Overview of the Evolution of EN1993: Eurocode 3 — Design of steel structures

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Structure of this slide deck

➔ General overview of the evolution of EN 1993
➔ Specific overview of the evolution of EN 1993 parts:

**PHASE 1**

Structure of this slide deck

- General overview of the evolution of EN 1993
- Specific overview of the evolution of EN 1993 parts:

**PHASE 2**
- **Part 1-3**: General rules – Supplementary rules for cold-formed members and sheeting
- **Part 1-5**: Plated structural elements
- **Part 1-6**: Strength and Stability of Shell Structures
- **Part 1-7**: Plate assemblies with elements under transverse loads
- **Part 1-2**: General – Structural fire design
General overview of the Evolution of EN1993: Eurocode 3 — Design of steel structures

15.10.2020
Agenda – Evolution of EN 1993

- Key changes to EN 1993
- New content included in the scope of EN 1993
- How ease of use has been enhanced

The following slides provide a general overview of the evolution of EN 1993. Complementary slides provide greater details for individual Eurocode Parts.
Key changes to EN 1993

→ Improve structure of Eurocode 3 parts

Table 3. Structure of future Eurocode 3 on steel structures and responsible SC3 Working Groups

<table>
<thead>
<tr>
<th>Part of Eurocode 3</th>
<th>Type</th>
<th>Topic</th>
<th>Working Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 1993-1-1</td>
<td>General rules and rules for buildings</td>
<td>General rules and rules for buildings</td>
<td>WG1</td>
</tr>
<tr>
<td>EN 1993-1-2</td>
<td>Structural fire design</td>
<td>Structural fire design</td>
<td>WG2</td>
</tr>
<tr>
<td>EN 1993-1-3</td>
<td>Supplementary rules for cold-formed members</td>
<td>Supplementary rules for cold-formed members</td>
<td>WG3</td>
</tr>
<tr>
<td>EN 1993-1-4</td>
<td>Stainless steels</td>
<td>Stainless steels</td>
<td>WG4</td>
</tr>
<tr>
<td>EN 1993-1-5</td>
<td>Plated structural elements</td>
<td>Plated structural elements</td>
<td>WG5</td>
</tr>
<tr>
<td>EN 1993-1-6</td>
<td>Strength and stability of shell structures</td>
<td>Strength and stability of shell structures</td>
<td>WG6</td>
</tr>
<tr>
<td>EN 1993-1-7</td>
<td>Plate assemblies with elements under transverse loads</td>
<td>Plate assemblies with elements under transverse loads</td>
<td>WG7</td>
</tr>
<tr>
<td>EN 1993-1-8</td>
<td>Design of joints</td>
<td>Design of joints</td>
<td>WG8</td>
</tr>
<tr>
<td>EN 1993-1-9</td>
<td>Fatigue</td>
<td>Fatigue</td>
<td>WG9</td>
</tr>
<tr>
<td>EN 1993-1-10</td>
<td>Material toughness and through-thickness properties</td>
<td>Material toughness and through-thickness properties</td>
<td>WG10</td>
</tr>
<tr>
<td>EN 1993-1-11</td>
<td>Design of structures with tension components</td>
<td>Design of structures with tension components</td>
<td>WG11</td>
</tr>
<tr>
<td>EN 1993-1-12</td>
<td>Additional rules for steel grades up to S960</td>
<td>Additional rules for steel grades up to S960</td>
<td>WG12</td>
</tr>
<tr>
<td>EN 1993-1-13</td>
<td>Steel beams with large web openings</td>
<td>Steel beams with large web openings</td>
<td>WG20</td>
</tr>
<tr>
<td>EN 1993-1-14</td>
<td>Design assisted by finite element analysis</td>
<td>Design assisted by finite element analysis</td>
<td>WG22*</td>
</tr>
<tr>
<td>EN 1993-2</td>
<td>Steel bridges</td>
<td>Steel bridges</td>
<td>WG13</td>
</tr>
<tr>
<td>EN 1993-3</td>
<td>Towers, masts and chimneys</td>
<td>Towers, masts and chimneys</td>
<td>WG14</td>
</tr>
<tr>
<td>EN 1993-4-1</td>
<td>Silos</td>
<td>Silos</td>
<td>WG15</td>
</tr>
<tr>
<td>EN 1993-4-2</td>
<td>Tanks</td>
<td>Tanks</td>
<td>WG16</td>
</tr>
<tr>
<td>EN1993-5</td>
<td>Piling</td>
<td>Piling</td>
<td>WG18</td>
</tr>
<tr>
<td>EN 1993-6</td>
<td>Crane supporting structures</td>
<td>Crane supporting structures</td>
<td>WG19</td>
</tr>
<tr>
<td>EN 1993-7</td>
<td>Design of sandwich panels</td>
<td>Design of sandwich panels</td>
<td>WG21</td>
</tr>
</tbody>
</table>

Existing

Application parts (8 parts)

→ „Master“ for use of General parts and other Eurocodes

New

Application parts

Part 1
- General rules and rules for buildings

Part 2
- Steel grades up to S700
- Fire
- Fatigue
- Design of joints
- Plates out of plane loading
- Shell structures

Part 3
- Material toughness
- Tension components
- Silos, Tanks and Pipelines

Part 4
- Towers, Masts and Chimneys
- Steel Bridges

Application parts

Part 5
- Crane supporting structures

Part 6
- Steel Bridges

Part 7
- Part 9

General parts (12 parts)
Key changes to EN 1993

- Improve structure of Eurocode 3 parts

  - Enhanced Ease of Use
    Avoiding or removing rules of little practical use in design

  - Withdrawal of part EN 1993-4-3: Eurocode 3 - Design of steel structures - Part 4-3: Pipelines


  - Integrate EN 1993-1-12: Additional rules for the extension of EN 1993 up to steel grades S700
    Design Rules of existing Part 1-12 integrated in Part 1-1, 1-5, 1-8, 1-9 and 1-10
    and define new EN 1993-1-12: Additional rules for steel grades up to S960
New content included in scope of EN 1993

- Integrate new findings from research and technical developments

- **Inclusion of latest development:** Extension to new materials, new products, new methods and new market requirements

- **New part EN 1993-1-14:** Eurocode 3 - Design of steel structures - Part 1-14: Design assisted by finite element analysis
  In order to harmonize the different approaches in the different parts of EN1993 and define common basic rules and definitions

- **New part EN 1993-1-13:** Steel beams with web openings together with SC4: Composite beams with large web openings

- **New part EN 1993-7:** Eurocode 3 - Design of steel structures – Part 7: Sandwich Panels (not within Mandate)
Overview of the Evolution of EN1993-1-1:

15.10.2020
Agenda – Evolution of Part 1-1

→ Key changes to EN 1993-1-1
→ New content included in the scope of EN 1993-1-1
→ How ease of use has been enhanced
Key changes to EN 1993-1-1

- Enhanced Ease of Use
  Improving and reducing number of methods for stability verification

- Simplification of the stability rules
- Unification of the rules between general and application parts
- Reduction of the rules in particular for lateral torsional buckling (LTB)


→ Reducing number of possible options of verifications from 7 to 3
Key changes to EN 1993-1-1 - Restructured

→ **Reduction of number of (informative) Annexes**

→ Annex AB.1: structural analysis taking into account material non-linearities -> moved to the main text.

