EC8 Webinars

Second Generation of Eurocode 8

Steel Buildings and Aluminum Buildings

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- Introduction
- Seismic design of Steel Buildings in the prEN1998-1-2
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- Conclusions

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INTRODUCTION
Background

CEN/TC 250/SC 8 – WG2

ECCS CECM EKS
European Convention for Constructional Steelwork
TC 13 SEISMIC DESIGN

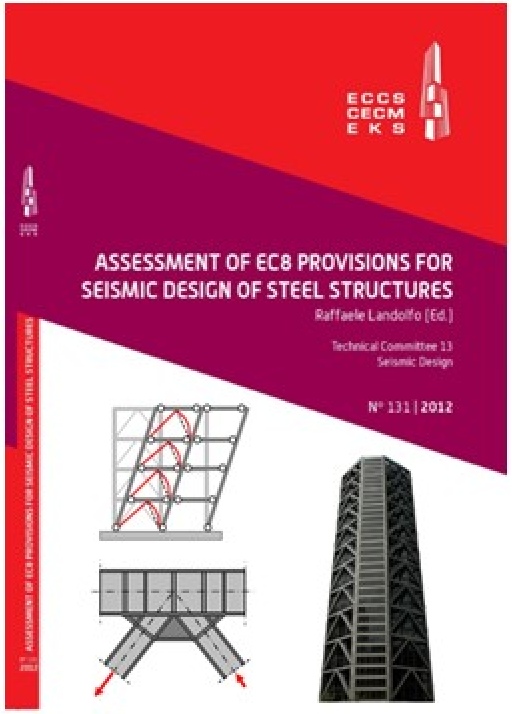
- The seismic design rules for **STEEL** and **ALUMINUM** structures codified within the **2nd generation of EC8** have been developed by **PT2**, strongly supported by the **joint committee CEN/TC250/SC8-WG2 and ECCS-TC13**
- The **WG2** is the Working Group of **SC8** dealing with **steel, composite and aluminium** structures
- The **TC13** is the Technical Committee set up within **ECCS** dealing with **seismic design**
- The aim of **ECCS is to promote the use of steelwork in the construction sector** by the development of standards and promotional information
- It also helps to influence decision makers through the management of **working committees**, **publications**, **conferences**, and by active representation on European and **International Committees dealing with standardisation**, research and development and education

INTRODUCTION

THE EFFORTS 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*



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SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Evolution of seismic rules

STEEL CHAPTER →

EC8 1ST GENERATION
EN 1998-1 (2005) Chapter 6

VS

EC8 2ND GENERATION
prEN 1998-1-2 (2022) Chapter 11

- **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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Table of contents

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Current EN1998-1 – Chapter 6

chapter 6 of current EC8 has 23 pages

prEN-1998-1-2 (2022) – Chapter 11

The number of pages of the last draft of Chapter 11 is 40 pages

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Current EN1998-1 – Chapter 6	prEN-1998 -1-2 (2022) – 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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Current EN1998-1 – Chapter 6	prEN1998-1-2 (2022) – Chapter 11
Structural systems: MRFs CBFs EBFs Dual Frames	Structural systems: MRFs CBFs EBFs BRBFs Dual Frames Light weight structures

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

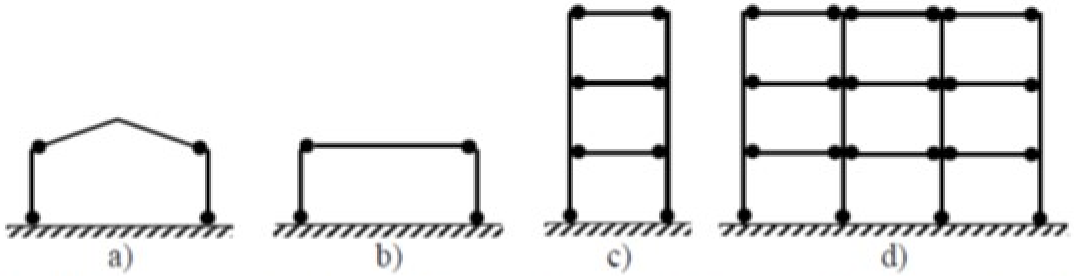


Figure 11.1 — Moment resisting frames (dissipative zones in beams and at bottom of columns): a) portal frame; b) single-storey MRF; c) single-span multi-storey MRF; d) multi-span multi-storey MRF

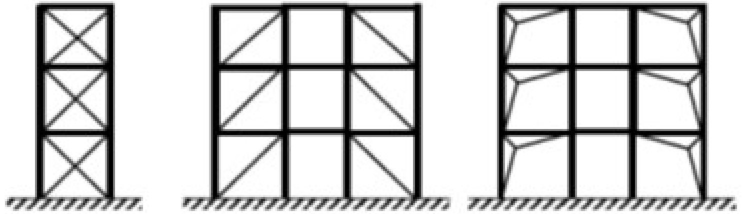


Figure 11.2 — Frames with concentric bracings where the concept of tension-only diagonals is allowed

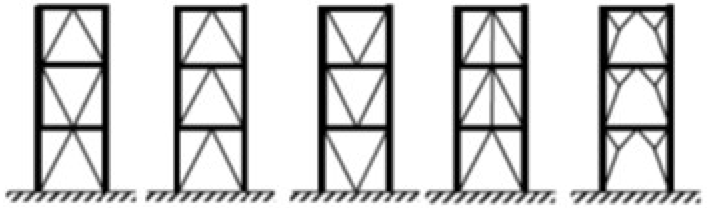
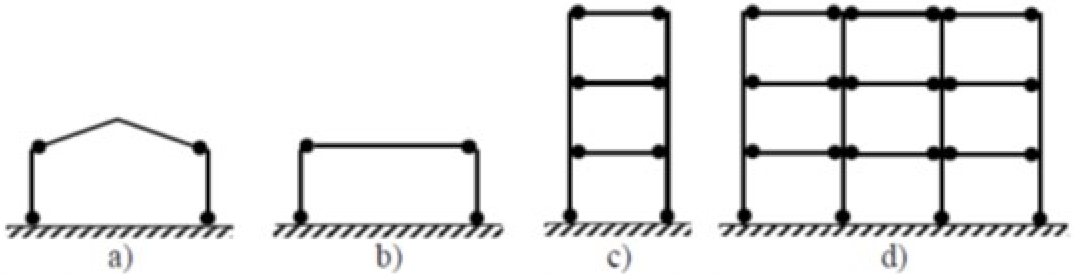


Figure 11.3 — Frames with concentric bracings where the concept of tension-compression diagonals is mandatory

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2



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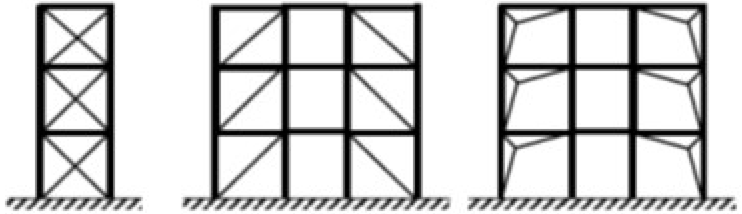

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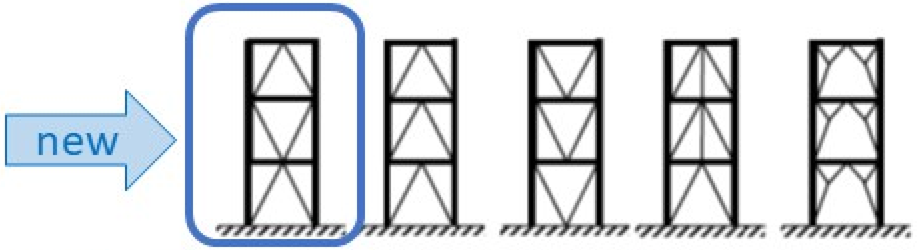

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SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

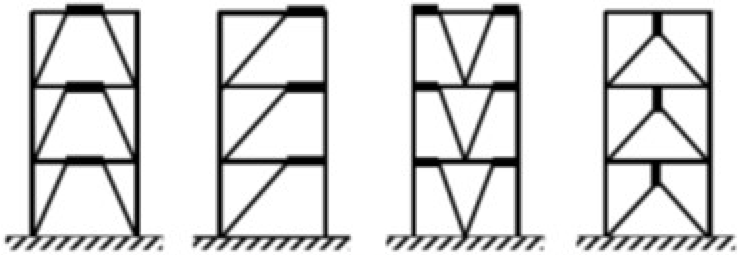


Figure 11.4 — Frames with eccentric bracings (dissipative zones in bending or shear links)

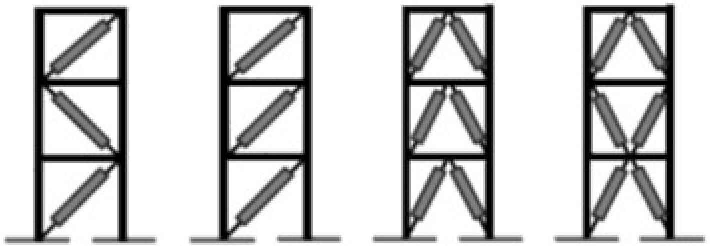


Figure 11.5 — Frames with buckling restrained bracings (dissipative zones in tension and compression diagonals)

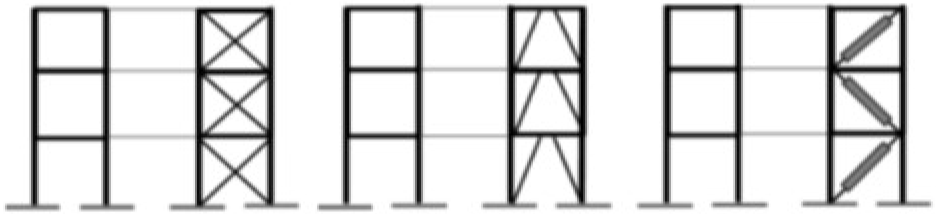
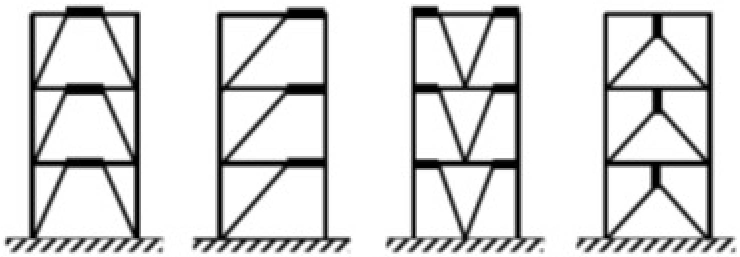


