Steel Buildings and Aluminum Buildings

Raffaele Landolfo
University of Naples “Federico II”, Italy

24th January 2023
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- Introduction
- Seismic design of Steel Buildings in the prEN1998-1-2
- Seismic design of Aluminum Buildings in the prEN1998-1-2
- Conclusions
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INTRODUCTION

Background

- 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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- Introduction
- Seismic design of Steel Buildings in the prEN1998-1-2
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SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Evolution of seismic rules

STEEL CHAPTER

EC8 1ST GENERATION

V

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

S

- 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
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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

NO ANNEXES

prEN-1998-1-2 (2022) - Chapter 11

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

Raffaele Landolfo

24th January 2023
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Current EN1998-1 – Chapter 6

Structural systems:
- MRFs
- CBFs
- EBFs
- Dual Frames

prEN1998-1-2 (2022) – Chapter 11

Structural systems:
- MRFs
- CBFs
- EBFs
- BRFs
- 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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Figure 11.3 — Frames with concentric bracings where the concept of tension-compression diagonals is mandatory

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

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

Figure 11.8 — Inverted pendulum: a) dissipative zones at the column base; b) dissipative zones in columns ($N_{Ed,C}/N_{pl,C} \geq 0.3$)

Figure 11.9 — Structures with concrete cores or concrete walls
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

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

Addressed topics

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

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

prEN1998-1-2(2022)
DC1-DC2-DC3

- Global + local ductility rules
  - $3.5 \leq \phi \leq 6.5$
  - DC3
  - $S_{6\text{lim}, \text{DC2}}$
  - 5-7.5 m/s²

- Simplified global + local ductility rules
  - $1.5 \leq \phi \leq 3.5$
  - DC2
  - $S_{6\text{lim}, \text{DC1}}$
  - 2.5-5 m/s²

- General rules apply
  - (prEN 1998-1-1, prEN 1998-1-2 Sections 4-5)
  - No capacity design
  - 1.5
  - DC1

- No seismic rules

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

prEN1998-1-2 (2022)
DC1-DC2-DC3

<table>
<thead>
<tr>
<th>( S_{6})</th>
<th>No limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global + local ductility rules</td>
<td>3.5 &lt; ( q ) ≤ 6.5</td>
</tr>
<tr>
<td>Simplified global + local ductility rules</td>
<td>1.5 &lt; ( q ) ≤ 3.5</td>
</tr>
<tr>
<td>General rules apply (prEN 1998-1-1, prEN 1998-1-2 Sections 4.5)</td>
<td>No capacity design</td>
</tr>
<tr>
<td>No seismic rules</td>
<td>1.3 m/s²</td>
</tr>
</tbody>
</table>

- \( S_{lim,DC2} \) 7.5 m/s²
- \( S_{lim,DC1} \) 5 m/s²
- \( S_{lim,DC1} \) 2.5 m/s²

INVERTED PENDULUM
LIGHTWEIGHT STEEL SYSTEMS
BRBS
## SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

### Design concepts: behaviour factors

<table>
<thead>
<tr>
<th>Structural Type</th>
<th>DC2</th>
<th>DC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Moment resisting frames (MRFs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portal frames and single-storey MRFs with class 3 and 4 cross sections</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>Portal frames and single-storey MRFs with class 1 and 2 cross sections</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Multi-storey MRFs</td>
<td>1.8</td>
<td>1.3</td>
</tr>
<tr>
<td>b) Frames with concentric bracings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagonal bracings</td>
<td>1.7</td>
<td>1</td>
</tr>
<tr>
<td>V-bracings</td>
<td></td>
<td></td>
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<tr>
<td>X-bracings on either single or two-storey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Frames with eccentric bracings</td>
<td>1.8</td>
<td>1.3</td>
</tr>
<tr>
<td>d) Frames with buckling restrained braces</td>
<td>3.3</td>
<td>1.2</td>
</tr>
<tr>
<td>e) Dual frames</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRFs with concentric bracing</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td>MRFs with eccentric bracing</td>
<td>2.1</td>
<td>1.3</td>
</tr>
<tr>
<td>MRFs with buckling restrained braces</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>f) Structures with concrete cores or concrete walls</td>
<td>See 10</td>
<td></td>
</tr>
<tr>
<td>g) Lightweight steel frame wall systems</td>
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<td></td>
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<tr>
<td>with flat strap bracing</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>with steel sheathing</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>with wood sheathing</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>with gypsum sheathing</td>
<td>1.1</td>
<td>1</td>
</tr>
<tr>
<td>h) Inverted pendulum</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>i) Moment resisting frames with infills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unconnected concrete or masonry infills, in contact with the frame</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Connected reinforced concrete infills</td>
<td>See 10</td>
<td></td>
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<tr>
<td>Infills isolated from moment frame</td>
<td>(see MRFs)</td>
<td></td>
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</table>
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design concepts: behaviour factors