→ Annex AB.2 on load arrangements for continuous floor beams -> removed

→ These two actions make Annex AB superfluous.

→ Annex BB.1 on elastic flexural buckling in lattice structures has been moved to Technical Report CEN/TR 1993-1-103.

→ Annex BB.2 on restraint stiffness has been made normative.

→ Annex BB.3 on the stable length method for lateral torsional buckling (mainly used in UK) is of limited use in all countries using the Eurocode and has therefore been omitted.
New content included in scope of EN 1993-1-1

→ Design of semi-compact sections

Schematic representation of the cross-sectional resistance of I-sections in bending as a function of the local, geometric plate slenderness c/t; discontinuity at the border between classes 2 and 3
New content included in scope of EN 1993-1-1

New informative Annex E: Basis for the calibration of partial factors

- Annex E not for direct use in design rules
- For the choice of $\gamma_{M1} = 1.0$ there are the following conditions:
  - For the steel the statistical values of Table E.1 and E.2 have to be guaranteed
  - The material values of product standards have to be used instead of Table 5.1

### Table E.1 — Assumed variability of material properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Steel grade</th>
<th>Mean value $X_m$</th>
<th>Coefficient of variation</th>
<th>Upper reference value $X_{95}$</th>
<th>Lower reference value $X_{05}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength, $f_y$</td>
<td>S235, S275</td>
<td>1.25 $R_{e0.2,3}^a$</td>
<td>5.5%</td>
<td>1.14 $R_{e0.2,3}^a$</td>
<td>1.06 $R_{e0.2,3}^a$</td>
</tr>
<tr>
<td></td>
<td>S355, S420</td>
<td>1.20 $R_{e0.2,3}^a$</td>
<td>5.0%</td>
<td>1.11 $R_{e0.2,3}^a$</td>
<td>1.03 $R_{e0.2,3}^a$</td>
</tr>
<tr>
<td></td>
<td>S460</td>
<td>1.15 $R_{e0.2,3}^a$</td>
<td>4.5%</td>
<td>1.07 $R_{e0.2,3}^a$</td>
<td>1.00 $R_{e0.2,3}^a$</td>
</tr>
<tr>
<td>Above S460</td>
<td>1.10 $R_{e0.2,3}^a$</td>
<td>3.5%</td>
<td>1.04 $R_{e0.2,3}^a$</td>
<td>1.00 $R_{e0.2,3}^a$</td>
<td></td>
</tr>
<tr>
<td>Ultimate tensile strength, $f_u$</td>
<td>S235, S275</td>
<td>1.20 $R_{e0.2,3}^a$</td>
<td>5.0%</td>
<td>1.11 $R_{e0.2,3}^a$</td>
<td>1.03 $R_{e0.2,3}^a$</td>
</tr>
<tr>
<td></td>
<td>S355, S420</td>
<td>1.15 $R_{e0.2,3}^a$</td>
<td>4.0%</td>
<td>1.08 $R_{e0.2,3}^a$</td>
<td>1.02 $R_{e0.2,3}^a$</td>
</tr>
<tr>
<td>S460 and above</td>
<td>1.10 $R_{e0.2,3}^a$</td>
<td>3.5%</td>
<td>1.04 $R_{e0.2,3}^a$</td>
<td>1.00 $R_{e0.2,3}^a$</td>
<td></td>
</tr>
<tr>
<td>Modulus of elasticity, $E$</td>
<td>All steel grades</td>
<td>210000 N/mm²</td>
<td>3.0%</td>
<td>200000 N/mm²</td>
<td>192000 N/mm²</td>
</tr>
</tbody>
</table>

* $R_{e0.2,3}^a$ and $R_{e0.2,3}^a$ are the minimum yield strength $R_{e0}$ and the lower bound of the ultimate tensile strength $R_{u}$ according to the applicable product standard, e.g., of the EN 10025 series.
How ease of use has been enhanced

→ Flowchart added on methods of structural analysis

<table>
<thead>
<tr>
<th>Flow chart</th>
<th>Method &amp; Clause</th>
<th>Imperfection</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_{\text{cr,y}} \geq k_0 ) see 7.2.1(4) and ( \alpha_{\text{cr,y}} \geq 10 ) see 7.2.1(5)</td>
<td>( \text{LTB can be neglected, see 7.2.1(6)} ) ( \text{yes} )</td>
<td>( \text{M0} ) 7.2.2(4)</td>
</tr>
<tr>
<td>( \text{no} )</td>
<td>Alternative Method EM, see 7.2.2(9)</td>
<td>( \text{M1} ) 7.2.2(5)</td>
</tr>
<tr>
<td>( \alpha_{\text{cr,y}} \geq 10 ) see 7.2.1(5)</td>
<td>( \text{yes} )</td>
<td>( \text{M2} ) 7.2.2(6)</td>
</tr>
<tr>
<td>( \text{no} )</td>
<td>Sway effects are accounted for: ( N_{\text{pl}} \leq N_{\text{cr}} / 4 ) see 7.3.4</td>
<td>( \text{M3} ) 7.2.2(7)a</td>
</tr>
<tr>
<td>( \text{yes} )</td>
<td>Sway effects and in-plane non sway effects are accounted for.</td>
<td>( \text{M4} ) 7.2.2(7)b</td>
</tr>
<tr>
<td>( \text{no} )</td>
<td>Sway effects and in-plane and out-of-plane non sway effects are accounted for.</td>
<td>( \text{M5} ) 7.2.2(8)</td>
</tr>
</tbody>
</table>

LTB: Lateral torsional buckling  
EM: Equivalent member method  
SI: Sway imperfection  
MBI: Member bow imperfection (in-plane)  
MBIT: Member bow imperfection including torsional effects (in-plane)
Overview of the Evolution of EN1993-1-8:
Agenda – Evolution of EN 1993-1-8: Design of joints

→ Key changes to EN 1993-1-8
→ New content included in the scope of EN 1993-1-8
→ How ease of use has been enhanced
Key changes to EN 1993-1-8

→ Restructuring to improve ease of use

Restructuring of Chapter 5 and 6

- Existing structure Chapter 5 and 6:
  - 5 Analysis, classification and modelling
  - 6 Structural joints connecting H or I sections

- New structure for Chapter 5 (7) and 6 (8) and Annexes:
  - 7 Structural analysis
  - 8 Structural joints connecting H or I sections

- Annex A (Normative). Structural properties of basic components
- Annex B (Normative). Design of moment-resisting beam-to-column joints and splices
- Annex C (Normative). Design of nominally pinned connections
- Annex D (Normative). Design of column bases
New content included in scope of EN 1993-1-8

→ **Improved rules for welding**

- Load bearing capacity of **fillet welded connections** of high strength steels

  → modified correlation factor with **equal** parent and filler metal strength
  = Improved design specifications also for steel grades up to 700 N/mm²

  → new rule for fillet welded connections of steel grades ≥ S460 and with **different** parent and filler metal strength:
  Possibilities to cover mismatch-effects,
  Undermatching may have advantages regarding ductility, weldability, quality

\[
\sigma_{w,Rd} = \frac{0.25 \cdot f_{u,PM} + 0.75 \cdot f_{u,FM}}{\beta_{w,mod} \cdot \gamma_{M2}}
\]

Issue 1
Date: 15/10/2020
New content included in scope of EN 1993-1-8

→ Improved rules for nominally pinned connections

→ New Annex C (normative)

The connections designed in accordance with this Annex may be classified as nominally pinned joints and are able to transmit shear forces without developing significant bending moments.