Figure 11.6 — Dual frames with moment resisting frame combined with either concentric, eccentric or buckling restrained bracing (dissipative zones in both moment and braced frames)

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2



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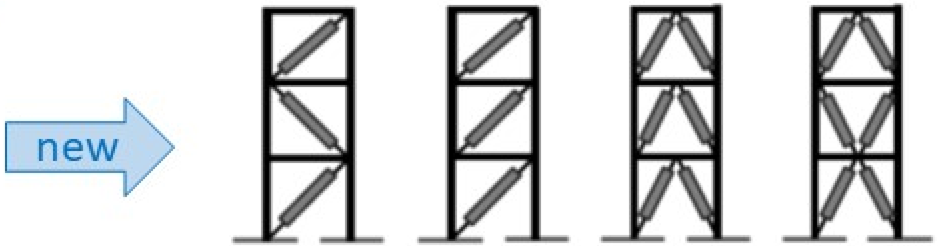

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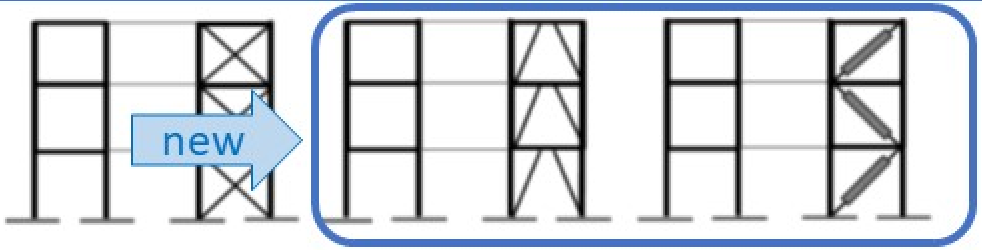

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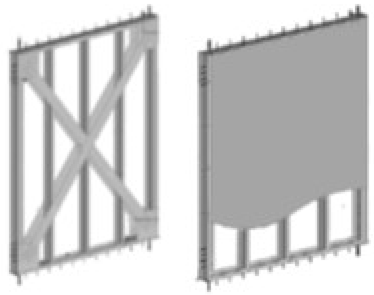
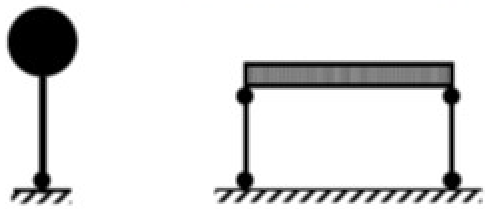


Figure 11.7 — Lightweight steel systems: a) Strap braced walls; b) Shear walls with steel sheet or wood sheathing or gypsum sheathing



a) b)

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

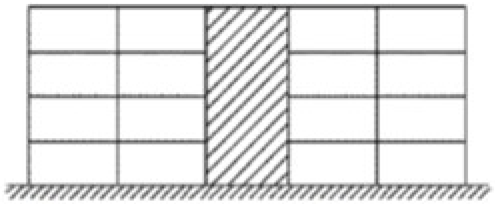
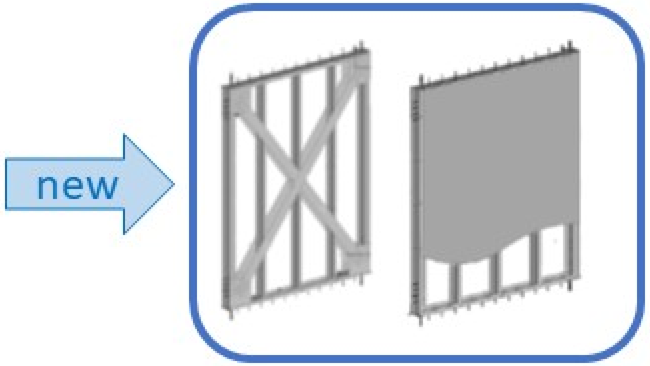


Figure 11.9 — Structures with concrete cores or concrete walls

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2



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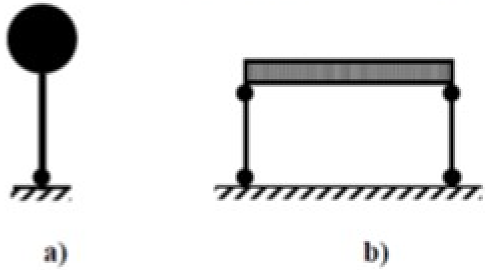

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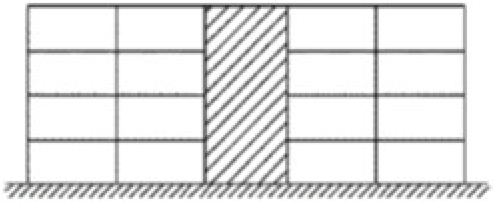

Figure 11.9 — Structures with concrete cores or concrete walls

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Addressed topics

General rules
- Design concepts: Ductility Classes and Behaviour factors
- Material
- Structural analysis (P-delta and drifts)

Specific rules per type
- Capacity design rules
- New annexes

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Addressed topics

General rules

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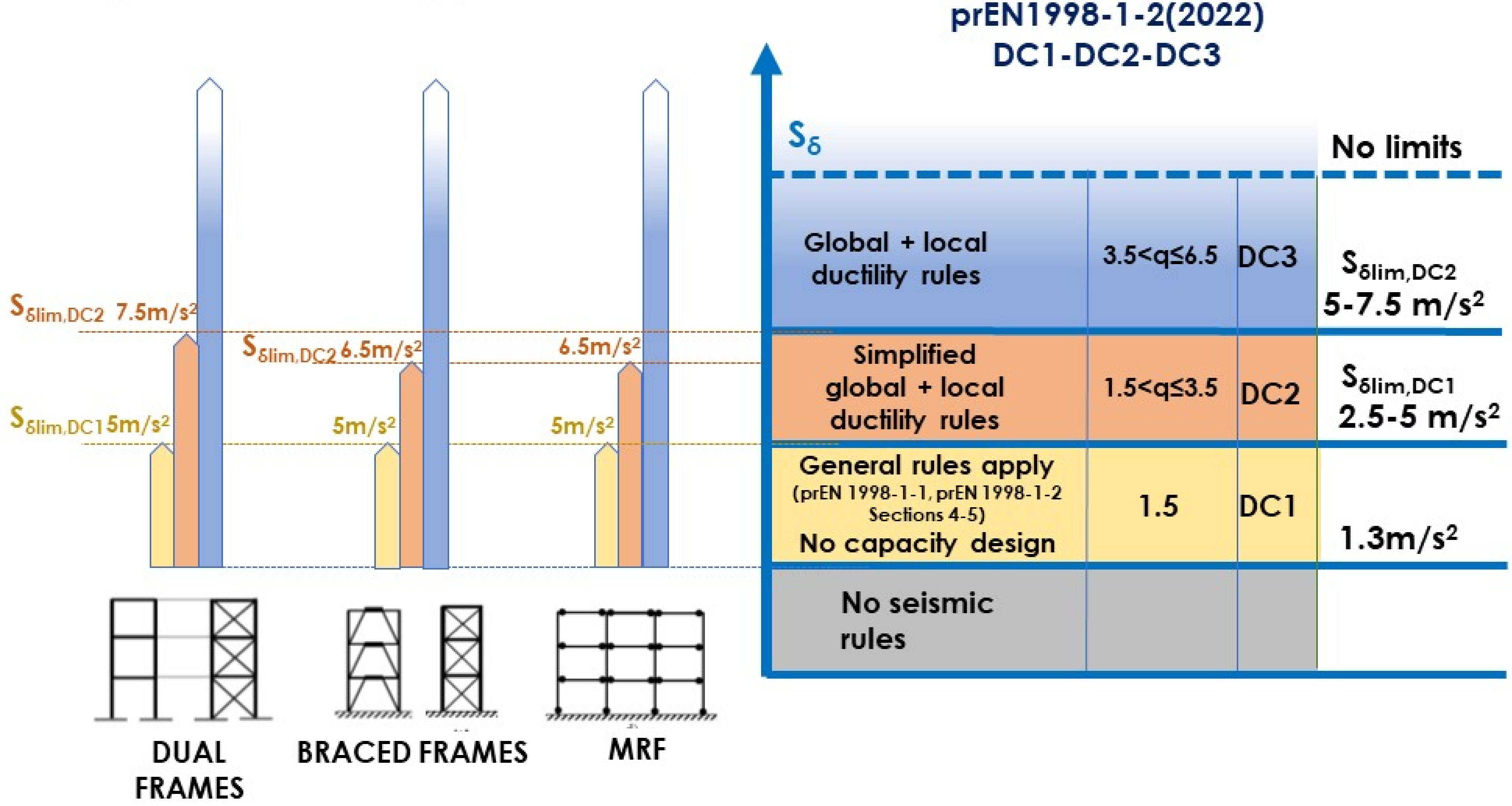
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design Concept: limits of application



