Design of *Steel Buildings* with worked examples

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- European Commission
  - DG Enterprise and Industry
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- European Convention for Constructional Steelwork
- European Committee for Standardization
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Basis of Design, a case study building

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Contents

✓ Definitions and basis of design

✓ Global analysis
  • Structural modeling
  • Structural analysis
  • Case study: building

✓ Classification of cross-sections
Support material from ECCS
VERSION 3.0 (May 2014):
- Tubular sections
- Beam-columns
- Geo referencing
Definitions and Basis of Design

✅ Conceptual Aspects

Codes of Practice and Standardization

Basis of Design

Materials

Geometric Characteristics and Tolerances
The conceptual of design of a steel building includes:

- **geometry and structural scheme** – isostatic/hyperstatic systems, trusses/portal frame, type of connections (rigid, hinged,...), type of floor systems, type and section orientation (hot-rolled, welded,...), bracing systems, type of supports (built-in, hinges,...), expansion joints, etc..., taking into account the loading (vertical loads, wind, seismic, $\Delta T$, settlement of supports, etc...)

- **definition of materials** – strength grades and steel quality, bolts, etc...;
Conceptual aspects

In addition, it must take into account:

- architecture project, installation of equipments and functional requirements (thermal and acoustic);
- safety checks;
- serviceability checks;
- durability of the structure;
- cost and construction time (e.g. bolted connections instead of welded connections);
- fabrication, transport and erection;
- sustainability (e.g. ease of disassembly).
**Braced and unbraced buildings**

- **Braced systems** - strength and stiffness to horizontal actions and global stability (2\textsuperscript{nd} order sway effects).
- Strength and stiffness (wind, seismic, etc...) may be achieved by:
  - i) triangular systems;
  - ii) rigid walls or pavements;
  - iii) stiffness of the structure (rigid connections).

Criteria for effective bracing – bracing system reduces the lateral flexibility by at least 80%
Conceptual aspects

Type of sections

Hot-rolled sections

Bolted beam-to-column and beam-to-beam joints

Type of connections

Tapered members

Castellated beams

Beam splices

Column bases
Difference between hot finished and cold formed

Maximum permissible tension and bending loads (cold-formed = 100%)

- Tension: 100 x 100 x 10.0 mm in S 355
- Bending: 100 x 100 x 10.0 mm in S 355

Cold-formed Hot-rolled

- Tension: 100% 107%
- Bending: 100% 112%

Larger cross-sectional areas thanks to smaller corner radii
Is difference in the resistance between HF and CF profiles decreasing with increase of the thickness? Why?
Answer:

Comparison of maximum permissible compression loads (cold-formed = 100 %) for 100 x 100, Grade S 355, buckling length 300 cm.
Conceptual aspects

Steel products (flat products)
Definitions and Basis of Design

Conceptual Aspects

✓ Codes of Practice and Standardization

Basis of Design

Materials

Geometric Characteristics and Tolerances
Codes of Practice and Standardization

- EN 1990  Eurocode: Basis of Structural Design
- EN 1991  Eurocode 1: Actions on Structures
- EN 1992  Eurocode 2: Design of Concrete Structures
- EN 1993  Eurocode 3: Design of Steel Structures
- EN 1994  Eurocode 4: Design of Composite Steel and Concrete Structures
- EN 1995  Eurocode 5: Design of Timber Structures
- EN 1996  Eurocode 6: Design of Masonry Structures
- EN 1997  Eurocode 7: Geotechnical Design
- EN 1998  Eurocode 8: Design of Structures for Earthquake Resistance
- EN 1999  Eurocode 9: Design of Aluminium Structures
EN 1993-1  General rules and rules for buildings
EN 1993-2  Steel bridges
EN 1993-3  Towers, masts and chimneys
EN 1993-4  Silos, tanks and pipelines
EN 1993-5  Piling
EN 1993-6  Crane supporting structures

EN 1993-1-1  General rules and rules for buildings
EN 1993-1-2  Structural fire design
EN 1993-1-3  Cold-formed thin gauge members and sheeting
EN 1993-1-4  Stainless steels
EN 1993-1-5  Plated structural elements
EN 1993-1-6  Strength and stability of shell structures
EN 1993-1-7  Strength and stability of planar plated structures transversely loaded
EN 1993-1-8  Design of joints
EN 1993-1-9  Fatigue strength of steel structures
EN 1993-1-10 Selection of steel for fracture toughness and through-thickness properties
EN 1993-1-11 Design of structures with tension components made of steel
EN 1993-1-12 Supplementary rules for high strength steel
Eurocodes - Design of steel buildings with worked examples

European Commission

Brussels, 16 - 17 October 2014

EC 0  87 p.
EC 1-1-1  44 p.
EC 1-1-3  43 p.
EC 1-1-4  52 p.
EC 1-1-7  35 p.
EC 3-1-1  82 p.  EC 3-1-5  53 p.
EC 3-1-8  129 p.
Totalt  525 p.