→ rules allow easy design in practice

Typical pinned connections

- a) Double angle web cleats
- b) Fin plate
- c) Partial depth end plate

Key
1 supported member
2 supporting member
How ease of use has been enhanced

→ Harmonisation with other Eurocodes

- New Annex D (normative) Design of column basis

The design resistance of anchor bolts and anchoring components should be determined from A.16.1, A.17, A18 and A.19 of this Standard and EN 1992-4.

Rules for a plastic design of joints with multiple rows of anchor bolts and anchoring components are given in CEN/TR 17081.

- Harmonisation with EN 1998-2 Seismic design regarding wording and definitions

Issue 1
Date: 15/10/2020
Overview of the Evolution of EN1993-1-3:
Eurocode 3 — Design of steel structures — Part 1-3: General rules – Supplementary rules for cold-formed members and sheeting

2020-08-10

apl. Prof. Dr.-Ing. habil. Bettina Brune,
Technical University of Dortmund, Germany
Agenda – Evolution of EN 1993-1-3

→ Key changes to EN 1993-1-3
→ New content included in the scope of EN 1993-1-3
→ How ease of use has been enhanced
Key changes to EN 1993-1-3 - General

- Improvements according to M515 Detailed Task Specification given by Volume 3 (Call for Tenders – Grant Agreement SA/CEN/GROW/EFTA/515/2016-2)

- Inclusion of new state-of-the-art material and new research results dealing with cold-formed steel members and sheeting which has been validated by through scientific investigations, tests or sufficient practical experience

- Incorporation of about 90 technical amendments worked out by the corresponding SC3.WG3, confirmed by SC3 (see list of amendments to EN 1993-1-3)
Key changes to EN 1993-1-3 - General

→ Reduction of NDPs  (2006: 19 NDPs (131 pages); FIN DOC: 14 NDPs – 9 „old“ and 5 „new“ resulting from AMDs (197 pages, 50% more content))

→ Reduction of informative Annexes  (2006: A-E; FIN DOC: A-C)
  - Annex C  removed because it contains textbook material
  - Annex E  removed because it contains a second, simplified, alternative design provisions for purlins
  - Annex A  improved and restructured for ease of use
  - Annex D  improved and included as new Annex C
Key changes to EN 1993-1-3 - Technical

→ **Clause 5: Materials**

- Inclusion and specification of new steel material with properties and chemical composition in compliance with the new standards to be used for cold-formed members/sheeting and the design acc. to EN 1993-1-3

Extract from Table 5.1b - Nominal values of basic yield strength $f_{yb}$ and ultimate tensile strength $f_{u}$

<table>
<thead>
<tr>
<th>Type of steel</th>
<th>Standard</th>
<th>Grade</th>
<th>$f_{yb}$ [N/mm²]</th>
<th>$f_{u}$ [N/mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuously hot-dip coated steel flat products for cold-forming</td>
<td>EN 10346</td>
<td>S220GD+Z, +ZF, +ZA, +ZM, +AZ</td>
<td>220</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S250GD+Z, +ZF, +ZA, +ZM, +AZ, +AS</td>
<td>250</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S280GD+Z, +ZF, +ZA, +ZM, +AZ, +AS</td>
<td>280</td>
<td>360</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S320GD+Z, +ZF, +ZA, +ZM, +AZ, +AS</td>
<td>320</td>
<td>390</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S350GD+Z, +ZF, +ZA, +ZM, +AZ, +AS</td>
<td>350</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S390GD+Z, +ZF, +ZA, +ZM, +AZ</td>
<td>390</td>
<td>460</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S420GD+Z, +ZF, +ZA, +ZM, +AZ</td>
<td>420</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S450GD+Z, +ZF, +ZA, +ZM, +AZ</td>
<td>450</td>
<td>510</td>
</tr>
</tbody>
</table>
Key changes to EN 1993-1-3 - Technical

→ Clause 7: Structural analysis

7.1: Structural modelling for analysis

- Providing relevant guidance for cold-formed sections and sheeting incl. FE-analysis with reference to new EN 1993-1-14

7.2: Global analysis for ultimate limit design check

- Specification of methods for global analysis for cold-formed sections considering torsional- and torsional-flexural buckling modes including imperfections (consistency with EN 1993-1-1, harmonized with EN 1993-1-14)
- Providing clear guidance in new Table 7.1
Key changes to EN 1993-1-3 - Technical

→ **Clause 7: Structural analysis**

*Providing clear guidance in new Table 7.1*

<table>
<thead>
<tr>
<th>Method acc. to EN 1993-1-1:2019, 7.2.2</th>
<th>Additional requirements for cold-formed steel sections</th>
<th>1st/2nd order effects for global analysis</th>
<th>Imperfections to be considered in the global analysis</th>
<th>Design check according to EN 1993-1-3, Clause 8.1 or 8.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>M0 7.2.2(4)</td>
<td>In-plane and out-of-plane buckling may be neglected</td>
<td>1st order effects</td>
<td>None</td>
<td>8.1: Cross-sectional resistance</td>
</tr>
<tr>
<td>M1 7.2.2(5)</td>
<td>In-plane buckling may be neglected, Out-of-plane buckling (Flexural, torsional, torsional-flexural or lateral-torsional buckling ) may not be neglected</td>
<td>1st order effects</td>
<td>None</td>
<td>8.1: Cross-sectional resistance and 8.2: Out-of-plane member buckling check</td>
</tr>
<tr>
<td>EM 7.2.2(9)</td>
<td></td>
<td>1st order effects</td>
<td>None</td>
<td>8.1: Cross-sectional resistance and 8.2: In-plane and out-of-plane member buckling check acc. to 8.2 based on an appropriate buckling length of “Equivalent Members”</td>
</tr>
<tr>
<td>M2 7.2.2(6)</td>
<td></td>
<td>1st order effects</td>
<td>Global sway imperfections</td>
<td>8.1: Cross-sectional resistance and 8.2: In-plane and out-of-plane member buckling check</td>
</tr>
<tr>
<td>M3 7.2.2(7)a</td>
<td></td>
<td>2nd order effects</td>
<td>Global sway imperfections</td>
<td>8.1: Cross-sectional resistance using γM1 and 8.2: In-plane and out-of-plane member buckling check</td>
</tr>
<tr>
<td>M4 7.2.2(7)b</td>
<td></td>
<td>2nd order effects</td>
<td>Global sway imperfections and in-plane member bow imperfections</td>
<td>8.1: Cross-sectional resistance using γM1 and 8.2: Out-of-plane member buckling check</td>
</tr>
<tr>
<td>M5 7.2.2(8)</td>
<td></td>
<td>2nd order effects</td>
<td>Global sway imperfections and in-plane and out-of-plane member bow imperfections and torsional effects (torsional, torsional-flexural or lateral-torsional buckling modes)</td>
<td>Stress verification based on FE-analysis acc. to EN 1993-1-14</td>
</tr>
</tbody>
</table>