EN1998-1

- DCL
  - $q \leq 1.5$

prEN1998-1-2

- DC1
  - $q = q_s = 1.5$
- 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
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Design concepts: behaviour factors

EN1998-1

prEN1998-1-2

\[ q \leq 1.5 \]

\[ q = q_s = 1.5 \]

\[ q = 2 \ \text{VCBF} \]

\[ q = 4 \ \text{XCBF} \]

\[ q = 2.5 \ \text{VCBF} \]

\[ q = 4 \ \text{XCBF} \]

\[ q = 2.5 \] for all types

\[ q = 4 \] for all types
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Design concepts: behaviour factors

EN1998-1

\[ DCL \quad q \leq 1.5 \quad \rightarrow \quad DC1 \quad q = q_s = 1.5 \]

\[ DCM \quad q = 4 \quad \rightarrow \quad DC2 \quad q = 3.5 \]

\[ DCH \quad q = 5-6 \quad \rightarrow \quad DC3 \quad q = 6 \]
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Design concepts: behaviour factors

EN1998-1

DCL  $q \leq 1.5$  $\rightarrow$  DC1  $q = q_s = 1.5$

prEN1998-1-2

DCM  $q = 4 \text{ MRF+CBF}$  $\rightarrow$  DC2

$\rightarrow$  $q = 3 \text{ MRF + CBF}$

$\rightarrow$  $q = 4 \text{ MRF + EBF}$

DC3

$\rightarrow$  $q = 4.8 \text{ MRF + CBF}$

$\rightarrow$  $q = 6.5 \text{ MRF+EBF and MRF+BRB}$
# Seismic Design of Steel Buildings in the prEN1998-1-2

## Design Concepts: Required Cross Sectional Classes

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<tr>
<td><strong>DCH</strong></td>
<td></td>
</tr>
<tr>
<td>2.5 &lt; q ≤ 6.5</td>
<td>Class 1</td>
</tr>
</tbody>
</table>

| **DCM**                  |                      |
| 2 < q ≤ 3.5              | Class 1, 2           |

| **DC2**                  |                      |
| 1.5 < q ≤ 2              | Class 1, 2           |

| **DC3**                  |                      |
| 2 < q ≤ 2.5              | Class 1, 2, 3 or 4   |
| 1.5 < q ≤ 2              | Class 1, 2, 3 or 4   |

- **Class 1**
- **Class 1, 2**
- **Class 1, 2, 3 or 4**
- **Class 1, 2, 3 or 4**
- **Class 1, 2**

- For lightweight systems
- For portal frames, lightweight systems and single storey MRF
- For inverted pendulum
- 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)
  - Capacity design rules
  - New annexes

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

\( Y_{ov} \) is the material overstrength factor used in design

\( \omega_{rm} \) 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

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Material randomness coefficient ( \omega_{rm} )</th>
</tr>
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<tbody>
<tr>
<td>S235</td>
<td>1.45</td>
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<tr>
<td>S275</td>
<td>1.35</td>
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<tr>
<td>S355</td>
<td>1.25</td>
</tr>
<tr>
<td>S420</td>
<td>1.25</td>
</tr>
<tr>
<td>S460</td>
<td>1.2</td>
</tr>
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</table>