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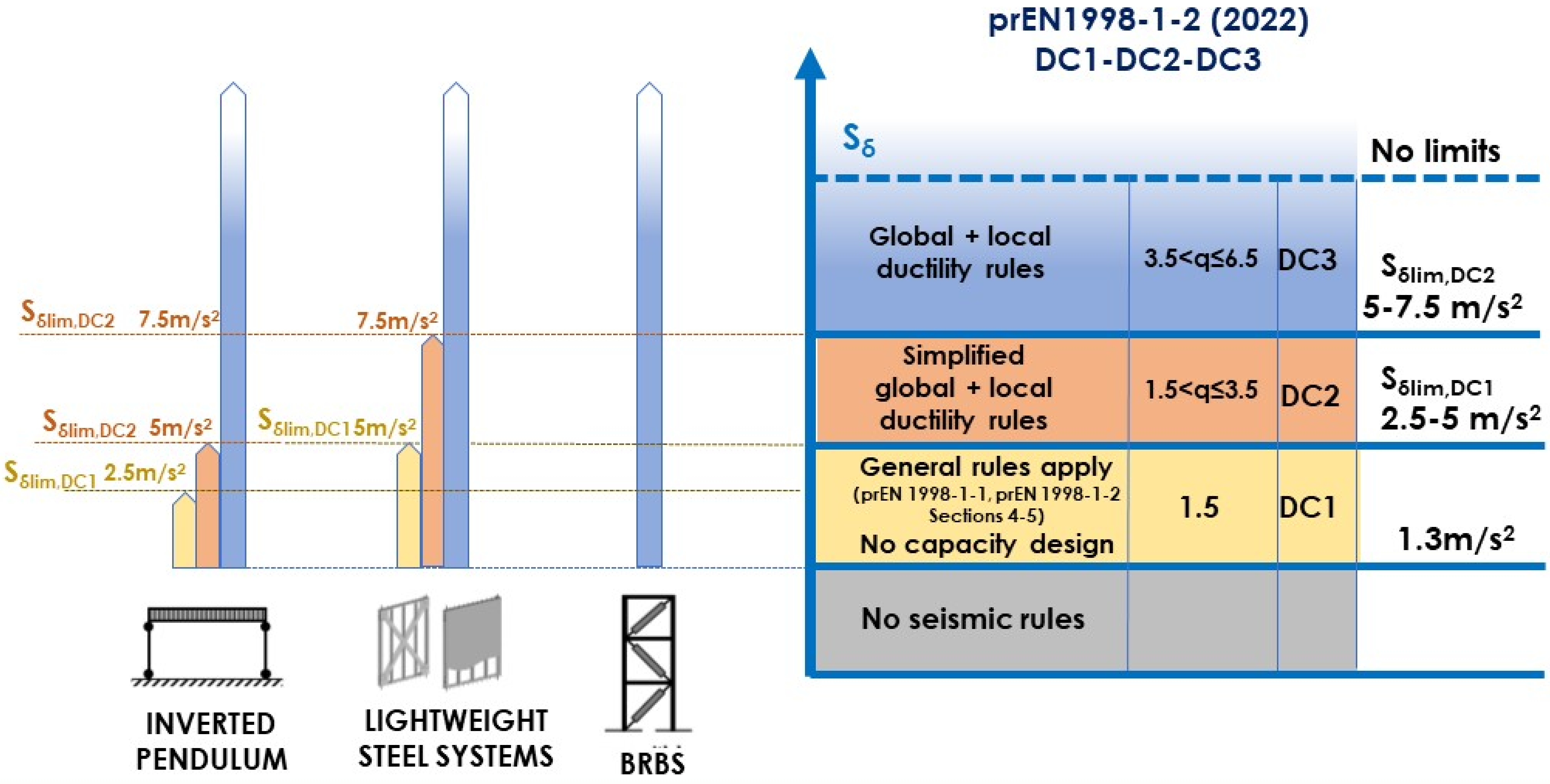
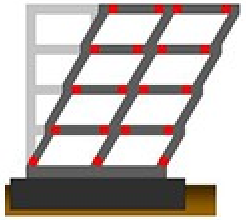


SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design concepts: behaviour factors

STRUCTURAL TYPE	Ductility Class DC2			Ductility Class 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)					

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design concepts: behaviour factors

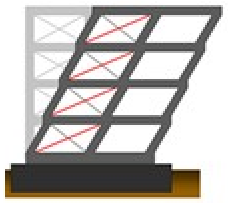
MRF



EN1998-1		prEN1998-1-2	
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*

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design concepts: behaviour factors

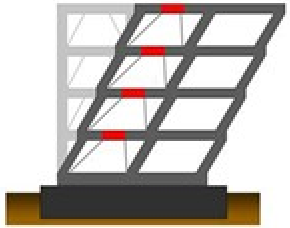
CBF



EN1998-1		prEN1998-1-2	
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*

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design concepts: behaviour factors

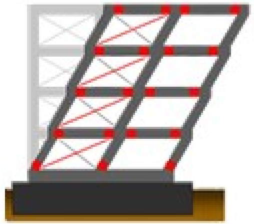
EBF



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*	$q=6$

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design concepts: behaviour factors

DUAL



EN1998-1		prEN1998-1-2	
DCL	$q \leq 1.5$	*DC1*	$q = q_s = 1.5$
DCM	$q = 4$ MRF+CBF	*DC2*	$q = 3$ MRF + CBF
			$q = 4$ MRF + EBF
DCH	$q = 4.8$ MRF+CBF	*DC3*	$q = 4.8$ MRF + CBF
			$q = 6.5$ MRF+EBF and MRF+BRB

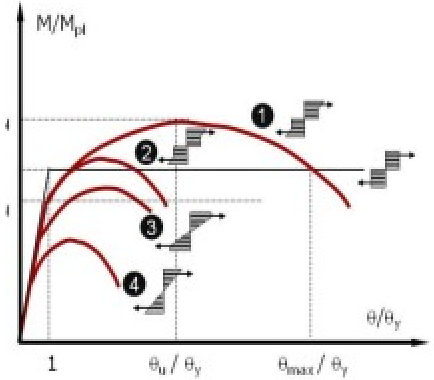
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design concepts: required cross sectional classes

Current EN-1998-1 (2005)

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

prEN-1998-1-2 (2022)

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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Addressed topics

General rules
- Design concepts: Ductility Classes and Behaviour factors
- Material
- Structural analysis (P-delta and drifts)

Specific rules per type
- Capacity design rules
- New annexes

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Material: random variability of steel strength

Current EN-1998 (2005)

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

NPD-Recommended Value 1,25

prEN-1998-1-2(2022)

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

These values are obtained by cross checking the findings obtained in OPUS and SAFEBRICTLE

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Addressed topics

General rules

- Design concepts: Ductility Classes and Behaviour factors
- Material
- Structural analysis (P-delta and drifts)

Specific rules per type

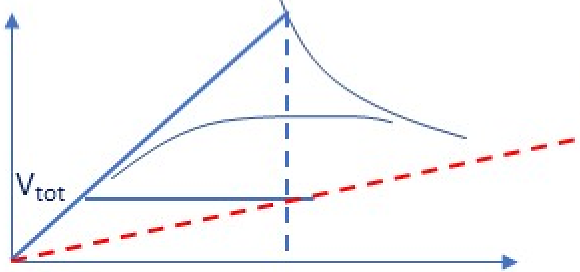
- Capacity design rules
- New annexes

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
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)

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

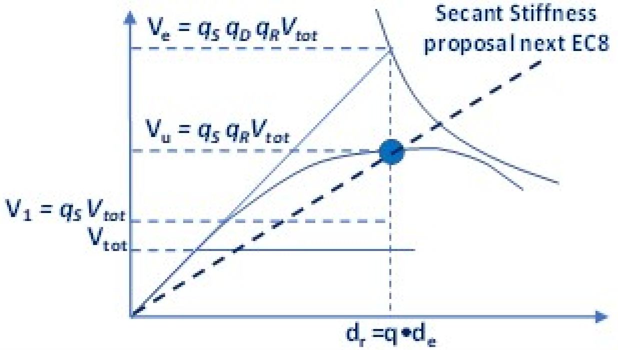


prEN-1998-1-2(2022)

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

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

$$for\ DC2 \quad \rightarrow q_s = 1.5$$
$$for\ DC3 \quad \rightarrow q_s = \omega_{rm} \Omega_d$$



SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Structural analysis: drift control

Current EN-1998(2005)

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

$$d_r \leq \alpha h$$

where a = 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:

$$d_r \leq \lambda h$$

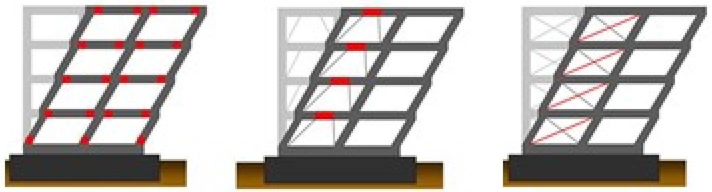
λ depeds on the structural system: λ= 0.01 for ligthweight systems; λ= 0.015 for braced frames and inverted pendulum λ= 0.02 for dual and MRFs

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Addressed topics

- General rules
  - Design concepts: Ductility Classes and Behaviour factors
  - Material
  - Structural analysis (P-delta and drifts)
- Specific rules per type
  - Capacity design rules
  - New annexes

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Capacity design: low-moderate/medium ductility class

General rule

Current EN-1998 (2005) DCM

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

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

prEN-1998 (2022) DC2

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

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

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

$\Omega =$ 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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

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)		
Portal frames with class 3 and 4 cross sections	1,5	columns
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		
Diagonal bracings	1,5	beams and columns
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		
with flat strap bracing	1,5	connections and framing: chord studs and tracks
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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Capacity design: high ductility class

General rule

Current EN-1998 (2005) DCH	prEN-1998 (2022) 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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

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	$\frac{(f_y + f_u)}{2f_y} \leq 1{,}2$
	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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

SPECIFIC RULES FOR MOMENT RESISTING FRAMES

1^{ST} VS 2^{ND} 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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

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/EC3 rules are retained

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)
  - Global hierarchy – overstrength factor for axial force, bending, shear
- **Joints**
  - Annex E: Prequalifed connections

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

SPECIFIC RULES FOR CONCENTRICALLY BRACED FRAMES

1ST VS 2ND GENERATION : main novelties

- Simplified hierarchy of resistances in DC2
- Use of TC model for XCBFs in DC3
- 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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

CBF

Summary

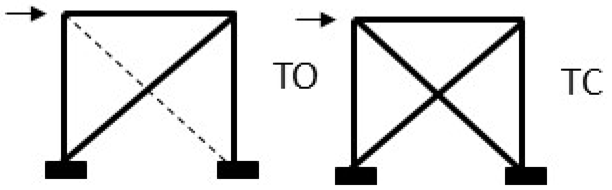
Design for DC2

X-CBF

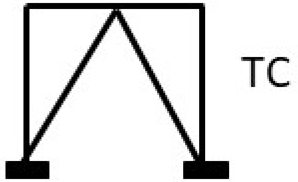
q=2.5

V-CBF

T-O model Elastic analysis
Slenderness within 1.5-2.5
or
T-C model Elastic analysis
Slenderness lower than 2.5



T-C model Elastic analysis
Slenderness lower than 2.5
Stiffness requirement for beam



Joints (gusset connections)

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

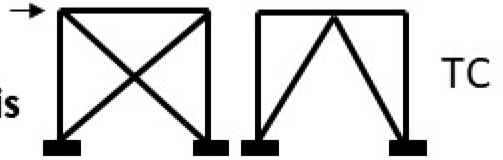
Design for DC3

Unified procedure

Diagonal CBF
X CBF
V CBF

q=4

T-C model
Plastic mechanism analysis
Slenderness lower than 2
Stiffness requirement for beam in V configurtion



SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

EBF

Summary

Design for DC2 — $q = 3.5$

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

Joints (gusset and link connections) — **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**