EC0  87 p.
EC1  174 p.
EC3  211+53=264 p.
CE Marking (01 July 2014)

CPR imposes the following ‘basic requirements for construction works’:
1. Mechanical resistance and stability;
2. Safety in case of fire;
3. Hygiene, health and the environment;
4. Safety and accessibility in use;
5. Protection against noise,
6. Energy economy and heat retention;
7. Sustainable use of natural resources.

For steel products the main harmonized product standards are:
- Steel sections and plates – EN 10025-1;
- Hollow sections – EN 10210-1 and EN 10219-1;
- Preloadable bolts – EN 14399-1;
- Non-preloadable bolts – EN 15048-1;
- Fabricated structural steelwork – EN 1090-1
CE Marking – warranty by the manufacturer that its products meet specified performance characteristics that are defined as essential to the application of the products in the field of construction. In order to do this, the manufacturer needs to:
- Know the requirements in terms of defined essential performance characteristics and required values to be met. For structural steel components, these requirements are defined in clause 4 of EN 1090-1.
- Use specified test methods that can evaluate whether products conform to the specified requirements. For structural steel components, these evaluation methods are defined in clause 5 of EN 1090-1.
- Implement a system for controlling regular production. For structural steel components, the system for evaluation of conformity is defined in clause 6 of EN 1090-1.
- Mark its products in the correct way using a suitable classification and designation system. For structural steel components, the marking system is defined in clauses 7 and 8 of EN 1090-1.
Definitions and Basis of Design

Conceptual Aspects

Codes of Practice and Standardization

✓ Basis of Design

Materials

Geometric Characteristics and Tolerances
Basis of Design

Basic Requirements (EN 1990) - structure must be designed and executed so as to perform the functions for which it was conceived, for a pre-determined service life.

- Conditions that prevent failure (ultimate limit states);
- Conditions that guarantee proper performance in service (serviceability limit state);
- Conditions related to durability (among others, protection against corrosion).

Verification of the limit states (EN 1990) requires:

- quantification and combination of actions;
- Definition of the mechanical properties of materials;
- Definition of the geometry of the structure and components.

Calculation of load effects requires appropriate methods of analysis (section 5 of EN 1990), including design assisted by testing (Annex D).
Basis of Design

ULTIMATE LIMIT STATES
- loss of static equilibrium;
- internal failure of the structure or its members and joints;
- failure or excessive deformation of the ground (EN 1997);
- fatigue failure (EN 1993-1-9).

Combinations according to EN 1990 (Annex A): fundamental, accidental and seismic.

SERVICEABILITY LIMIT STATES
- deformation,
- vibration.

Combinations according to EN 1990 (Annex A): characteristic; frequent and quasi-permanent.
Basis of Design

SERVICEABILITY LIMIT STATES:
NCCI: Non-conflicting Complementary Information

<table>
<thead>
<tr>
<th>Description</th>
<th>$w_{\text{max}}$</th>
<th>$w_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofs in general</td>
<td>$L/200$</td>
<td>$L/250$</td>
</tr>
<tr>
<td>Roofs often used by people</td>
<td>$L/250$</td>
<td>$L/300$</td>
</tr>
<tr>
<td>Floors in general</td>
<td>$L/250$</td>
<td>$L/300$</td>
</tr>
<tr>
<td>Floors and roofs supporting plaster or other fragile finishes or non-flexible partition walls</td>
<td>$L/250$</td>
<td>$L/350$</td>
</tr>
<tr>
<td>Floors that bear columns (unless the displacement has been included in the global analysis for the ultimate limit state)</td>
<td>$L/400$</td>
<td>$L/500$</td>
</tr>
<tr>
<td>When $w_{\text{max}}$ may affect the appearance of the building</td>
<td>$L/250$</td>
<td>-</td>
</tr>
<tr>
<td>Cantilever beam ($L = 2 \ L_{\text{cable}}$)</td>
<td>Previous limits</td>
<td></td>
</tr>
</tbody>
</table>
Definitions and Basis of Design

Conceptual Aspects

Codes of Practice and Standardization

Basis of Design

✓ Materials

Geometric Characteristics and Tolerances
Materials: properties

Design values (e.g. yield stress) are obtained from characteristic values/nominal values dividing by partial safety coefficients $\gamma_M$.