NPD-Recommended Value 1.25

These values are obtained by cross checking the findings obtained in OPUS and SAFEBRICLTE
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Addressed topics

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

General rules

Specific rules per type
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)

\[
\theta = \frac{P_{\text{tot}} \cdot d}{V_{\text{tot}} \cdot h}
\]

Secant Stiffness current EC8

**PrEN-1998-1-2(2022)**

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

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

for DC2 \( \rightarrow q_s = 1.5 \)

for DC3 \( \rightarrow q_s = \omega \Omega_d \)

Secant Stiffness proposal next EC8
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Structural analysis: drift control

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

$$d_r \leq \alpha h$$

where $\alpha = 0.05; 0.075; 0.01$ depending on the non-structural elements

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

$$d_r \leq \lambda h$$

$\lambda$ depends on the structural system: $\lambda = 0.01$ for lightweight systems; $\lambda = 0.015$ for braced frames and inverted pendulum $\lambda = 0.02$ for dual and MRFs
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

Addressed topics

- Design concepts: Ductility Classes and Behaviour factors
- Material
- Structural analysis (P-delta and drifts)
- Capacity design rules
- New annexes
### SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

**Capacity design: general rules**

<table>
<thead>
<tr>
<th>Ductility Class</th>
<th>Capacity design rules</th>
<th>Current VS Next EC8</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC3</td>
<td>Capacity design rules</td>
<td>Improved as respect to current DCM and DCH</td>
</tr>
<tr>
<td>DC2</td>
<td>Simplified capacity design rules</td>
<td>Completely new as respect to current EC8</td>
</tr>
<tr>
<td>DC1</td>
<td>No capacity Design</td>
<td>Similar to current DCL</td>
</tr>
</tbody>
</table>
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Capacity design: low-moderate/medium ductility class


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

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

prEN-1998 (2022) DC2

\[ M_{Rd} \geq M_{Ed,G}'' + ''M_{Ed,E} \]
\[ V_{Rd} \geq V_{Ed,G}'' + ''V_{Ed,E} \]
\[ N_{Rd} \geq N_{Ed,G}'' + ''\Omega \cdot N_{Ed,E} \]

\[ \Omega = \text{seismic action magnification factor} \]
(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>
<thead>
<tr>
<th>Structural Type</th>
<th>Ω</th>
<th>Members to which (1) or (2) apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moment resisting frames (MRFs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portal frames with class 3 and 4 cross sections</td>
<td>1.5</td>
<td>columns</td>
</tr>
<tr>
<td>Single-storey MRFs with class 3 and 4 cross sections</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Portal frames and single-storey MRFs with class 1 and 2 cross sections</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>Multi-storey MRFs</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>MRFs with friction connections</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Frames with concentric bracings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagonal bracings</td>
<td>1.5</td>
<td>beams and columns</td>
</tr>
<tr>
<td>V-bracings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-bracings on either single or two-storey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frames with eccentric bracings</td>
<td>2</td>
<td>beams outside the link, braces and columns</td>
</tr>
<tr>
<td>Dual frames</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRFs with concentric bracing</td>
<td>1.7</td>
<td>beams and columns of the concentric bracing, columns of the MRF</td>
</tr>
<tr>
<td>MRFs with eccentric bracing</td>
<td>2</td>
<td>beams out of the link, braces and columns of the eccentric bracing, columns of the MRF</td>
</tr>
<tr>
<td>Structures with concrete cores or concrete walls</td>
<td>See 10</td>
<td></td>
</tr>
<tr>
<td>Lightweight steel frame wall systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with flat strap bracing</td>
<td>1.5</td>
<td>connections and framing, chord studs and tracks</td>
</tr>
<tr>
<td>with steel sheeting</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>with wood sheeting</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>with gypsum sheeting</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Inverted pendulum structures</td>
<td>1.5</td>
<td>columns</td>
</tr>
<tr>
<td>Moment resisting frames with infills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with unconnected with non-interacting concrete or masonry infills</td>
<td>1.5</td>
<td>columns</td>
</tr>
<tr>
<td>with connected reinforced concrete infills</td>
<td>See 10</td>
<td></td>
</tr>
<tr>
<td>with non-interacting infills</td>
<td>(see MRFs)</td>
<td>columns</td>
</tr>
</tbody>
</table>

