, eccentric or buckling restrained bracing (dissipative zones in both moment and braced frames)

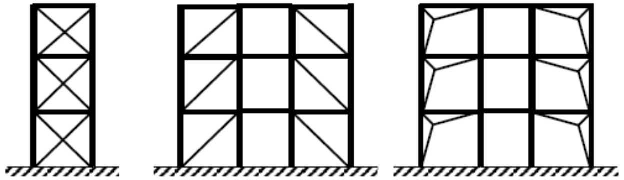


Figure 11.2 — Frames with concentric bracings where the concept of tension-only diagonals is allowed

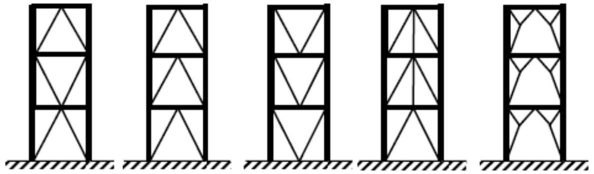
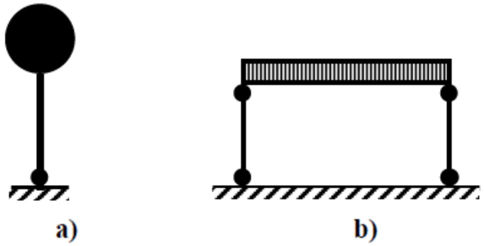


Figure 11.3 — Frames with concentric bracings where the concept of tension-compression diagonals is mandatory