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

SPECIFIC RULES FOR BUCKLING RESTRAINED BRACES

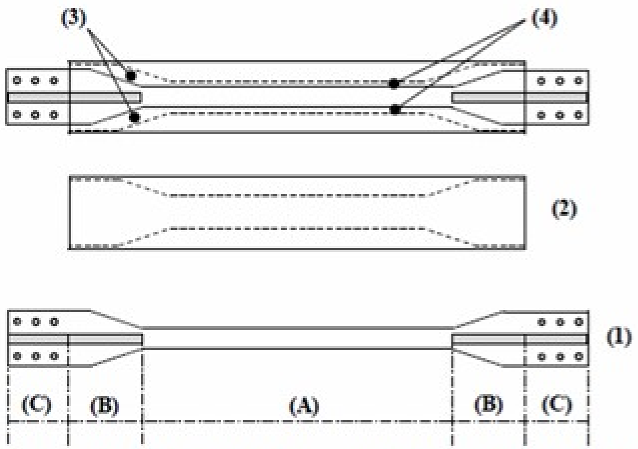
1ST VS 2ND GENERATION : main novelties

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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

BRB

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

Joints — **Specific rules are given in Annex E**

Design for DC3 — q=6

- Diagonals — **Elastic analysis Stability of sleeve**
- Beam, columns — **Plastic mechanism analysis**

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Capacity design: Buckling restrained braces
Design of braces

Current EN-1998-1 (2005)	prEN-1998-1-2(2022) DC3
X	**REQUIRED STRENGTH** $N_{Rd,i} \geq N_{Ed,i}$ **COMPRESSION STRENGTH ADJUSTMENT FACTOR** $\gamma_{CT} = \frac{N_{C,Rd}}{N_{T,Rd}} \leq 1.30$ **OVESTRENGTH HOMOGENEITY CONDITION** $[(\Omega_{d,i} - \Omega_d)\Omega_d] \leq 0.25$ $\Omega_d = \min(\Omega_{d,i}) = \min\left(\frac{N_{Rd,i}}{N_{Ed,i}}\right) \quad i \in [1, n]$ **STABILITY OF THE SLEEVE** $\frac{N_{CT,BRS}}{N_{Rd}} \geq 2.50$

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Capacity design: Buckling restrained braces
Design of beams and columns

Current EN-1998	prEN-1998-1-2(2022) DC3
X	Beams and columns should be designed to resist the most severe condition between a) and b):

a) $R_d \geq E_{Ed,G} + \omega_{rm} \cdot \omega_{sh} \cdot \gamma_{CT} \cdot \Omega_d \cdot E_{Ed,E}$

$$\Omega_d = \min(\Omega_{d,i}) = \min\left(\frac{N_{Rd,i}}{N_{Ed,i}}\right) \; i \in [1,n]$$

$$\gamma_{CT} = (1.1, 1.3)$$

b) the internal forces calculated considering a free-body distribution of axial forces in both tension and

$$N_C = \omega_{rm} \cdot \omega_{sh} \cdot \gamma_{CT} \cdot N_{Rd}$$

$$N_T = \omega_{rm} \cdot \omega_{sh} \cdot N_{Rd}$$

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Addressed topics

General rules

- Design concepts: Ductility Classes and Behaviour factors
- 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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Annex E: seismic design of connections for steel buildings

Scope

This **annex** should be used for the **design of beam-to-column joints of moment resisting and dual frames and for the design of gusset connections in concentrically, eccentrically and buckling restrained bracings**.

Rules in **Annex E should be applied for joints of primary DC3 structures** in addition to those given in 11 and EN 1993.

NOTE 1: The rules in Annex E **may** also be used for joints of primary DC2 and DC1 structures.

NOTE 2: The rules may be also applied to connections different from those specified in Annex E, However, in those cases the validity and effectiveness of their performance shall be demonstrated by means of either experimental evidence, past experimental results available in the literature or refined finite element simulations.

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Annex E: seismic design of connections for steel buildings

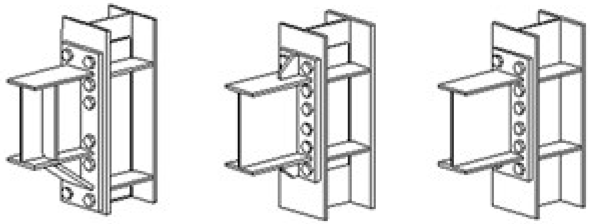
Background

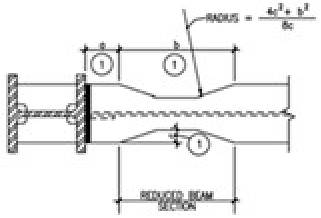
European Qualification of Seismic Resistant Steel Beam-to-column Joints

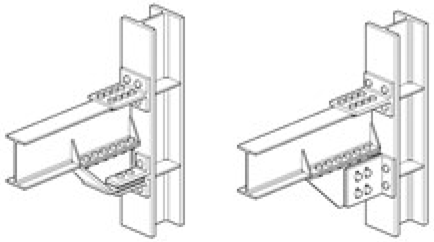
- The **EQUALJOINTS** research project aimed at providing **pre-qualification procedure** for a set of selected seismic resistant steel beam-to-column joints, introducing a **codified practice currently missing in Europe.**

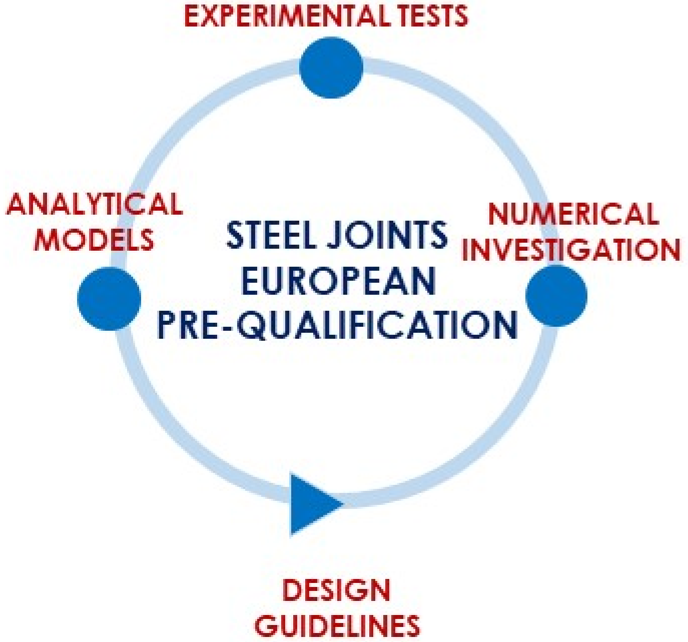
- The **guidelines** for the seismic design of joints developed within the Equaljoints project constitute the **scientific background** seismic rules given for beam.to-column joints in **the Annex E of EN 1998-1-2.**

Friction joints have been recently prequalified in the **RFCS FREEDAM** project. Thanks to the ongoing dissemination project **FREEDAM Plus**, all rules and requirements are available.





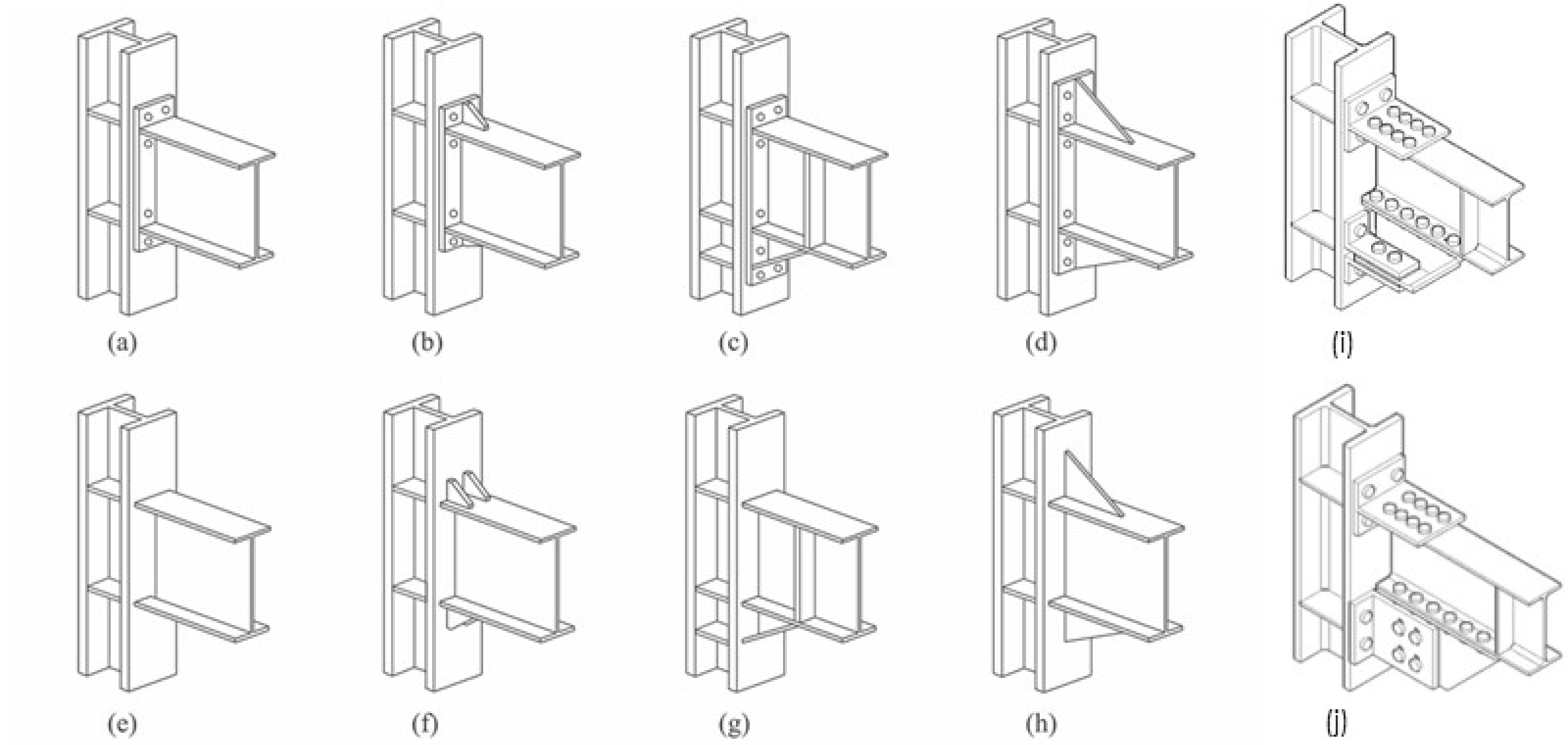




More details in:
R. Landolfo, European seismic prequalification of steel beam-to-column joints: EQUALJOINTS and EQUALJOINTS-Plus projects, Journal of Constructional Steel Research 192 (2022) 107238

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex E: seismic design of connections for steel buildings
Introduction of partial-strength friction joints