**NEW**
Key changes to EN 1993-1-3 - Technical

-Clause 8: Ultimate limit states

8.1.6: Resistance to transverse forces

- Improved design provisions for cross-sections with a single unstiffened web (sections) and with two or more unstiffened webs (sheeting) according to new research (accounting for high-strength steel as well)

Figure - Examples of cross-sections with a single web

Figure - Examples of cross-sections with two or more webs
Key changes to EN 1993-1-3 - Technical

→ Clause 8: Ultimate limit states

8.2.5: Bending and compression

- Improvement of design provisions for cold-formed steel members in bending and compression with regard to safe, but economic design and consistency with EN 1993-1-1, where possible

For major principle axis buckling:

\[
\left( \omega_{x,y} \frac{N_{Ed}}{\chi_y N_{c,Rd}} \right)^{\alpha_y} + \left( \omega_{x,LT} \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}} \right)^{\beta_y} + \left( \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd}} \right)^{\delta_y} \leq 1 \quad (8.71)
\]

For minor principle axis buckling:

\[
\left( \omega_{x,z} \frac{N_{Ed}}{\chi_z N_{c,Rd}} \right)^{\alpha_z} + \left( \omega_{x,LT} \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}} \right)^{\beta_z} + \left( \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd}} \right)^{\delta_z} \leq 1 \quad (8.72)
\]
Clause 10: Design of joints

10.3: Connections with mechanical fasteners

- Enlargement and improvement of design provisions and specifications for mechanical fasteners used in cold-formed steel structures such as blind rivets, self-tapping screws, bolts and cartridge-fired pins according to new research.

Key changes to EN 1993-1-3 - Technical

→ Clause 11: Special consideration for members, liner trays and sheeting

11.4: Lateral and torsional restraints of members provided by sheeting, liner trays and sandwich panels

- New Clause 11.4 which summarizes all design provisions for stabilization of steel members provided by the stabilizing elements

- Reference to the new Clause 11.4 can be made by other parts of EN 1993-1
Key changes to EN 1993-1-3 - Technical

Annex A: Testing procedures

- Restructuring of design provisions and clear guidance for testing procedures of cold-formed structures, members and sheeting as well as evaluation with regard to harmonization with EN 1990
  - Tests on material
  - Tests on single beams and columns
  - Tests on structures and sub-assemblies
  - Tests on profiled sheeting and liner trays
  - Tests on torsionally restrained beams
  - Tests on fastenings
Key changes to EN 1993-1-3 - Technical

→ Annex C: **Mixed effective widths/effective thickness method for outstand elements**  
  
  - Inclusion of an improved buckling curve for local plate buckling of outstand elements according to new researches and SC3.WG3 amendments to use overcritical buckling reserves

(3) The reduction factor for local buckling is given by:

\[
\rho = \begin{cases} 
\frac{1}{\lambda_p} - \frac{0,188}{\lambda_p^2} & \leq 1 \\
0,77 & \text{if } 0,749 \leq \lambda_p < 1,2 \\
\sqrt[\lambda_p] & \text{if } 1,2 \leq \lambda_p \leq 3,2 
\end{cases}
\]

where:

- $\lambda_p$ is the relative slenderness for local buckling of plane elements given in 7.6.2

**consistency with EN1993-1-5**

**overcritical buckling reserves verified by research and new state-of-the-art material**
New content included in scope of EN 1993-1-3

→ **Clause 7.6.5:** Special provisions of sinusoidal or similar sheeting

→ **Clause 8.1.4.4:** Curved sheeting and sections
New content included in scope of EN 1993-1-3

→ **Clause 9.4:** Walkability of trapezoidal sheeting (during and after installation)  

- providing overall robustness and serviceability
- providing tests and assessment criteria in Clause A.5.6

**Table A.4 - Assessment criteria for walkability**

<table>
<thead>
<tr>
<th>Type of loading</th>
<th>Loading pattern</th>
<th>Loading $F_{\text{min}}$ [kN]</th>
<th>Assessment criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge loading</td>
<td><img src="image" alt="Edge loading" /></td>
<td>1.2</td>
<td>significant permanent deformation</td>
</tr>
<tr>
<td>Outermost completely formed rib in direction of lay</td>
<td><img src="image" alt="Outermost completely formed rib" /></td>
<td>1.5</td>
<td>failure load</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Outermost completely formed rib" /></td>
<td>2.0</td>
<td>sudden failure without significant overall deformation</td>
</tr>
<tr>
<td>Central loading</td>
<td><img src="image" alt="Central loading" /></td>
<td>2.0</td>
<td>failure load $^*$</td>
</tr>
</tbody>
</table>

$^*$ After a decrease in load following the first load peak, membrane effects may lead to a subsequent increase in load. Assessment criteria may be applied to the second load peak, provided that the additional criterion $F_{\text{min}} \geq 1.5$ kN is satisfied at the first load peak.
New content included in scope of EN 1993-1-3

→ **Clause 11.3 and 8.1.6.5:**  

**M515 task specification**

**Concentrated line loads and point loads on trapezoidal sheeting (without intermediate systems)**

- Distribution of concentrated line loads introduced by photovoltaic systems and design of roofs (green and ecologic aspect)

![Diagram showing load distribution](image)

**Key**  
- $F_{Ed}$ applied load  
- $F_{Ed,1}$, $F_{Ed,2}$ assumed load distribution

**Figure** - Load distribution without intermediate load-distributing systems
New content included in scope of EN 1993-1-3

→ **Clause 11.3.3:** Sheeting with an opening

Key
(a) Top view on upper flange with circular holes
(b) Top view on the upper flange with square holes

**Figure** - Sheeting with circular (a) or square (b) holes in flange
New content included in scope of EN 1993-1-3

Clause 11.3.4: Trapezoidal sheeting with overlap at support

M515 task specification

Table 11.12 - Static system of the overlapping sheeting with single or double overlap or reinforcement

<table>
<thead>
<tr>
<th>11.3.4.2</th>
<th>Single overlap with cantilevered lower sheeting</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOL-L</td>
<td></td>
</tr>
</tbody>
</table>

Clause 11.3.5: Trapezoidal sheeting with side overlaps
How ease of use has been enhanced

→ Clarification
  ▪ Including explanatory text and additional information
  ▪ Specification of design provisions to provide clear guidance
  ▪ Including clear references (to EN 1993-1-3 and other EN 1993 provisions where required) to ease the navigation between the relevant standards

→ Restructuring
  ▪ Restructuring of e.g. Clause 11 and Annex A for clarification

→ Harmonization with relevant parts of EN1993
  ▪ All design provisions have been checked and harmonized with the relevant parts of EN 1993 (part 1-1, 1-5, 1-8, 1-14, EN 1090-2) and the product standards, if possible
Overview of the Evolution of EN1993-1-5:
Eurocode 3 — Design of steel structures — Part 1-5: Plated structural elements
Agenda – Evolution of EN 1993-1-5: Plated structural elements

-> Key changes to EN 1993-1-5
-> New content included in the scope of EN 1993-1-5
-> How ease of use has been enhanced
Key changes to EN 1993-1-5