Raffaele Landolfo

24th January 2023
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Capacity design: high ductility class

**General rule**

**Current EN-1998 (2005) DCH**

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

\[ \Omega \text{ Design overstrength of dissipative members} \]

**prEN-1998 (2022) DC3**

\[ R_d \geq E_{Ed,G} + \omega_{rm} \cdot \omega_{sh} \cdot \Omega_d \cdot E_{Ed,E} \]

\[ \Omega_d \text{ Design overstrength of dissipative members} \]
\[ \omega_{sh} \text{ hardening overstrength factor} \]
\[ \omega_{rm} \text{ material randomness coefficient} \]

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 $\omega_h$ accounting for hardening of the dissipative zones

<table>
<thead>
<tr>
<th>Structural Type</th>
<th>Dissipative Zones</th>
<th>Plastic Mechanism</th>
<th>$\omega_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moment resisting frames</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>beams</td>
<td>yielding</td>
<td>bending</td>
<td>$\frac{(f_y + f_u)}{2f_y} \leq 1.2$</td>
</tr>
<tr>
<td>connections</td>
<td>connections</td>
<td>columns at base</td>
<td></td>
</tr>
<tr>
<td>friction</td>
<td>friction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>connections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Frames with concentric</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bracings (simple and dual)</td>
<td>diagonal</td>
<td>axial</td>
<td>1.1</td>
</tr>
<tr>
<td>members</td>
<td>all members</td>
<td>bending (see 11.10.5 and 11.10.6)</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Frames with eccentric</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bracings (simple and dual)</td>
<td>short links</td>
<td>shear</td>
<td></td>
</tr>
<tr>
<td>connections</td>
<td>$\leq \frac{M_p}{V_p \text{link}}$</td>
<td>$\leq \frac{1.6M_p \text{link}}{V_p \text{link}}$ (very short links)</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>shear</td>
<td>$\leq \frac{2.6M_p \text{link}}{V_p \text{link}}$ (short links)</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>bending and shear</td>
<td>$\leq \frac{3M_p \text{link}}{V_p \text{link}}$ (short links)</td>
<td>1.35</td>
</tr>
<tr>
<td><strong>Frames with eccentric</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bracings (simple and dual)</td>
<td>intermediate</td>
<td>bending and shear</td>
<td></td>
</tr>
<tr>
<td>links</td>
<td></td>
<td>shear</td>
<td></td>
</tr>
<tr>
<td>connections</td>
<td>$\leq \frac{3M_p}{V_p \text{link}}$</td>
<td>$\leq \frac{5M_p}{V_p \text{link}}$ (very short links)</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>bending and shear</td>
<td>$\leq \frac{5M_p \text{link}}{V_p \text{link}}$ (very short links)</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Bending</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bending</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\omega_{sh} = \frac{(f_y + f_u)}{2f_y} \leq 1.2$</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Frames with buckling</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>restrained braces</td>
<td>diagonal</td>
<td>axial</td>
<td></td>
</tr>
<tr>
<td>connections</td>
<td>beams - columns</td>
<td>bending (see 11.12.6)</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

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

MRF

**Summary**

- Cross section class 1,2,3,4 (Portal frames)
- Design shear force calculated from elastic analysis
- Lateral-torsional stability according to EC3

- No local hierarchy (no WB-SC criterion)
- Simplified global hierarchy – assumed design overstrength factor for axial force