Recommended values (EN 1993-1-1):

$$\gamma_{M0} = 1.00; \quad \gamma_{M1} = 1.00; \quad \gamma_{M2} = 1.25.$$

Ductility properties

- $f_u / f_y \geq 1.1$;
- Failure strain $> 15\%$;
- $\varepsilon_u \geq 15 \varepsilon_y$.

- Modulus of elasticity
- Poisson’s ratio in elastic range
- Coefficient of linear thermal expansion
- Volumetric mass
**Materials: properties**

<table>
<thead>
<tr>
<th>Steel grades and qualities</th>
<th>Minimum yield strength $R_{yH}$ (MPa)</th>
<th>Tensile strength $R_m$ (MPa)</th>
<th>Minimum percentage elongation after fracture $L_o = 5.65 \sqrt{S_o}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal thickness (mm)</td>
<td>Nominal thickness (mm)</td>
<td>Nominal thickness (mm)</td>
<td></td>
</tr>
<tr>
<td>≤ 16</td>
<td>&gt;16 ≤ 40</td>
<td>&gt;40 ≤ 63</td>
<td>&gt;63</td>
</tr>
<tr>
<td>S235JR</td>
<td>235</td>
<td>360 to 510</td>
<td>26</td>
</tr>
<tr>
<td>S235J0</td>
<td>235</td>
<td>360 to 510</td>
<td>25</td>
</tr>
<tr>
<td>S235J2</td>
<td>235</td>
<td>360 to 510</td>
<td>24</td>
</tr>
<tr>
<td>S275JR</td>
<td>275</td>
<td>430 to 580</td>
<td>23</td>
</tr>
<tr>
<td>S275J0</td>
<td>275</td>
<td>430 to 580</td>
<td>22</td>
</tr>
<tr>
<td>S275J2</td>
<td>275</td>
<td>430 to 580</td>
<td>21</td>
</tr>
<tr>
<td>S355JR</td>
<td>355</td>
<td>510 to 680</td>
<td>22</td>
</tr>
<tr>
<td>S355J0</td>
<td>355</td>
<td>510 to 680</td>
<td>21</td>
</tr>
<tr>
<td>S355J2</td>
<td>355</td>
<td>510 to 680</td>
<td>20</td>
</tr>
<tr>
<td>S355K2</td>
<td>335</td>
<td>510 to 680</td>
<td>19</td>
</tr>
<tr>
<td>S450J0</td>
<td>450</td>
<td>550 to 720</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 2.1 of EN 1993-1-10 ensures adequate behaviour against brittle fracture.
Definitions and Basis of Design

Conceptual Aspects

Codes of Practice and Standardization

Basis of Design

Materials

✓ Geometric Characteristics and Tolerances
Geometric characteristics and tolerances

**Geometric Data**
Dimensions, shape, ... - Characteristic or nominal values.

EN 1090 (and product standards) establishes two types of tolerances:

- **Fundamental tolerances** – required to ensure resistance and stability of the structure;
- **Functional tolerances** – required to ensure aesthetical appearance of the structure.
### Table 1.11 – Essential manufacturing tolerances – welded sections (EN 1090-2)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Parameter</th>
<th>Tolerance Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>Overall depth h</td>
<td>( \Delta = -h/50 ) No positive value given</td>
</tr>
<tr>
<td>Flange width</td>
<td>Width ( b = b_1 ) or ( b_2 )</td>
<td>( \Delta = -b/100 )</td>
</tr>
<tr>
<td>Squareness at bearings</td>
<td>Verticality of web at supports for components without bearing stiffeners</td>
<td>( \Delta = \pm 200 ) but ( \Delta \geq t_w ) ( (t_w = \text{web thickness}) )</td>
</tr>
<tr>
<td>Plate curvature</td>
<td>Deviation ( \Delta ) over plate height ( b )</td>
<td>( \Delta = \pm b/100 ) but ( \Delta \geq t ) ( (t = \text{plate thickness}) )</td>
</tr>
</tbody>
</table>