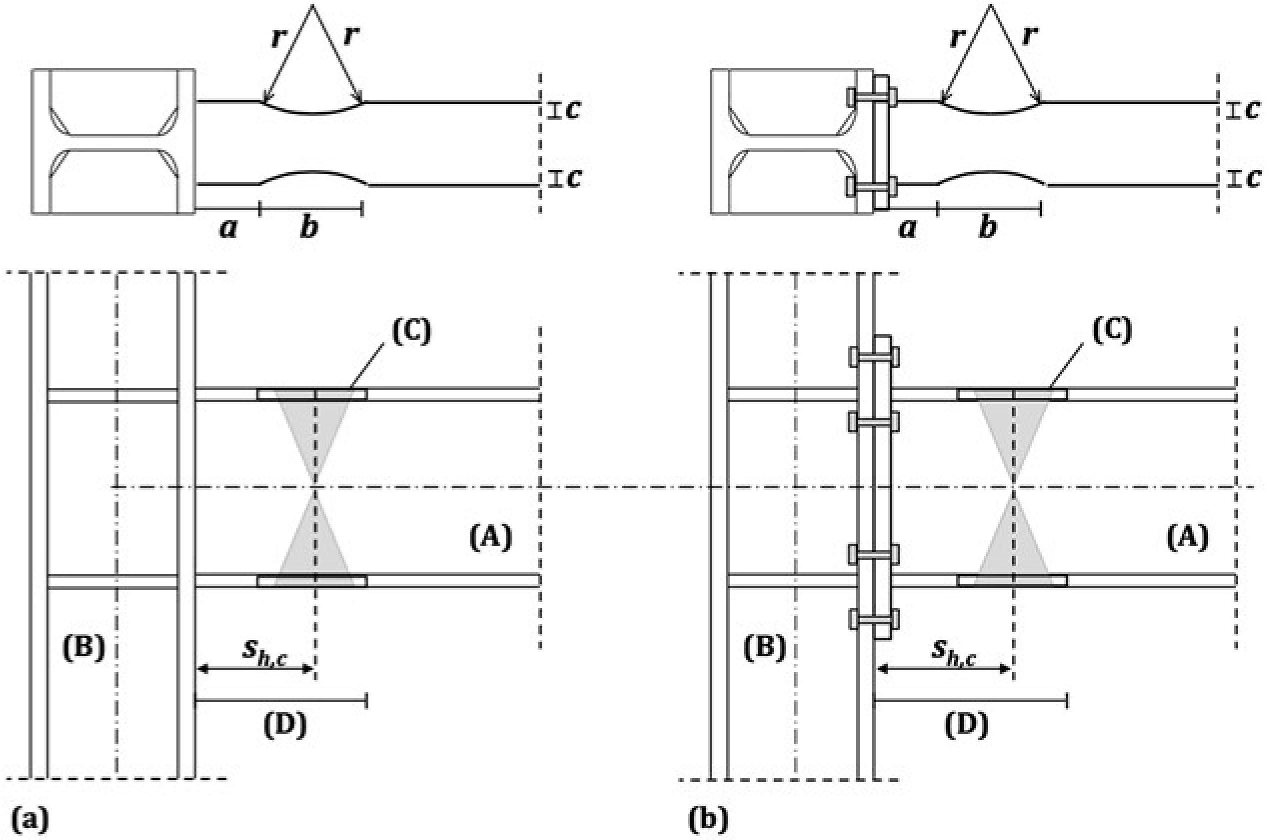
Types of beam-to-column joints covered by Annex E



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)

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex E: seismic design of connections for steel buildings

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



Joints with reduced beam section

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

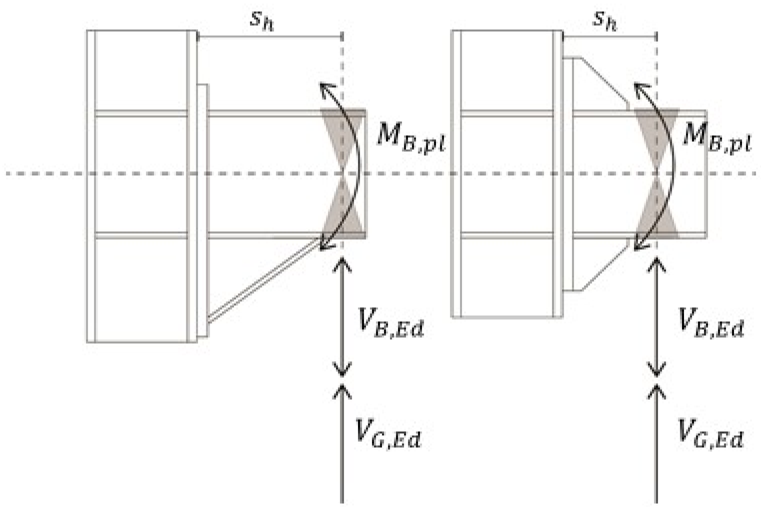
Annex E: seismic design of connections for steel buildings

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:

Full strength or "non-yielding" connections: the plastic deformations are localized in the beam.



SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

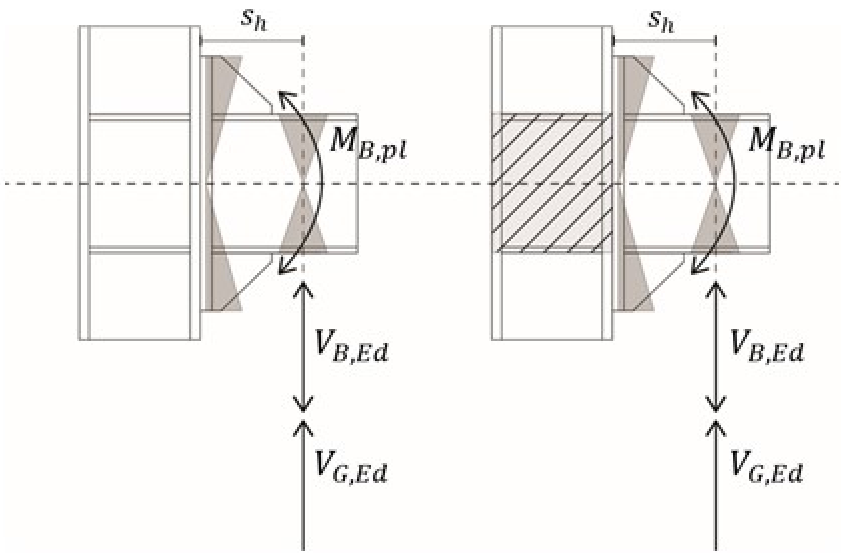
Annex E: seismic design of connections for steel buildings

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:

Equal strength or "balance yielding" connections: the plastic deformations occur in both the beam and the connection



SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Annex E: seismic design of connections for steel buildings

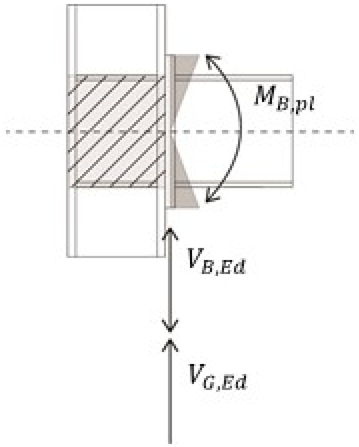
Moment resisting beam-to-column joints

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:

Partial strength "yielding" connections, where the plastic deformations are localized in the connection

Partial strength "friction" connections, where the dissipation mechanism is due to the slippage of the clamped friction surfaces between the lower part of the beam and its connection



SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Annex E: seismic design of connections for steel buildings

Gusset plate connections in concentrically bracings

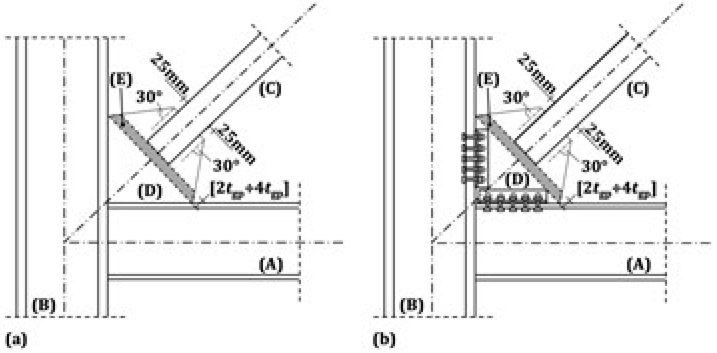


Figure E.18 — Configurations of gusset plate connections for out-of-plane buckling: a) welded connection; (b) bolted connection; (b) bolted connection; (A) beam; (B) column; (C) diagonal brace; (D) gusset plate; (E) linear clearance

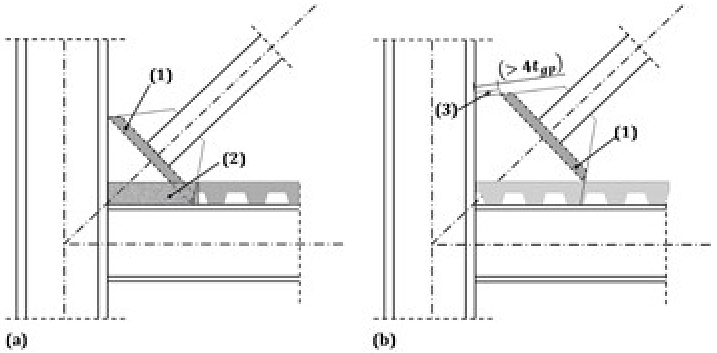


Figure E.19 — slab-to-gusset details: a) isolated from the slab; (b) restrained by the slab; (1) linear clearance; (2) compressible material; (3) edge stiffener

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Annex E: seismic design of connections for steel buildings

Brace connections in eccentric bracings

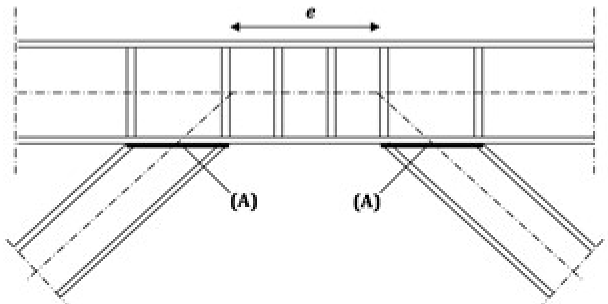
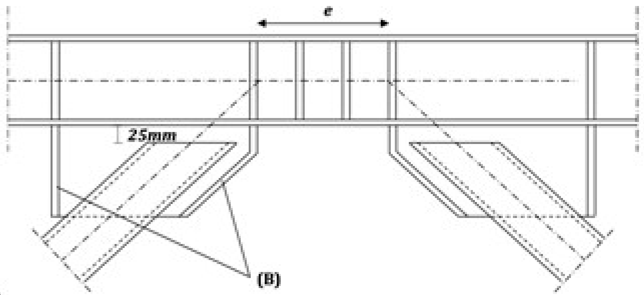
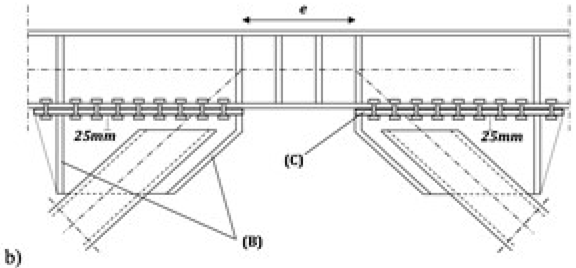