→ **Improved structure for ease of use**

→ **Reduction of number of (informative) Annexes**
  - Annex C (informative) Finite Element Methods of Analysis (FEM) moved to EN 1993-1-14
  - Annex D Plate girders with corrugated webs integrated into main text
  - Annex E Alternative methods for determining effective cross sections integrated into main text

→ **Section 10 Reduced stress method**
  reorganized and improved for ease of use

→ **Reduction of NDP**

  Ø Today: 15 NDPs
  Final draft: only 3 NDPs

---

Issue 1
Date: 15/10/2020
Key changes to EN 1993-1-5

→ Inclusion of latest developments

- Development of new amendments (2011-2020) for the implementation in the new draft

- shear resistance
- resistance to direct stresses
- resistance of girders subjected to patch loading
- minimum requirement for transverse stiffener
- rules for corrugated webs
- biaxial compression
- consideration of torsional stiffness of closed section stiffeners
- flange induced buckling
New content included in scope of EN 1993-1-5 (examples)

→ *Improved rules for M-V-F interaction of corrugated web girders*

- Based on new experimental and numerical research

Balázs Kövesdi, Technical University of Budapest

Issue 1
Date: 15/10/2020
New content included in scope of EN 1993-1-5 (examples)

→ New M-V-F interaction design rules for stiffened and unstiffened girders

Based on extended numerical research program

New design interaction equation:

\[
\eta_1^{3.6} + \left[ \eta_3 \cdot \left( 1 - \frac{F_{Ed}}{2 \cdot V_{Ed}} \right) \right]^{1.6} + \eta_2 \leq 1.0
\]

Benjamin Braun, University of Stuttgart

COMBRI research project
New content included in scope of EN 1993-1-5 (examples)

→ Improved rules for flange induced buckling

Based on new experimental and numerical research

Very conservative assumptions with current EN 1993-1-5 formulas especially for HSS!

José Oliveira Pedro, Technical University of Lisbon

\[
\frac{h_w}{t_w} \leq k \frac{E}{\beta f_{yt}} \left(\sqrt{\frac{A_w}{A_{fc}}}\right)
\]

where $A_w$ is the cross-section area of the web;
$A_{fc}$ is the effective cross-section area of the compression flange;
$h_w$ is the depth of the web;
$t_w$ is the thickness of the web.
New content included in scope of EN 1993-1-5 (examples)

→ Improved rules for non-rectangular panels

➢ Verification of cross sections in a non-rectangular panel

Proposal for non-rectangular panels:

- Section 3 or 4
- Section 5

→ Same sections like bending

\[ N_{x,f} = \frac{M(x)}{(h_{wf} + t_f)} \]

\[ V_{z,f} = N_{x,f} \cdot \tan \phi \]

\[ V_{int} = V_{modified} = |F - V_{z,f}| \]

→ Shear stresses should be modified due to inclined flange

Based on new experimental and numerical research
How ease of use has been enhanced

- Complete restructuring of former section 10 now 12
- Reduced stresses method
- Flowchart added for the application of the reduced stress method

Notes:
(a) For stiffened plates, the global buckling of the stiffened plate and each individual sub-panel should be verified.
(b) In case of biaxial compression, section 6.5.3 and the modified buckling length according to section 6.4.2 (4) for transverse forces for each sub-panel should be considered.
(c) In case of biaxial compression, the longitudinal stiffeners should be designed by using a beam model and second order analysis.
Overview of the Evolution of EN1993-1-6:
Eurocode 3 — Design of steel structures — Part 1-6: Strength and Stability of Shell Structures

15.10.2020 Content has been taken from TC250/SC3/N3075 Presentation prepared in the absence of Professor J. Michael Rotter by Adam J. Sadowski and Chris Brown, University of Edinburgh, Scotland, Imperial College, London, Brunel University London, UK

Issue 1
Date: 15/10/2020
Agenda – Evolution of EN 1993-1-6: Strength and Stability of Shell Structures

- Key changes to EN 1993-1-6
- New content included in the scope of EN 1993-1-6
- How ease of use has been enhanced
Key changes to EN 1993-1-6

- Reduced number of NDPs

- Published standard (2007) had 18 NDPs

- Third draft has 3 NDPs, e.g.
  - Gamma factors for different failure modes
  - Imperfection amplitudes for manufactured tubes
Key changes to EN 1993-1-6

→ **Major technical changes**

→ Extensive textual revisions to improve ease of use
→ Many enhancements on imperfections and tolerances
→ Enhancements on computational modelling
→ Expansion of boundary condition cases for external pressure and removal of unsafe short cylinder rules
→ Enhanced rules for buckling under axial compression including addition of stainless steel
→ Extensive rules for global bending with axial compression and moment gradient
→ Revised rules on spherical domes
New content included in scope of EN 1993-1-6

- Imperfections and computational modelling

- The 4 buckling relevant tolerance controls
  - Out of roundness
  - Unintended eccentricity between constituent plates
  - Dimples
  - Interface flatness

- Dimple tolerances generally dominate (5 measures)
New content included in scope of EN 1993-1-6

- *Imperfections and computational modelling*
- Each of the 4 tolerance measurements has its own limit for each Fabrication Quality Class
- The published standard (2007) says that the worst measure on all measurements determines the Fabrication Quality Class
- This is unfortunate because different tolerances are critical for different load cases
  - (e.g. Interface flatness is only important for axial compression)
- Result: many constructed shells are required to meet tolerances that are irrelevant to the true resistance of the structure
New content included in scope of EN 1993-1-6

$\Rightarrow$ **Imperfections and computational modelling**

$\Rightarrow$ The designer now must identify and specify the tolerances that a particular shell should meet to achieve the required buckling resistance.

$\Rightarrow$ This is particularly important in the context of legal disputes and insurance claims, because tolerances are often invoked to show that a structure is unsatisfactory when the tolerance has no relevance to the structural resistance.

<table>
<thead>
<tr>
<th>Stress state dominated by membrane stresses</th>
<th>Out of roundness</th>
<th>Unintended eccentricity</th>
<th>Dimple</th>
<th>Interface flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meridional compression</td>
<td>Applies</td>
<td>Applies</td>
<td>$l_{x}$ and $l_{wy}$ only</td>
<td>Applies</td>
</tr>
<tr>
<td>Circumferential compression</td>
<td>Applies</td>
<td></td>
<td>$l_{x}$ and $l_{wy}$ only</td>
<td></td>
</tr>
<tr>
<td>Shear</td>
<td>Applies</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
New content included in scope of EN 1993-1-6

→ **Imperfections and computational modelling**
→ The new concept works well for simple structures with a dominant membrane stress, but is more difficult where all 3 membrane stresses are acting, identified by a new procedure
→ “Assessment of the dominant stress condition”, identifies whether a stress state can be treated as simple or not
→ It uses the ratios of each acting stress component to its resistance at every location

\[
k_x = \frac{\sigma_{x,Ed}}{\sigma_{x,Rd}} \quad k_\theta = \frac{\sigma_{\theta,Ed}}{\sigma_{\theta,Rd}} \quad k_{x\theta} = \frac{\tau_{x\theta,Ed}}{\tau_{x\theta,Rd}}
\]