### Table 1.8 – Dimensional tolerances for structural steel I and H sections (EN 10034)

<table>
<thead>
<tr>
<th>Section height ( h ) (mm)</th>
<th>Tol. (mm)</th>
<th>Flange width ( b ) (mm)</th>
<th>Tol. (mm)</th>
<th>Web thickness ( s ) (mm)</th>
<th>Tol. (mm)</th>
<th>Flange thickness ( t ) (mm)</th>
<th>Tol. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h \leq 180 )</td>
<td>+3.0</td>
<td>( b \leq 110 )</td>
<td>+4.0</td>
<td>( s \leq 7 )</td>
<td>+0.7</td>
<td>( t \leq 6.5 )</td>
<td>+1.5</td>
</tr>
<tr>
<td>( 180 &lt; h \leq 400 )</td>
<td>+4.0</td>
<td>( 110 &lt; b \leq 210 )</td>
<td>+4.0</td>
<td>( 7 \leq s \leq 10 )</td>
<td>+1.0</td>
<td>( 6.5 \leq t \leq 10 )</td>
<td>+2.0</td>
</tr>
<tr>
<td>( 400 &lt; h \leq 700 )</td>
<td>+5.0</td>
<td>( 210 &lt; b \leq 325 )</td>
<td>+4.0</td>
<td>( 10 \leq s \leq 20 )</td>
<td>+1.5</td>
<td>( 10 \leq t \leq 20 )</td>
<td>+2.5</td>
</tr>
<tr>
<td>( h &gt; 700 )</td>
<td>+5.0</td>
<td>( b &gt; 325 )</td>
<td>+6.0</td>
<td>( 20 \leq s \leq 40 )</td>
<td>+2.0</td>
<td>( 20 \leq t \leq 30 )</td>
<td>+2.5</td>
</tr>
<tr>
<td></td>
<td>-3.0</td>
<td></td>
<td>-3.0</td>
<td>( 40 \leq s \leq 60 )</td>
<td>+2.5</td>
<td>( 30 \leq t \leq 40 )</td>
<td>+2.5</td>
</tr>
<tr>
<td></td>
<td>-5.0</td>
<td></td>
<td>-5.0</td>
<td>( s \geq 60 )</td>
<td>+3.0</td>
<td>( 40 \leq t \leq 60 )</td>
<td>+3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( s \geq 60 )</td>
<td></td>
<td>( t \geq 60 )</td>
<td>+4.0</td>
</tr>
</tbody>
</table>

- \( h \) – Height measured at the centre line of web thickness
- \( b \) – Flange width
- \( s \) – Web thickness measured at the midpoint of dimension \( h \)
- \( t \) – Flange thickness measured at the quarter flange width point
Table 1.9 – Tolerances on out-of-square and web off-centre of structural steel I and H sections (EN 10034)

<table>
<thead>
<tr>
<th>Out-of-square ( k+k_1 )</th>
<th>Tol. ( (mm) )</th>
<th>Web off-centre ( e ) ( (mm) )</th>
<th>Tol. ( (mm) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b \leq 110 )</td>
<td>1.50</td>
<td>( t &lt; 40mm )</td>
<td>( b \leq 110 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>110 ( \leq b &lt; 325 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( b &gt; 325 )</td>
</tr>
<tr>
<td>( b &gt; 110 )</td>
<td>2 % of ( b ) ( (\text{max. } 6.5 \text{ mm}) )</td>
<td>( t \geq 40mm )</td>
<td>110 ( &lt; b \leq 325 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( b &gt; 325 )</td>
</tr>
</tbody>
</table>

\( b \) – Flange width  
\( t \) – Flange thickness

Table 1.10 – Tolerances on straightness of structural steel I and H sections (EN 10034)

<table>
<thead>
<tr>
<th>Section height ( h ) ( (mm) )</th>
<th>Tolerance on straightness ( q_{xx} ) and ( q_{yy} ) on length ( L ) ( (%) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 80 &lt; h &lt; 180 )</td>
<td>0.30 ( L )</td>
</tr>
<tr>
<td>( 180 &lt; h &lt; 360 )</td>
<td>0.15 ( t )</td>
</tr>
<tr>
<td>( h &gt; 360 )</td>
<td>0.10 ( L )</td>
</tr>
</tbody>
</table>
Global Analysis

✓ Structural modeling

Structural analysis

Case-study building
Global Analysis: structural modeling

The model should simulate real conditions (structural elements, connections, loading, supports, ...).

i) Type of element
   - Modeling with linear, two-dimensional or three-dimensional elements.