Figure E.25 — Welded brace connections of EBF: (A) full penetration groove welds in accordan with E.3.3.3(6)



a)

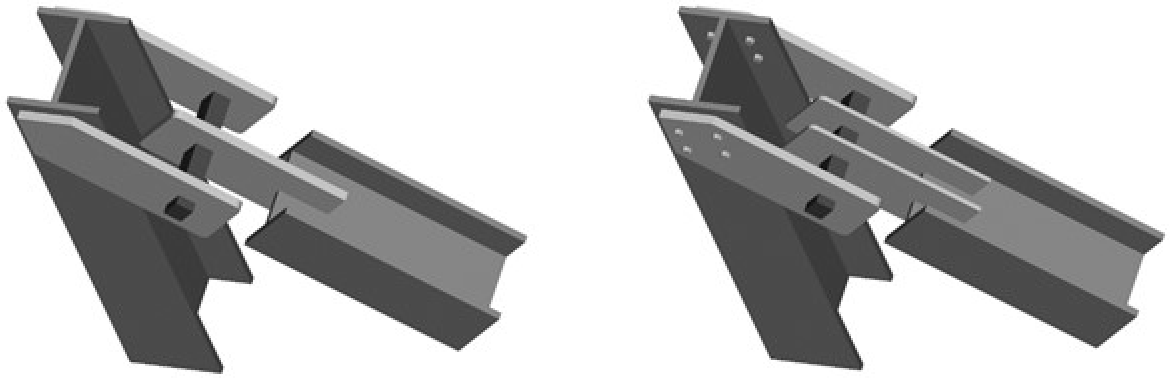


b)

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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex E: seismic design of connections for steel buildings
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 H
SEISMIC DESIGN OF EXPOSED AND EMBEDDED STEEL AND COMPOSITE COLUMN BASE CONNECTIONS

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

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.

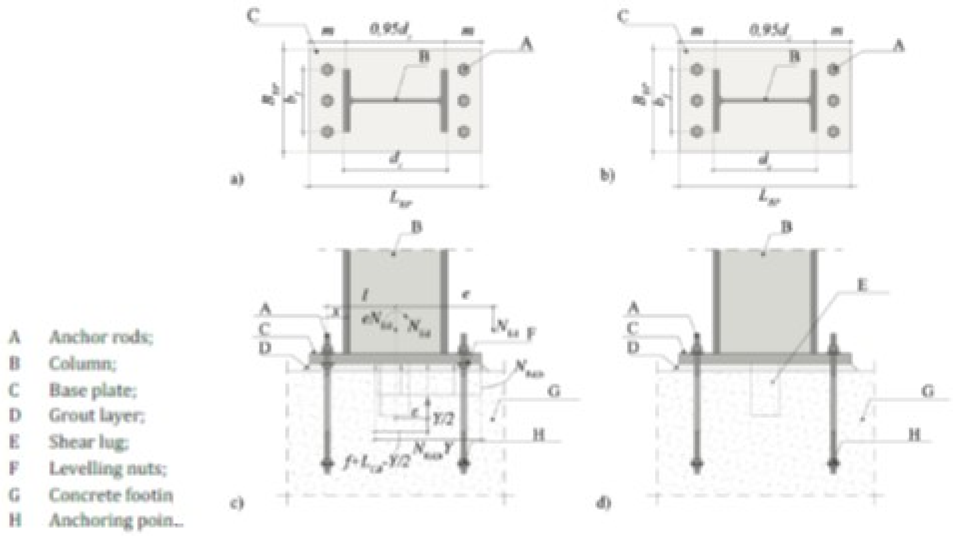


Figure H.1 — Schematic representation of exposed column base connection

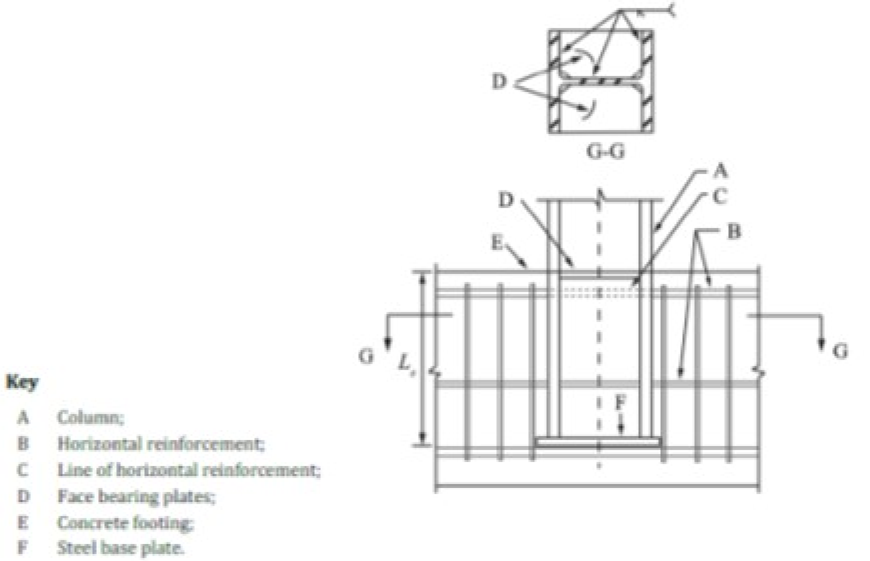


Figure H.3 — Typical embedded column base connection detail

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

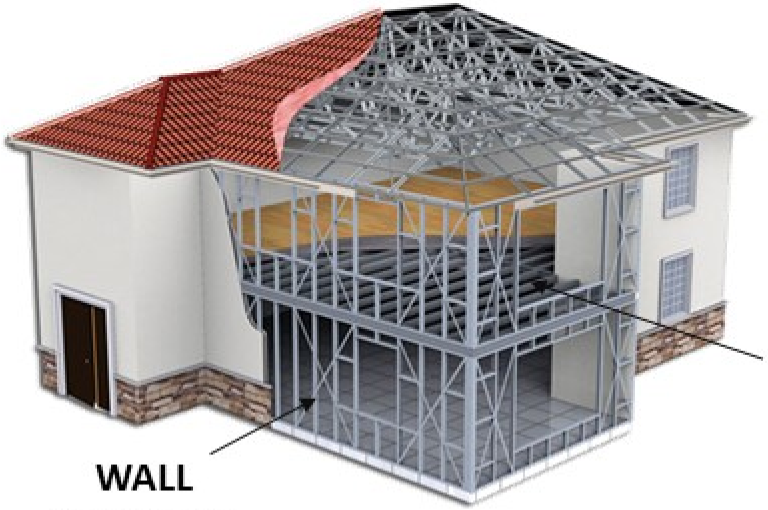
Annex F
STEEL LIGHT WEIGHT STRUCTURES

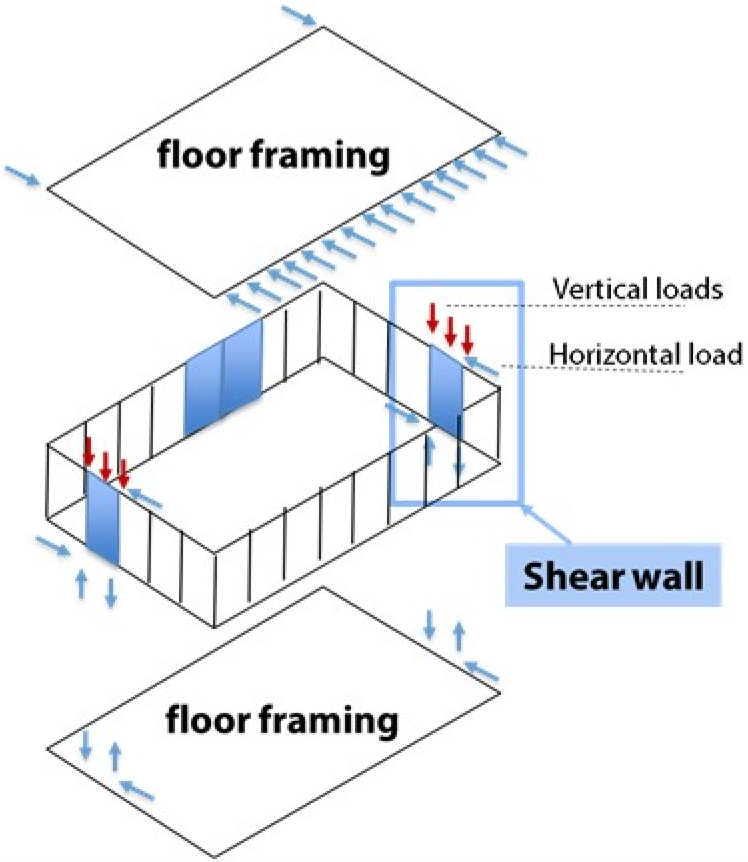
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex F: Steel light weight structures

Lightweight Steel-Framed Construction using cold-formed steel members are even more light

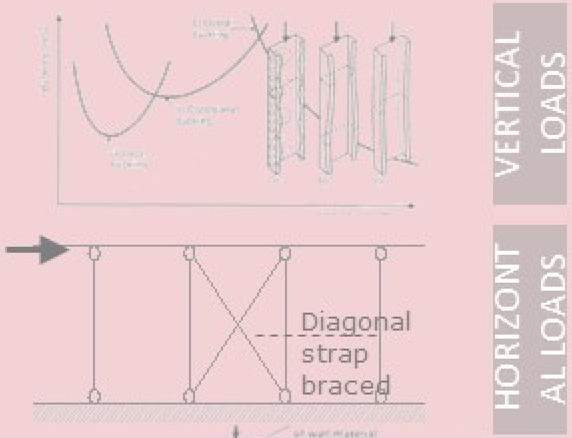
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex F: Steel light weight structures

The load-bearing **structural units** under vertical and horizontal loads are the **Shear walls**

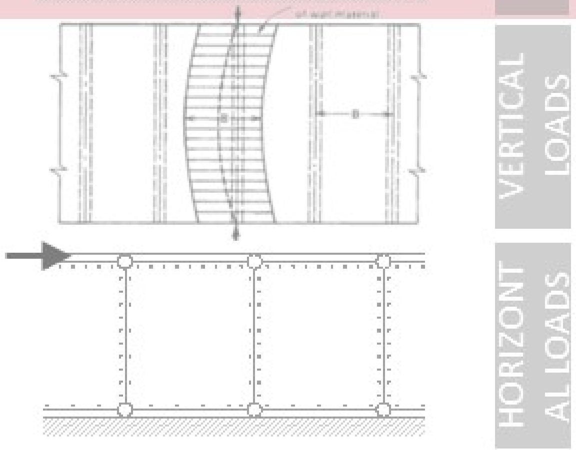




SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex F: Steel light weight structures
Design approaches



Strap braced walls design



Shear walls with sheetings design

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex F: Steel light weight structures
Design approaches

In the last years, the application of Lightweight Steel-Framed Constructions has spread especially in non-seismic areas, but how they should be properly designed **in seismic areas**?