<table>
<thead>
<tr>
<th>Stress state dominated by membrane stresses</th>
<th>Required tolerance dependent on the shell stress state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meridional compression</td>
<td>Out of roundness</td>
</tr>
<tr>
<td>Applies</td>
<td>Applies</td>
</tr>
<tr>
<td>Circumferential compression</td>
<td>Applies</td>
</tr>
<tr>
<td>Shear</td>
<td>Applies</td>
</tr>
</tbody>
</table>

Table 8.1

Copyright: Professor JM Rotter
New content included in scope of EN 1993-1-6

- **Buckling of stepped walls under external pressure and wind**
- The procedures in the 2007 published standard were very difficult to use, involving reading values from tiny charts
- This is replaced by the rationally based Weighted Smeared Wall Method, leading to a much simpler process for stepped walls, treating both external pressure and wind
New content included in scope of EN 1993-1-6

- **Cylindrical shells under global bending**
  - Very substantial new provisions have been introduces
  - Uniform bending resistance carefully defined
  - Bending combined with axial compression
  - Bending with moment gradient (shear)
  - Each of these has been fully defined in terms of Reference Resistance Design
    - The 2 reference resistances (LBA and MNA)
    - The 6 parameters that characterise the interaction, each of which depends on the geometry and imperfection amplitude
  - Uniform bending
    - Reference resistances LBA and MNA relatively easily defined $M_{cr}$ and $M_{pl}$
    - Geometric nonlinearity $\alpha_G$ mostly in ovalisation
      - Very sensitive length

\[
\omega = \frac{c}{\sqrt{r}}
\]

\[
\Omega = \frac{c}{r} \sqrt{\frac{1}{r}} = \omega \frac{l}{r}
\]

\[
\alpha_{cr} = 0.9
\]

\[
\alpha_{pl} = 0.016 + (0.38 \sin \varphi + 0.48 \cos \varphi) e^{-0.8 \varphi}
\]

where $\varphi = 0.85 \Omega$

when $\Omega < 0.5$

when $\Omega \geq 0.5$
New content included in scope of EN 1993-1-6

→ **Shell buckling & boundary conditions**

→ Boundary conditions are especially important under external pressure, where the conditions at each end of a cylinder of
  - Radial, axial and bending restraint are all important
→ The 2007 standard had only 4 real boundary conditions
→ The revised standard allows for all 14 possible bc combinations
→ Some previous relationships for short cylinders were unsafe
→ Short cylinders occur commonly in stepped walls of tanks and silos
New content included in scope of EN 1993-1-6

→ **Buckling of spherical and similar shells**

→ The focus of this ST5 has been on upgrading the treatment of spherical domes (important for tanks)

→ The previous treatment used the wrong criteria to define both the plastic failure condition and the elastic critical condition

→ This has been remedied now

→ The previous treatment also used in unrealistic boundary conditions that were difficult to relate to a real structure

\[ p_{R,cr} = \frac{2}{\sqrt{3(1-v^2)}} \cdot C_{cr} \cdot E \cdot \left(\frac{t}{r_s}\right)^2 \]

\[ p_{R,pl} = f_y \cdot k \cdot C_{pl} \cdot \frac{2t}{r_s} \]
How ease of use has been enhanced

- Implementation of the revised chapter structure
- Extensive critical examination of the text throughout the standard
- Addition of further definitions for clarity (now 59)
- More precise definitions of technical terms
- Extensive use of new explanatory NOTES to help the reader to understand the purpose and intention of new provisions
- Re-structuring of long or complicated sections (e.g. LBA-MNA)
- Retention of some Editorial Notes in the Third Draft to pose questions to the reviewer on choices to be made
Overview of the Evolution of EN1993-1-7:
Eurocode 3 — Design of steel structures — Part 1-7: Plate assemblies with elements under transverse loads

15.10.2020 Content has been taken from TC250/SC3/N3075 Presentation prepared in the absence of Professor J. Michael Rotter by Adam J. Sadowski and Chris Brown, University of Edinburgh, Scotland, Imperial College London, Brunel University London, UK
Agenda – Evolution of EN 1993-1-7: Plate assemblies with elements under transverse loads

→ Key changes to EN 1993-1-7
→ New content included in the scope of EN 1993-1-7
→ How ease of use has been enhanced
Key changes to EN 1993-1-7

→ Reduced number of NDPs

→ Published standard (2007) had 1 NDP

→ Final draft (completely different standard) has 5 NDPs, e.g.
  • Gamma factors for different failure modes
  • Design by testing
  • Limiting strain at plastic failure (gross deformations)
  • Acceptable deflection ULS in the longest side of a plate assembly
Key changes to EN 1993-1-7

→ **Major technical changes**

→ **Complete new structure for the later parts dividing into**
  - Plate assemblies
  - Unstiffened plates in plate assemblies
  - Uni-directionally stiffened plates
  - Bi-directionally stiffened plates

→ **New annexes to give algebraic expressions for elastic and plastic design under different load patterns**

→ **A significant body of text on plate assemblies**

→ **Good links to EN 1993-1-5**
New content included in scope of EN 1993-1-7

→ Transformation of EN 1993-1-7 to deal with box-like assemblies of plates
→ New clause structure implemented
→ Plate assemblies
→ Unstiffened plates including triangular and trapezoidal
→ Uni-directionally stiffened plates
→ Bi-directionally stiffened plates

→ New annexes to give algebraic expressions for
  • Simple analysis for small plate assemblies
  • Elastic deflections and moments in single plates under practical load patterns
  • Plastic collapse of plates and assemblies under practical load patterns

→ Significant advice on the interactions between and support requirements for plates in plate assemblies
How ease of use has been enhanced

→ Complete new logical structure
→ Extensive critical examination of the text throughout the standard
→ Definitions for clarity (now 20)
→ Use of explanatory NOTES to help the reader to understand the purpose and intention of new provisions
→ Annexes containing extensive material that cannot be found in texts or guides
Overview of the Evolution of EN1993-1-2:
Eurocode 3 — Design of steel structures — Part 1-2: General – Structural fire design

12.10.2020

Paulo Vila Real, Professor of Structural Engineering and Steel Construction,
Department of Civil Engineering, University of Aveiro
PORTUGAL
Agenda – Evolution of EN 1993-1-2: General – Structural fire design

- Key changes to EN 1993-1-2
- New content included in the scope of EN 1993-1-2
- How ease of use has been enhanced
Key changes to EN 1993-1-2

- Reduction in number of National Choices (NDPs): NDPs have reduced from 5 to 4;
- Enhanced ease of use;
- New structure harmonized with fire parts of other Eurocodes;
- High strength steels: Nominal fires are applicable to steel grades up to and including S700. Physically based thermal actions are applicable to steel grades up to and including S500;
- Emissivity coefficient for hot-dip galvanized steel;
Key changes to EN 1993-1-2

- Existing buckling curve for LTB has been improved to take in to account the beneficial effect of non-uniform bending diagrams;
- Annex C for stainless steel member has been changed with a completely new content;
- Annex D now include welded steel tubular joints;
- Former Annex E for Class 4 cross-sections was withdrawn. New design rules for class 4 cross-sections were included in EN 1993-1-2;
- New Annex E for beams with large web openings;
New content included in scope of EN 1993-1-2