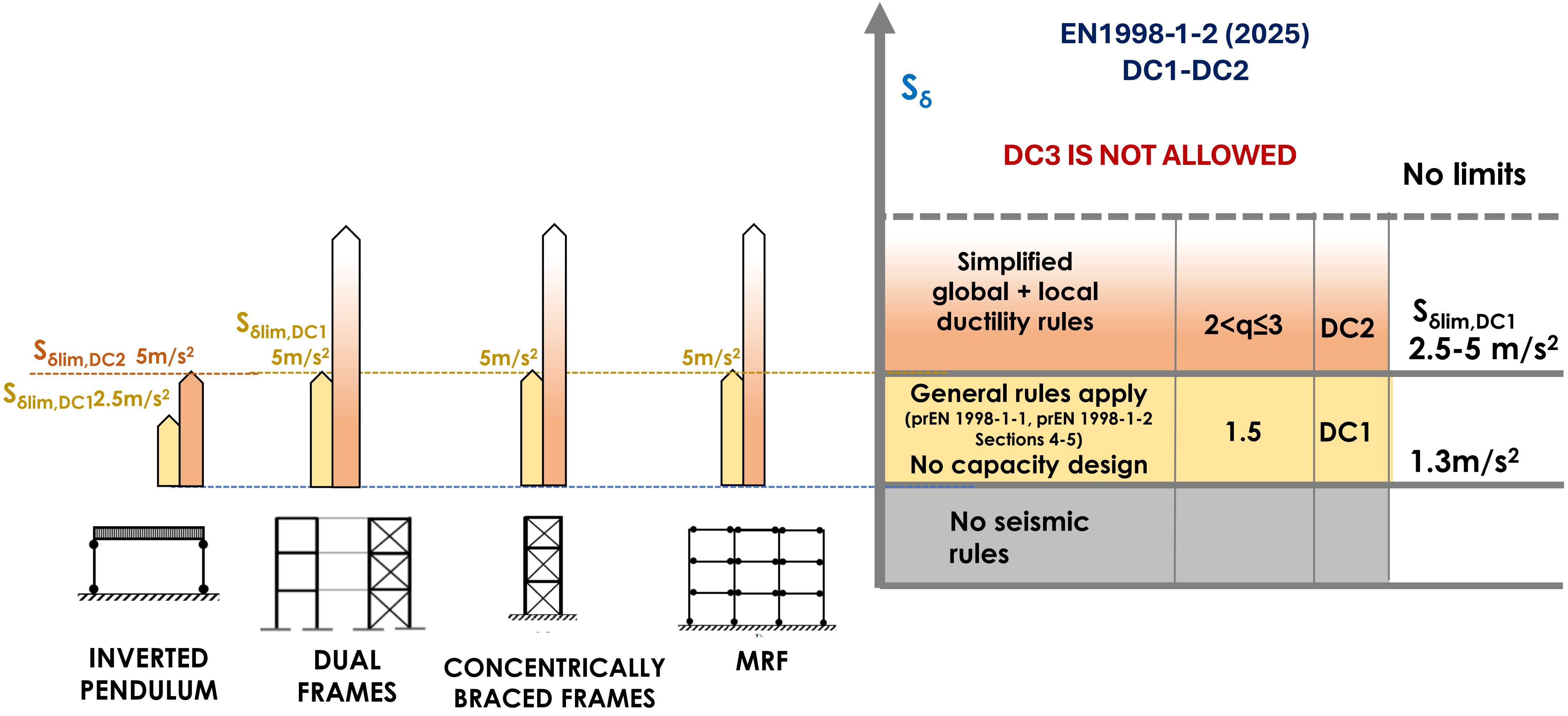


igure 11.8 — Inverted pendulum: a) dissipative zones at the column base; b) dissipative zones in columns ($N_{Ed,G}/N_{pl,Rd} \geq 0,3$)

EBFS ARE NOT ALLOWED

Specific rules for aluminium buildings

Basis of Design: limits of seismic action



Basis of Design: behaviour factors

	Ductility Class		
STRUCTURAL TYPE	DC2		
	q_D	q_R	q
Moment resisting frames (MRFs) Single-storey MRFs Multi-storey MRFs	 1,5 1,5	 1,1 1,3	 2,5 3,0
Frames with concentric bracings Diagonal bracings V-bracings X-bracings on either single or two-storey	1,5	1,0	2,3
Dual frames (MRFs with concentric bracing)	1,7	1,2	3,0
Inverted pendulum	1,3	1,0	2,0

Specific rules for aluminium buildings

Material

Permitted alloys and temper for dissipative parts in DC2

Structural element	Product form	alloy	temper	thickness
Sheet, strip and plate	-	5052	H12 | H22/H32	≤40
		5049	O / H111	≤100
		5083	O/H111	≤80
		5383	O/H111	≤120
			H116/H321	≤80
		5454	O/H111	≤80
		5754	O/H111	≤100
		6061	T4 / T451	≤12,5
		6082	T4 / T451	≤12,5
Extruded profiles, extruded tube, extruded rod/bar and drawn tube	ET,EP,ER/B	5083	O/H111 F/H112	≤200
	ET,EP,ER/B	5454	O/H111 F/H112	≤25
	ET,EP,ER/B	5754	O/H111 F/H112	≤25
	DT	6060	T6	≤20
	EP,ET,ER/B		T64	≤15
	EP,ET,ER/B	6061	T4	≤25
	DT		T4	≤20
	EP,ET,ER/B	6082	T4	≤25

Legend:
EP- Extruded profiles ET- Extruded tube
ER/B- Extruded rod and bar DT- Drawn tube

Alloys different from those specified in Table 15.2 may be used, provided that the ratio f_u/f_0 is not smaller than 1,10 and the elongation at failure is not smaller than 10%

where $\mathbf{f_u}$ is the ultimate tensile strength and $\mathbf{f_0}$ is the conventional elastic strength

Specific rules for aluminium buildings

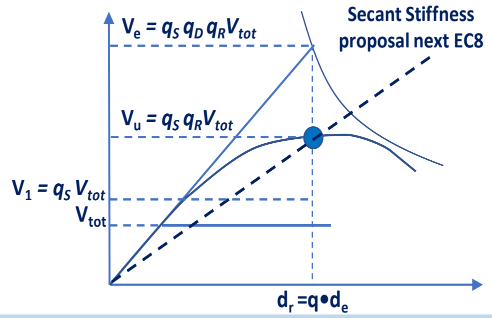
Structural analysis: second order effects and drift limitation