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Annex F: Steel light weight structures

Type covered by ANNEX F


1. strap braced walls


2. shear walls with steel sheet sheathing


3. shear walls with wood sheathing

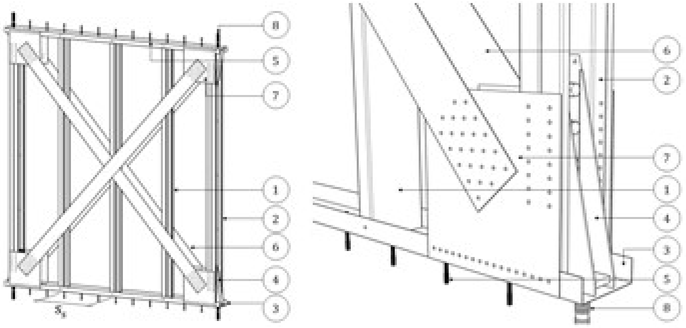

4. shear walls with gypsum sheathing

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

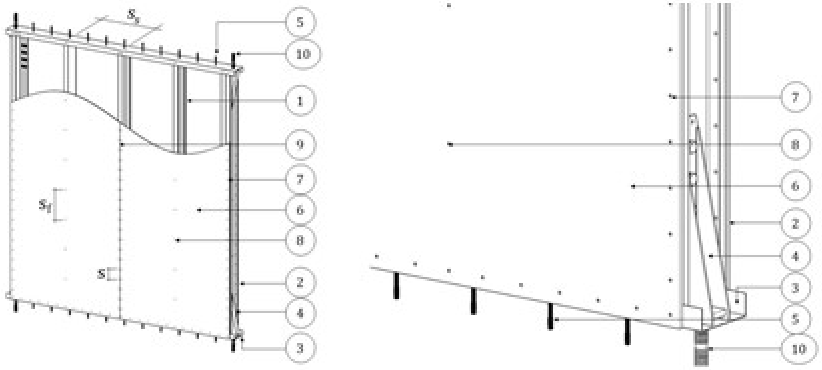
Annex F: Steel light weight structures

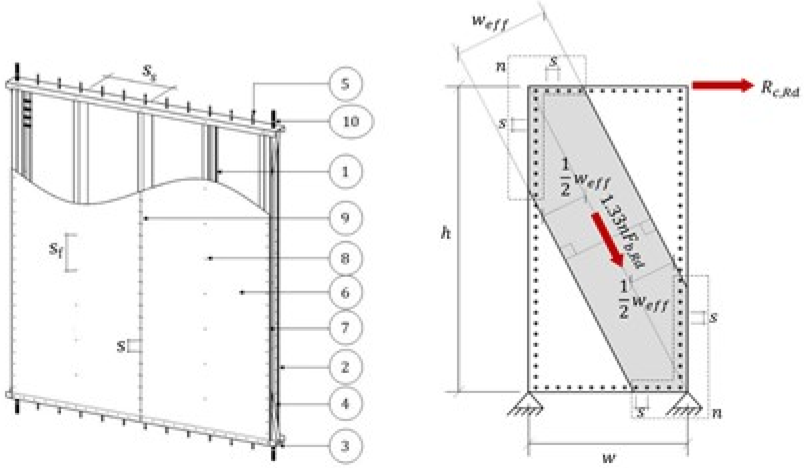
Type covered by ANNEX F

Shear walls with wood or gypsum sheathing



Strap braced walls





Shear walls with steel sheet sheathing

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

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Annex F: Steel light weight structures

Seismic design according to EC8 2nd generation

All-steel structure

Structural type	DC2	DC3	Design approach
	q	*q*	
Strap braced walls	2	2.5	Dissipative

Shear walls with sheetings

Structural type	DC2	DC3	Design approach
	q	*q*	
Shear with steel sheetings.	2	2.5	Dissipative
Shear wall with wood sheetings	2	2.5	Dissipative
Shear walls with gypsum sheetings	1.7	2	Dissipative

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex F: Steel light weight structures
Capacity design rules in DC2 common to all lightweight steel systems

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

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

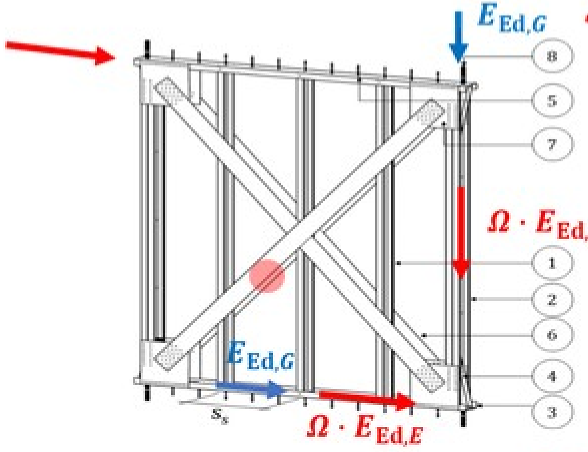
where:

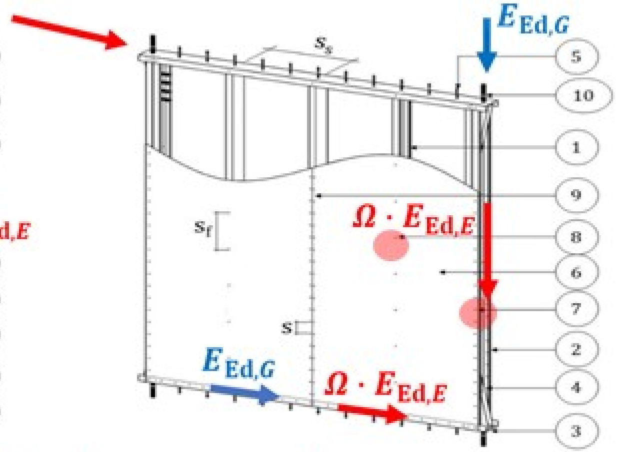
$E_{Ed,G}$ is the action effect due to the non-seismic actions in the seismic design situation;

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

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

DC2





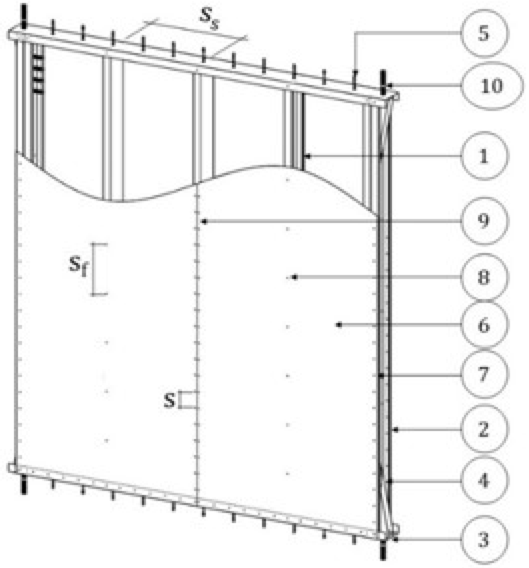
LFRS	DC2
	Ω
Strap-braced walls	1.5
Shear walls with steel sheet sheathing;	1.5
Shear walls with wood sheathing	1.5
Shear walls with gypsum sheathing	1.3

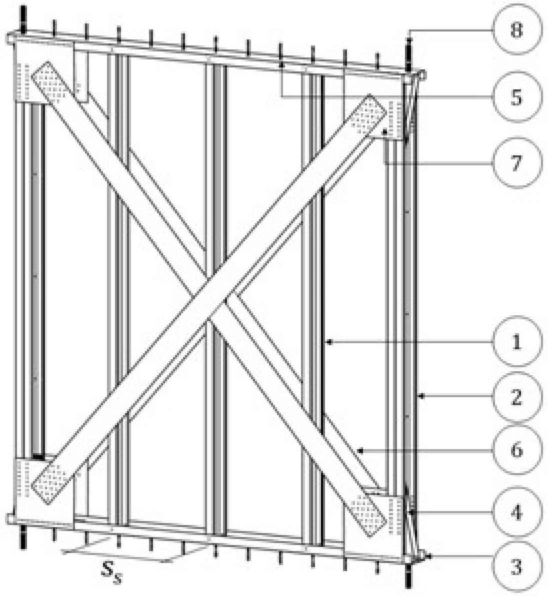
Dissipative component in DC2 and DC3 structures

SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Annex F: Steel light weight structures
Capacity design rules in DC3