→ *Emissivity coefficient for hot-dip galvanized steel*

<table>
<thead>
<tr>
<th>Type of steel</th>
<th>$\varepsilon_m (\leq 500^\circ C)$</th>
<th>$\varepsilon_m (&gt; 500^\circ C)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel</td>
<td></td>
<td>0,7</td>
</tr>
<tr>
<td>HDG steel(^a)</td>
<td>0,35</td>
<td>0,7</td>
</tr>
</tbody>
</table>

\(^a\) Steel that has been hot-dip galvanized according to EN ISO 1461 and with steel composition according to Category A or B of EN ISO 14713-2, Table 1.
New content included in scope of EN 1993-1-2

⇒ Emissivity coefficient for hot-dip galvanized steel

Background documents

- Jirku, J. & Wald, F. & Jandera, M. Increase of the fire endurance of the structure by galvanizing
- Jirku, J. & Wald, F. & Jana, T. Heat transfer into galvanized components verification by fire tests in experimental.building
- Sala, A. 1986. Radiant Properties of Materials
- Gaigl C., Mensinger M.: Influence of hot dip galvanization to the heating of hot rolled steal section; research report, 2018
New content included in scope of EN 1993-1-2

→ Influence of the bending diagrams on the LTB

![Graphs showing influence of bending diagrams on LTB](image)

a) \( \Psi = 1 \)

b) \( \Psi = 0 \)

c) \( \Psi = -1 \)
New content included in scope of EN 1993-1-2

→ Influence of the bending diagrams on the LTB

(6) In order to take into account the effects of moment distribution between the lateral restraints of the members, the reduction factor may be modified as follows:

$$\chi_{LT,n,mod} = \frac{\chi_{LT}}{f} \quad \text{but} \quad \chi_{LT,n,mod} \leq 1.0$$  \hspace{1cm} (7.23)

where $f$ should be taken to depend on the loading type, according to the Formula:

$$f = 1 - 0.5(1 - k_c)$$  \hspace{1cm} (7.24)

where $k_c$ is a correction factor according to Table 7.1.

<table>
<thead>
<tr>
<th>Moment distribution</th>
<th>$k_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$0.6 + 0.3\psi + 0.15\psi^2$ but $k_c \leq 1.0$</td>
</tr>
<tr>
<td>![Moment Diagram 1]</td>
<td>0.91</td>
</tr>
<tr>
<td>![Moment Diagram 2]</td>
<td>0.90</td>
</tr>
<tr>
<td>![Moment Diagram 3]</td>
<td>0.91</td>
</tr>
<tr>
<td>![Moment Diagram 4]</td>
<td>0.79</td>
</tr>
<tr>
<td>![Moment Diagram 5]</td>
<td>0.73</td>
</tr>
<tr>
<td>![Moment Diagram 6]</td>
<td>0.75</td>
</tr>
</tbody>
</table>

NOTE: For other bending diagrams $k_c = 1.0$. 

Issue 1  
Date: 15/10/2020
New content included in scope of EN 1993-1-2

→ **Influence of the bending diagrams on the LTB**

**Background documents**

- CEN/TC 250/SC 3/WG 2 N 30
- CEN/TC 250/SC 3/WG 2 N 31
New content included in scope of EN 1993-1-2

→ Design rules for class 4 cross-sections

Present situation (EN1993-1-2:2005)

More than 30% wasted resistance

New proposal

Class 2

Class 4

S355
New content included in scope of EN 1993-1-2

→ **Design rules for class 4 cross-sections**

**Background documents (1)**

- Couto C., Sanzel A., Vila Real P., Lopes N., Zhao B. (2016) – Beam-columns with thin wall cross-sections in case of fire. 9th International Conference Structures in Fire (SiF’16).
New content included in scope of EN 1993-1-2

Design rules for class 4 cross-sections

Background documents (2)


- Proposal from Prof. Paulo Vila Real, Prof. Nuno Lopes and Doctor Carlos Couto from University of Aveiro and Doctor Bin Zhao and Mr. Arnaud Sanzel from CTICM
New content included in scope of EN 1993-1-2

→ Annex C: Stainless Steel (new formulations)

There are no Classes for stainless steel cross-sections

(3) Compression elements with $\bar{\lambda}_{p,\theta} \leq \bar{\lambda}_{p0,\theta}$ should be classified as non-slender. Compression elements that do not satisfy the criteria for non-slender (i.e. those with $\bar{\lambda}_{p,\theta} > \bar{\lambda}_{p0,\theta}$) should be classified as slender, where $\bar{\lambda}_{p0,\theta}$ should be obtained from C.4.2.2(1).

(4) The class of a cross-section should be taken as slender if any of the constituting compression elements is classified as slender. A cross-section should be classified as non-slender only if all of the constituting compression elements are classified as non-slender.

C.4.3.2 Compression members

(1) The design buckling resistance $N_{b,fi,t,Rd}$ at time $t$ of a compression member with a uniform temperature $\theta_a$ is given by:

$$N_{b,fi,t,Rd} = \frac{\chi_{fi} A k_{2,\theta} f_y}{\gamma_{M,fi}} \leq N_{t,Rd} \quad \text{for non-slender sections} \quad (C.23a)$$

$$N_{b,fi,t,Rd} = \frac{\chi_{fi} A_{eff} k_{2,\theta} f_y}{\gamma_{M,fi}} \leq N_{t,Rd} \quad \text{for slender sections} \quad (C.23b)$$
New content included in scope of EN 1993-1-2

→ Annex C: Stainless Steel (new formulations):
  Background documents (1)

Stress-strain properties

New content included in scope of EN 1993-1-2

→ Annex C: Stainless Steel (new formulations):
  Background documents (2)

Local buckling assessment of stainless steel elements in fire

New content included in scope of EN 1993-1-2

→ Annex C: Stainless Steel (new formulations):
  Background documents (3)

Resistance of stainless steel compression members in fire

New content included in scope of EN 1993-1-2

→ Annex C: Stainless Steel (new formulations):
  Background documents (4)

Resistance of stainless steel beams in fire

New content included in scope of EN 1993-1-2

→ Annex C: Stainless Steel (new formulations): Background documents (5)

Resistance of stainless steel beam-columns in fire


New content included in scope of EN 1993-1-2

→ Annex C: Stainless Steel (new formulations):
   Background documents (6)

Thermal expansion thermal conductivity and specific heat

- DIN SEW 310:1992-08, Physikalische Eigenschaften von Stahlen
Annex D: Joints
Temperature of joints in fire

D.3 Temperature of joints in fire

D.3.1 General

(1) The temperature of a joint may be assessed using the local A/V value of the parts forming that joint. For unprotected joints, the local A/V value may be calculated as $2/t$ where “$t$” is the total thickness of the connected steel plates (e.g. endplate/column flange, fin plate/beam web) in the thinnest part of the joint.

(2) Alternatively, as a simplification, the unprotected joint temperature may be taken as the maximum temperature of the unprotected connected steel members.