Deformation-related requirements

Second order effects

Modified stability coefficient based, which account for design overstrength and the plastic distribution

$$\theta = \frac{P_{tot} \cdot d_r}{q_s \cdot q_R \cdot V_{tot} \cdot h}$$



Interstorey drift

The interstorey drift at SD limit state should be limited to:

a) $d_{r,SD} \leq 0{,}02\ h$ for moment frames;

b) $d_{r,SD} \leq 0{,}015\ h$ for frames with concentric bracings, for dual frames and inverted pendulum structures;

Specific rules for aluminium buildings

Capacity design: general rules

For aluminum systems DC2 all seismic induced effects are magnified

EN1998-1-2 (2025) DC2

$$M_{Rd} \geq M_{Ed,G} " + " \Omega \cdot M_{Ed,E}$$

$$V_{Rd} \geq V_{Ed,G} " + " \Omega \cdot V_{Ed,E}$$

$$N_{Rd} \geq N_{Ed,G} " + " \Omega \cdot N_{Ed,E}$$

$\Omega =$ from the Table 15.5

Capacity design: general rules

Table 15.5 — Members to which (1) apply. Values of seismic action magnification factor Ω in DC2

STRUCTURAL TYPE	Ω	Members to which (1) apply
Moment resisting frames (MRFs)		
Single-storey MRFs	1,8	columns
Multi-storey MRFs	2,0	
Frames with concentric bracings		
Diagonal bracings V-bracings X-bracings on either single or two-storey	1,5	beams and columns
Dual frames (MRFs with concentric bracing)	2,0	beams and columns of the concentric bracing; columns of the MRF
Inverted pendulum	1,5	columns

Specific rules for aluminium buildings

Capacity design: general rules

Rules for connections in dissipative zones

The general rules for non dissipative connections is similar to the steel structures, namely:

$$R_d \geq \omega_{rm} \cdot \omega_{sh} \cdot R_{fo}$$

where:

R_d is the resistance of the connection in accordance with EN 1999-1-1;

R_{f0} is the plastic resistance of the connected dissipative member evaluated in the expected position of the plastic hinge and based on the nominal conventional elastic strength of the material as defined in EN 1999-1-1;

$\boldsymbol{\omega_{rm}}$ **is the overstrength factor accounting for variability of f_0 in the dissipative zones**. In absence of experimental characterization of the material in the dissipative zones, ω_{rm} can be assumed equal to 1.5;

$\boldsymbol{\omega_{sh}}$ **is the overstrength factor accounting for the hardening in the dissipative zones.**

ω_{sh} =1.3 For elements in plastic bending, or the value calculated in accordance with Annex L of EN1999-1-1, whichever is greater;

ω_{sh} =1.5 For elements in plastic tension: as 1,5 or the ratio $\frac{f_u}{f_o}$, whichever is greater

Contents

Conclusions

- The new Eurocode 8 is significantly changed as respect to the current EN1998-1(2004) regarding both general (EN 1998-1-1) and new buildings (EN 1998-1-2) rules;

- With reference to steel, steel-concrete composite and aluminum structures, the contribution provided by the joint committee SC8/WG2-ECCS/TC13 was fundamental, and it provided the scientific background for all the proposed changes;

- The new Chapter (11) on steel structures and Chapter (12) on steel-concrete composite structures are significantly improved and more complete: many criticisms have been eliminated, as well as new structural types, such as the BRB and light structures, have been included. The introduction of seismic prequalification of beam-to-column joints represents one of the most important novelties;

- The new Chapter (15) on aluminum structures is one of the major novelties of EN19981-2 (2025), being the first set of rules in Europe for seismic design of aluminum structures;

- In the near future, wide use of the new rules is expected, by application in both scientific and professional communities.

EC8-2G

Il nuovo standard europeo per la progettazione sismica

Materiali e tipologie costruttive

EN1998-1-2. Strutture metalliche e composte acciaio-cls

Thank You

for your kind attention

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Pavia - 5 Giugno 2025