Design of chord studs and shear anchors in a strap braced wall in **DC3**

DC3





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

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

Contents

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
Evolution of seismic rules

ALUMINUM CHAPTER →

EC8 1ST GENERATION
NO SEISMIC RULES

VS

EC8 2ND GENERATION
prEN 1998-1-2 (2022) Chapter 15

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

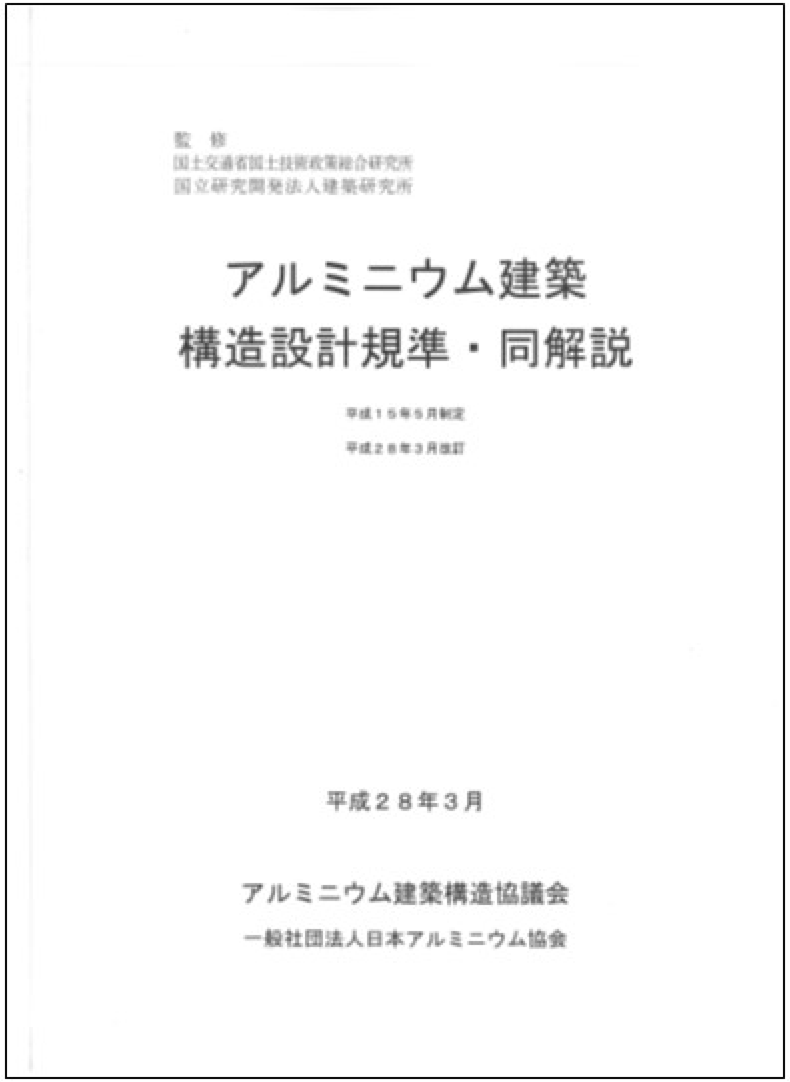
MAIN NOVELTIES

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

Table of contents

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
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

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

Addressed topics

General rules
- **Design concepts: Ductility Classes and Behaviour factors**
- **Material**
- **Structural analysis (P-delta and drifts)**

Specific rules per type
- **Capacity design rules**

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

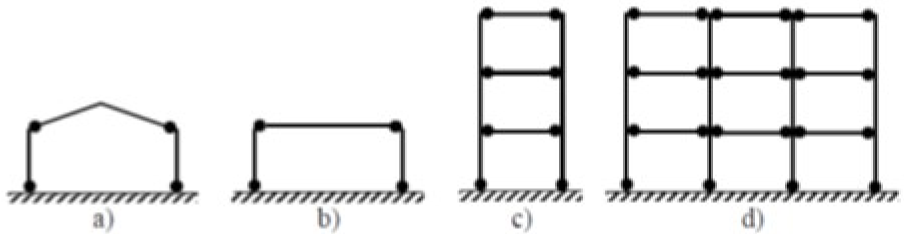


Figure 11.1 — Moment resisting frames (dissipative zones in beams and at bottom of columns): a) portal frame; b) single-storey MRF; c) single-span multi-storey MRF; d) multi-span multi-storey MRF

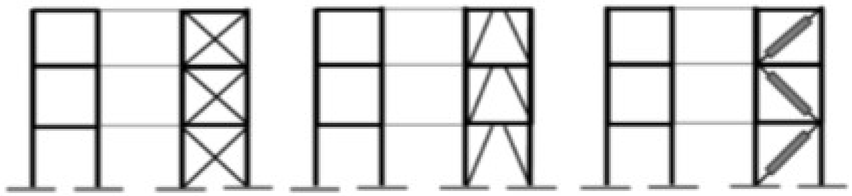


Figure 11.6 — Dual frames with moment resisting frame combined with either concentric, eccentric or buckling restrained bracing (dissipative zones in both moment and braced frames)

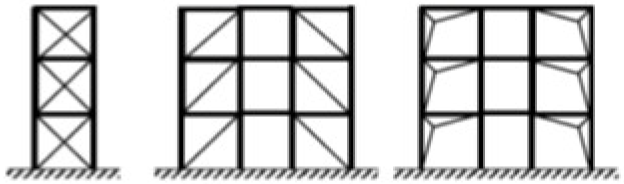


Figure 11.2 — Frames with concentric bracings where the concept of tension-only diagonals is allowed

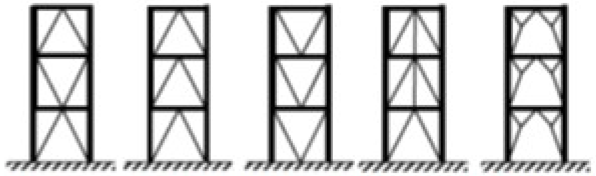
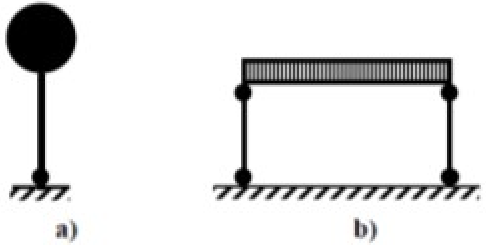


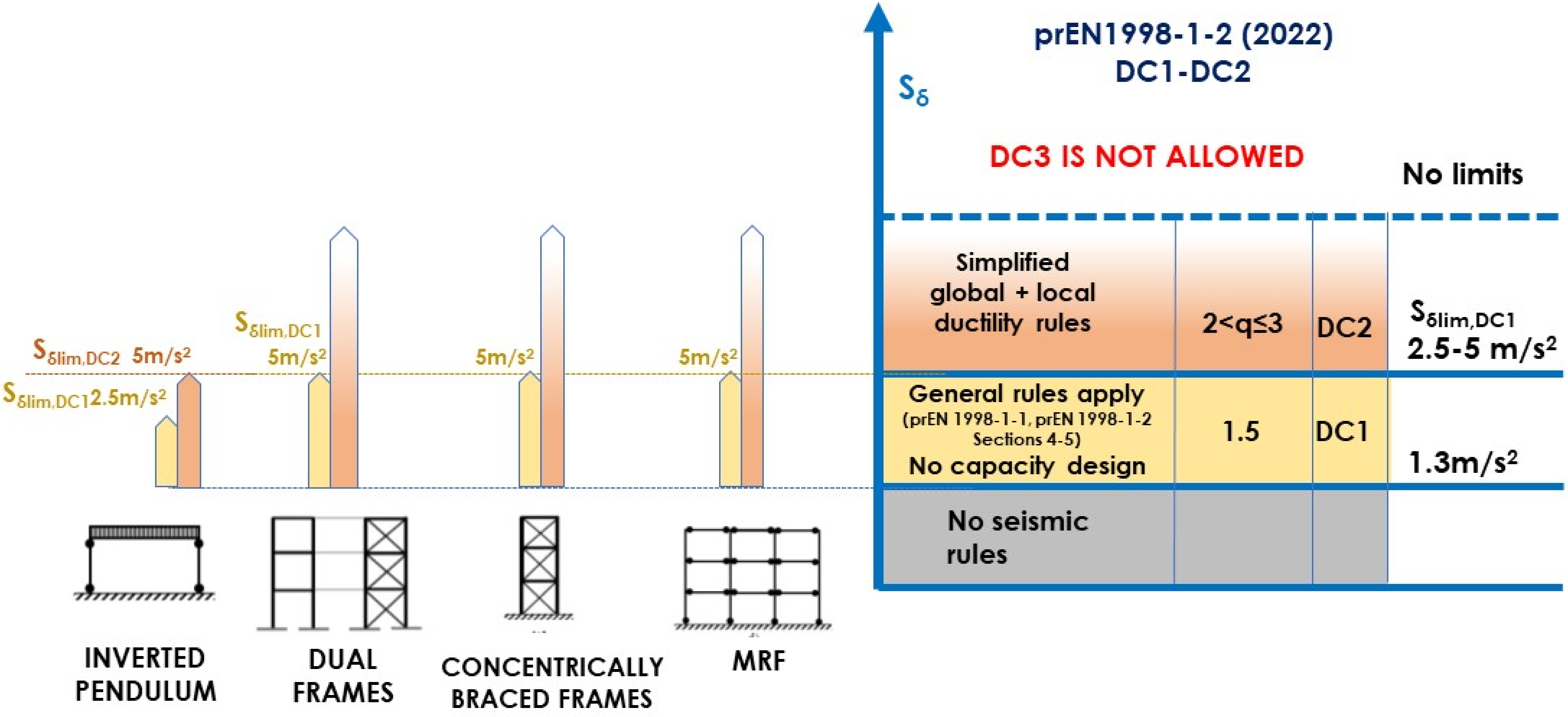
Figure 11.3 — Frames with concentric bracings where the concept of tension-compression diagonals is mandatory



'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

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
Ductility classes



SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
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

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

Addressed topics

- General rules
  - Design concepts: Ductility Classes and Behaviour factors
  - Material
  - Structural analysis (P-delta and drifts)
- Specific rules per type
  - Capacity design rules

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
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 f_u is the ultimate tensile strength and f_0 is the conventional elastic strength

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

Addressed topics

- **General rules**
  - Design concepts: Ductility Classes and Behaviour factors
  - Material
  - Structural analysis (P-delta and drifts)
- **Specific rules per type**
  - Capacity design rules

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

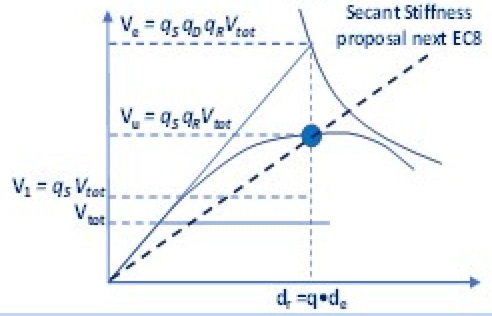
Structural analysis

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;

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

Addressed topics

General rules
- Design concepts: Ductility Classes and Behaviour factors
- Material
- Structural analysis (P-delta and drifts)

Specific rules per type
- Capacity design rules

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
Capacity design: moderate ductility

GENERAL RULES

For aluminum systems DC2 all seismic induced effects are magnified

prEN-1998 (2022) 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

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
Capacity design: moderate ductility

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	columns
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

SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
Capacity design: moderate ductility
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;

ω_{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;

ω_{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

- Introduction
- Seismic design of Steel Buildings in the prEN1998-1-2
- Seismic design of Aluminum Buildings in the prEN1998-1-2
- Conclusions

CONCLUSIONS

- The new Eurocode 8 is significantly changed as respect to the current EN1998 (2004) regarding both general (EN 1998-1-1) and new buildings (EN 1998-1-2) rules;
- With reference to steel 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 is 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 prEN1998 (2022), 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.

Thanks for your kind attention