(3) For protected joints, the joint temperature should be taken equal to the maximum temperature of the protected connected steel members.
New content included in scope of EN 1993-1-2

➔ **Annex D: Joints**

*Temperature of joints in fire: Background documents*

- Ding, J. and Wang, Y.C. (2007), Experimental study of structural fire behaviour of steel beam to concrete filled tubular column assemblies with different types of joints, Engineering Structures, 29(12), pp. 3485-3502 doi:10.1016/j.engstruct.2007.08.018
Annex D: Joints

Elevated temperature resistance of welded tubular joints with axial load or in-plane bending in brace members

D.4 Welded steel tubular joints

D.4.1 General

(1) D.4 covers uniplanar joints only.
(2) The temperature ($\theta$) of a welded tubular joint should be taken equal to the highest temperature of the connected members.
(3) The elevated temperature resistance of the joint should be obtained by multiplying its resistance for normal temperature design by $k_{\theta}$, except for the cases in D.4.2 and D.4.3.

D.4.2 Welded tubular joints with axial compression in brace members

(1) In T-, Y- and X-circular, rectangular, square, and elliptical hollow section joints where the brace member is connected to the wide face of the chord member, and when the joint fails by chord face plastification, the elevated temperature resistance of the joint should be obtained by multiplying its resistance for normal temperature design by a factor $k_{c1,\theta}$ given in Table D.2.

D.4.3 Welded tubular joints with in-plane bending moment in brace members

(1) The elevated temperature resistance of a joint which fails by chord face plastification should be obtained by multiplying its resistance for normal temperature design by a factor $k_{c2,\theta}$ given in Table D.2.
New content included in scope of EN 1993-1-2

→ **Annex D: Joints**

*Elevated temperature resistance of welded tubular joints with axial load or in-plane bending in brace members:*

**Background documents**

- Wang, Y.C. and Ozyurt, E. (2018), Welded joint strength at elevated temperature, 1st Interim report of CIDECT project 15U, CIDECT, August 2018
New content included in scope of EN 1993-1-2

→ Annex E: Beams with large web openings

Key
1 Cross-section used in the section factor calculation
2 Cross-section used in the load-bearing capacity calculation
New content included in scope of EN 1993-1-2

→ Annex E: Beams with large web openings: Background documents (1)


Additional related documents (1)

New content included in scope of EN 1993-1-2

Annex E: Beams with large web openings: Background documents (2)

Additional related documents (2)

How ease of use has been enhanced

Some clauses were improved in terms of ease of use

Example:

Before

The non-dimensional slenderness $\bar{\lambda}_\theta$ for the temperature $\theta_i$ is given by:

$$\bar{\lambda}_\theta = \bar{\lambda} \left[ \frac{k_{y,\theta}}{k_{E,\theta}} \right]^{0.5} \quad (4.7)$$

where:

- $k_{y,\theta}$ is the reduction factor from section 3 for the yield strength of steel at the steel temperature $\theta_i$ reached at time $t$;
- $k_{E,\theta}$ is the reduction factor from section 3 for the slope of the linear elastic range at the steel temperature $\theta_i$ reached at time $t$.

After

$$\bar{\lambda}_\theta = \bar{\lambda} \left[ \frac{k_{y,\theta}}{k_{E,\theta}} \right]^{0.5} \quad (7.12)$$

where:

$$\bar{\lambda} = \frac{N_{gy}}{N_{cr}} \quad \text{for class 1, 2 or 3 cross-sections; (7.13)}$$

$$\bar{\lambda} = \frac{\Delta N_{gy}}{N_{cr}} \quad \text{for class 4 cross-sections; (7.14)}$$

- $k_{y,\theta}$ is the reduction factor from 5 for the yield strength of steel at the steel temperature $\theta_i$ reached at time $t$;
- $k_{E,\theta}$ is the reduction factor from 5 for the slope of the linear elastic range at the steel temperature $\theta_i$ reached at time $t$;
- $N_{cr}$ is the elastic critical force for the relevant buckling mode based on the gross cross-sectional properties, using the buckling length under fire conditions.
How ease of use has been enhanced

Some clauses were improved in terms of ease of use

Example:

Before

$$\tilde{\lambda}_{LT,\theta,\text{com}} = \tilde{\lambda}_{LT} \left( \frac{k_{y,\theta,\text{com}}}{k_{E,\theta,\text{com}}} \right)^{0.5} \quad (4.15)$$

where:

- $k_{E,\theta,\text{com}}$ is the reduction factor from section 3 for the slope of the linear elastic range at the maximum steel temperature in the compression flange $\theta_{\text{com}}$ reached at time $t$.

After

$$\tilde{\lambda}_{LT,\theta,\text{com}} = \tilde{\lambda}_{LT} \sqrt{\frac{k_{y,\theta,\text{com}}}{k_{E,\theta,\text{com}}}} \quad (7.19)$$

where:

- $k_{E,\theta,\text{com}}$ is the reduction factor from 5 for the slope of the linear elastic range at the maximum steel temperature in the compression flange $\theta_{\text{com}}$ reached at time $t$.

and the relative slenderness $\tilde{\lambda}_{LT}$ is given by:

$$\tilde{\lambda}_{LT} = \sqrt{\frac{W_{y,LT}}{M_{cr}}} \quad (7.20)$$

$M_{cr}$ is the elastic critical moment for lateral-torsional buckling based on the gross cross-sectional properties, taking into account loading conditions, actual moment distribution and lateral restraints.
How ease of use has been enhanced

Some clauses were improved in terms of ease of use

Example:

Before

(3) The buckling length $l_b$ of a column for the fire design situation should generally be determined as for normal temperature design. However, in a braced frame the buckling length $l_b$ of a column length may be determined by considering it as fixed in direction at continuous or semi-continuous joints to the column lengths in the fire compartments above and below, provided that the fire resistance of the building components that separate these fire compartments is not less than the fire resistance of the column.

(5) In the case of a braced frame in which each storey comprises a separate fire compartment with sufficient fire resistance, in an intermediate storey the buckling length $l_b$ of a continuous column may be taken as $l_b = 0.5L$, and in the top storey the buckling length may be taken as $l_b = 0.7L$, where $L$ is the system length in the relevant storey, see figure 4.1.

After

(3) The buckling length $l_b$ of a column for the fire design situation should generally be determined as for normal temperature design.

(4) In the case of a non-steel frame in which each storey comprises a separate fire compartment with a fire resistance not less than the fire resistance of the column, the buckling length $l_b$ of a continuous column may be taken as $l_b = 0.5L$ in an intermediate storey and as $l_b = 0.7L$ in the top storey, where L is the system length in the relevant storey, see Figure 7.1.

Key

a Shear wall or other bracing system
b Height of separate fire compartments in each storey
c Columns buckling length exposed to fire
d Deformation mode in fire
Summary and Conclusions

→ Summary of procedure

➢ Principles for the future development of Eurocode 3
  • Principles have been accepted by SC3 at an early stage of development which are in conformity with TC250 aims of Reduction of NDPs and Ease of Use

➢ Technical issues to be extensively discussed and decided
  • Development of amendments by the relevant experts of the CEN/TC250/SC3 Working Groups
  • Allow for sufficient discussion and clarification in TC250/SC3 and in National Mirror Groups

➢ Clear decisions as guidance for Project Team Work
  • Transparent decisions of SC3 form a reliable basis for work of Project Teams
Thanks for attention!

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