- Current EC8/EC3 rules are retained

**Design for DC2**

- $q = [2; 3.5]$

- Beams
- Columns
- Joints

**Design for DC3**

- $q = [5.5; 6.5]$

- Beams
- Columns
- Joints

- Cross section class 1,2
- Design shear force calculated in the expected position of plastic hinge
- Lateral torsional stability: specific rules for DC3

- Local hierarchy calculated for the expected position of plastic hinge (WB-SC criterion)
- Global hierarchy – overstrength factor for axial force, bending, shear

- Annex E: Prequalified 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
    - T-O model Elastic analysis
      - Slenderness within 1.5-2.5
    - T-C model Elastic analysis
      - Slenderness lower than 2.5
    - Stiffness requirement for beam
  - q=2.5

- Design for DC3
  - X-CBF
    - T-C model Elastic analysis
      - Slenderness lower than 2.5
    - Stiffness requirement for beam in V configuration
  - V-CBF
    - T-C model
      - Plastic mechanism analysis
    - Slenderness lower than 2
    - Stiffness requirement for beam in V configuration
  - q=4

- Joints (gusset connections)
  - Both DC2 and DC3 shall comply with similar requirements for brace connections. Specific rules are given in Annex E
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

\[ q = 3.5 \]

Beams, braces, columns

Simplified global hierarchy
(only axial force is magnified)

Design for DC3

\[ q = 6 \]

Beam, braces

Columns

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

Link

Elastic analysis

Link

Plastic mechanism analysis

Global hierarchy
with magnification factor
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

SPECIFIC RULES FOR BUCKLING RESTRAINED BRACES

1\textsuperscript{ST} VS 2\textsuperscript{ND} 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

Design for DC3

q=6

Beam, columns

Elastic analysis
Stability of sleeve

Specific rules are given in Annex E

Figure 11.17 — Geometrical features and main components of a typical BRB
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2
Capacity design: Buckling restrained braces

Design of braces


prEN-1998-1-2(2022) DC3

**REQUIRED STRENGTH**

\[ N_{RD,i} \geq N_{Ed,i} \]

**COMPRESSION STRENGTH ADJUSTMENT FACTOR**

\[ Y_{CT} = \frac{N_{C,Rd}}{N_{T,Rd}} \leq 1.30 \]

**OVERSTRENGTH HOMOGENEITY CONDITION**

\[ \left| (\Omega_{di} - \Omega_d) \Omega_d \right| \leq 0.25 \]

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

**STABILITY OF THE SLEEVE**

\[ \frac{N_{CTBRs}}{N_{Rd}} \geq 2.50 \]
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

Beams and columns should be designed to resist the most severe condition between a) and b):

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

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

\[ \gamma_{CT} = (1.1,1.3) \]

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

\[ N_G = \omega_{rm} \cdot \omega_{sh} \cdot \gamma_{CT} \cdot N_{Rd} \]

\[ N_T = \omega_{rm} \cdot \omega_{sh} \cdot N_{Rd} \]
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
SEISMIC DESIGN OF STEEL BUILDINGS IN THE prEN1998-1-2

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:
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 with 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.10 — 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 EB: (A) full penetration groove welds in accordance with E.3.3.3(6)

Figure E.26 — Gusset plate connections of diagonal braces of EB: (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

- 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
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
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
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

<table>
<thead>
<tr>
<th>Structural type</th>
<th>DC2</th>
<th>DC3</th>
<th>Design approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strap braced walls</td>
<td>2</td>
<td>2.5</td>
<td>Dissipative</td>
</tr>
</tbody>
</table>

### Shear walls with sheetings

<table>
<thead>
<tr>
<th>Structural type</th>
<th>DC2</th>
<th>DC3</th>
<th>Design approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear with steel sheetings</td>
<td>2</td>
<td>2.5</td>
<td>Dissipative</td>
</tr>
<tr>
<td>Shear wall with wood sheetings</td>
<td>2</td>
<td>2.5</td>
<td>Dissipative</td>
</tr>
<tr>
<td>Shear walls with gypsum sheetings</td>
<td>1.7</td>
<td>2</td>
<td>Dissipative</td>
</tr>
</tbody>
</table>
(1) In DC2, non-dissipative components should be designed to resist the action effect $E_{Ed}$ calculated with Formula (11.54):

$$E_{Ed} = E_{Ed,G} + \Omega E_{Ed,E}$$  \hspace{1cm} (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;
- $\Omega$ is the seismic action magnification factor, see Table 11.6.

<table>
<thead>
<tr>
<th>LFRS</th>
<th>DC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strap-braced walls</td>
<td>1.5</td>
</tr>
<tr>
<td>Shear walls with steel sheet sheathing</td>
<td>1.5</td>
</tr>
<tr>
<td>Shear walls with wood sheathing</td>
<td>1.5</td>
</tr>
<tr>
<td>Shear walls with gypsum sheathing</td>
<td>1.3</td>
</tr>
</tbody>
</table>
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

\[ E_{Ed} = E_{Ed,G} \cdot \left( 1 + k \cdot E_{r,c,Rd} \right) \]

\[ E_{Ed} = E_{Ed,G} \cdot \left( 1 + I \cdot I \cdot \omega_{rm} \cdot E_{Nf} \right) \]
Contents

- Introduction
- Seismic design of Steel Buildings in the prEN1998-1-2
- Seismic design of Aluminum Buildings in the prEN1998-1-2
- Conclusions
SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
Evolution of seismic rules

ALUMINUM CHAPTER

EC8 1ST GENERATION
NO SEISMIC RULES

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

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

The most of rules about materials, connections and hierarchy are derived from Japanese seismic recommendantions on Aluminum structures
SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

Addressed topics

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

General rules

Specific rules per type
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 11.2 — 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

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 11.8 — Inverted pendulum: a) dissipative zones at the column base; b) dissipative zones in columns (N_{fac}/N_{min} \geq 0.3)

EBFS ARE NOT ALLOWED
SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2 Ductility classes

prEN1998-1-2 (2022)
DC1-DC2

DC3 is not allowed

No limits

Simplified global + local ductility rules

$2 \leq q \leq 3$

DC2

$S_{\text{lim, DC1}}$

2.5-5 m/s²

General rules apply (prEN 1998-1-1, prEN 1998-1-2 Sections 4.5)

No capacity design

1.5

DC1

1.3 m/s²

No seismic rules

$S_5$

$S_{\text{lim, DC1}}$

5 m/s²

$S_{\text{lim, DC2}}$

5 m/s²

$S_{\text{lim, DC1.25 m/s²}}$

5 m/s²

INVERTED PENDULUM

DUAL FRAMES

CONCENTRICALLY BRACED FRAMES

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

#### Behaviour factors

<table>
<thead>
<tr>
<th>Structural Type</th>
<th>Ductility Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DC2</td>
</tr>
<tr>
<td></td>
<td>$q_D$</td>
</tr>
<tr>
<td>Moment resisting frames (MRFs)</td>
<td>1.5</td>
</tr>
<tr>
<td>Single-storey MRFs</td>
<td></td>
</tr>
<tr>
<td>Multi-storey MRFs</td>
<td>1.5</td>
</tr>
<tr>
<td>Frames with concentric bracings</td>
<td></td>
</tr>
<tr>
<td>Diagonal bracings</td>
<td></td>
</tr>
<tr>
<td>V-bracings</td>
<td>1.5</td>
</tr>
<tr>
<td>X-bracings on either single or two-storey</td>
<td></td>
</tr>
<tr>
<td>Dual frames (MRFs with concentric bracing)</td>
<td>1.7</td>
</tr>
<tr>
<td>Inverted pendulum</td>
<td>1.3</td>
</tr>
</tbody>
</table>
SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

Addressed topics

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

General rules

Specific rules per type
### SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2 Material

Permitted alloys and temper for dissipative parts in DC2

<table>
<thead>
<tr>
<th>Structural element</th>
<th>Product form</th>
<th>alloy</th>
<th>temper</th>
<th>thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet, strip and plate</td>
<td>-</td>
<td>5052</td>
<td>H12</td>
<td>≤40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5040</td>
<td>O/H111</td>
<td>≤100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5083</td>
<td>O/H111</td>
<td>≤80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5383</td>
<td>O/H111</td>
<td>≤120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5454</td>
<td>H116/H321</td>
<td>≤80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5754</td>
<td>O/H111</td>
<td>≤80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6061</td>
<td>T4 / T451</td>
<td>≤12.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6082</td>
<td>T4 / T451</td>
<td>≤12.5</td>
</tr>
<tr>
<td>Extruded profiles, extruded tube, extruded rod/bar and drawn tube</td>
<td>ET, EP, ER/B</td>
<td>5083</td>
<td>O/H111</td>
<td>≤200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5454</td>
<td>O/H111</td>
<td>≤25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5754</td>
<td>O/H111</td>
<td>≤25</td>
</tr>
<tr>
<td></td>
<td>DT</td>
<td>6060</td>
<td>T6</td>
<td>≤20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6061</td>
<td>T6</td>
<td>≤15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6082</td>
<td>T4</td>
<td>≤25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6082</td>
<td>T4</td>
<td>≤25</td>
</tr>
</tbody>
</table>

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)
- Capacity design rules

Specific rules per type
SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2
Structural analysis

Deformation-related requirements

Modified stability coefficient based, which account for design overstrength and the plastic distribution
\[
\theta = \frac{P_{\text{tot}} \cdot d_r}{q_s \cdot q_R \cdot V_{\text{tot}} \cdot h}
\]

Second order effects

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

- Design concepts: Ductility Classes and Behaviour factors
- Material
- Structural analysis (P-delta and drifts)
- Capacity design rules
SEISMIC DESIGN OF ALUMINUM BUILDINGS IN THE prEN1998-1-2

Capacity design: moderate ductility

GENERAL RULES

prEN-1998 (2022) DC2

For aluminum systems DC2 all seismic induced effects are magnified

\[ M_{Rd} \geq M_{Ed,G} + \Omega \cdot M_{Ed,E} \]
\[ V_{Rd} \geq V_{Ed,G} + \Omega \cdot V_{Ed,E} \]
\[ N_{Rd} \geq N_{Ed,G} + \Omega \cdot N_{Ed,E} \]

\[ \Omega = \text{from the Table 15.5} \]
## 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 $\Omega$ in DC2

<table>
<thead>
<tr>
<th>STRUCTURAL TYPE</th>
<th>$\Omega$</th>
<th>Members to which (1) apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moment resisting frames (MRFs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-storey MRFs</td>
<td>1.8</td>
<td>columns</td>
</tr>
<tr>
<td>Multi-storey MRFs</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Frames with concentric bracings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagonal bracings</td>
<td>1.5</td>
<td>beams and columns</td>
</tr>
<tr>
<td>V-bracings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-bracings on either single or two-storey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual frames (MRFs with concentric bracing)</td>
<td>2.0</td>
<td>beams and columns of the concentric bracing; columns of the MRF</td>
</tr>
<tr>
<td>Inverted pendulum</td>
<td>1.5</td>
<td>columns</td>
</tr>
</tbody>
</table>
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:

$$R_d \geq \omega_{rm} \cdot \omega_{sh} \cdot R_{f0}$$

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;
- $\omega_{rm}$ 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, $\omega_{rm}$ can be assumed equal to 1.5;
- $\omega_{sh}$ is the overstrength factor accounting for the hardening in the dissipative zones.

- $\omega_{sh} = 1.3$ For elements in plastic bending, or the value calculated in accordance with Annex L of EN1999-1-1, whichever is greater;
- $\omega_{sh} = 1.5$ For elements in plastic tension: as 1.5 or the ratio $\frac{f_u}{f_0}$, 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