Alternative ways of modeling floors (stiffness in its own plan) in the behaviour of the structure

Beam elements

Plate or shell elements
Global Analysis: structural modeling

ii) Influence of member axis (resistance formulae derived with respect to the centroid of the section)

iii) Influence of eccentricities and supports.

iv) Influence of joints
Global Analysis

Structural modeling

✓ Structural analysis

Case-study building
Global Analysis: structural analysis

**Global elastic analysis**
- plastic,
- elastic perfectly plastic,
- elastic-plastic.

**Isostatic structures**

**Hiperstatic structures**

**NOTES (EC3-1-1, Cl. 5.4):**
- Although internal forces may be obtained from a **global elastic analysis**, the design resistance may be quantified based on the plastic resistance of the section (depending on the class of the section).
- Re-distribution of internal forces is allowed in **global elastic analysis**.
- **Global plastic analysis** – entails the capacity for re-distribution of forces - requirements: ductile material, compact sections, braced and symmetric.
Global Analysis: structural analysis

Effects to consider in global analysis:

i) deformability and stiffness of the structure and supports;
ii) stability of the structure (global, members and local);
iii) behaviour of cross-sections (classification of sections);
iv) behaviour of joints (strength and stiffness);
v) imperfections (global and in members).
Global Analysis: structural analysis

1\textsuperscript{st} order analysis vs. 2\textsuperscript{nd} order analysis

1\textsuperscript{st} order analysis – Internal forces and displacements are evaluated in relation to the undeformed structure (EC3-1-1, cl. 5.2.1(1)).

2\textsuperscript{nd} order analysis – The deformation of the structure is considered in the evaluation of internal forces and displacements (iterative procedure).

Structures sensitive to 2\textsuperscript{nd} order effects – structures with high compressed members and structures with low stiffness (e.g.: structures with cables).

2\textsuperscript{nd} order effects

\textbf{P-\delta effects} (local effects).

\textbf{P-\Delta effects} (global effects).
Global Analysis: structural analysis

Need to consider 2\textsuperscript{a} order analysis - EC3-1-1 - cl. 5.2.1(3):

\[
\alpha_{cr} = \frac{F_{cr}}{F_{Ed}} \leq 10 \quad \text{(elastic analysis)}
\]
\[
\alpha_{cr} = \frac{F_{cr}}{F_{Ed}} \leq 15 \quad \text{(plastic analysis)}
\]

$F_{Ed}$: design loading for a given load combination;

$F_{cr}$: elastic critical load.
Global Analysis: structural analysis

i) Analytical evaluation
   
ii) Numerical calculation
   
iii) Approximate methods (Horne, Wood, ...)

ii) NUMERICAL CALCULATION: Linear eigenvalue analysis
Global Analysis: structural analysis

iii) APPROXIMATE METHODS (EC3, cl.5.2.1(4)B) (Horne, Wood, ...)

HORNE’s METHOD

Applicable for plane frames and one-storey frames with low inclination of the beams
(\( \leq 26^\circ \)), unbraced and with low axial force (\( \overline{\lambda} \leq 0,3 \sqrt{\frac{Af_y}{N_{Ed}}} \)):

\[
\alpha_{cr} = \left( \frac{H_{Ed(top)}}{V_{Ed(base)}} \frac{h_i}{\delta_{H,Ed}} \right)
\]
Global Analysis: structural analysis

WOOD’s METHOD

\[ \eta_1 = \frac{K_c + K_1}{K_c + K_1 + K_{11} + K_{12}} \]
\[ \eta_2 = \frac{K_c + K_2}{K_c + K_2 + K_{21} + K_{22}} \]

\[ N_{cr} = \frac{\pi^2 EI}{L_e^2} \quad \alpha_{cr} = \frac{N_{cr}}{N_{Ed}} \]

Table 2.19 – \( K_f \) stiffness coefficients in beams

<table>
<thead>
<tr>
<th>Restriction to rotation at the opposite end</th>
<th>( K_f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td>1.0 ( L/L )</td>
</tr>
<tr>
<td>Pinned</td>
<td>0.75 ( L/L )</td>
</tr>
<tr>
<td>Equal rotation (single curvature)</td>
<td>0.5 ( L/L )</td>
</tr>
<tr>
<td>Equal rotation but in the opposite way (double curvature)</td>
<td>1.5 ( L/L )</td>
</tr>
<tr>
<td>General case (( \delta_b ) next to the column and ( \delta_b ) at the opposite end)</td>
<td>( 1=0.5(\delta_b/\delta_b) L/L )</td>
</tr>
</tbody>
</table>
Global Analysis: structural analysis

2nd ORDER ANALYSIS

i) Numerical methods (iterative procedures)

ii) Simplified methods

NUMERICAL METHODS ("EXACT")

- Modeling
- Convergence
- Validation
Global Analysis: structural analysis

SIMPLIFIED METHODS (APPROX)

- Amplified sway moment method (clause 5.2.2(4));
- Sway-mode buckling length method (clause 5.2.2(8)).

Amplified sway moment method

\[
M_{ap}^{II} = M_{NS}^{I} + \frac{1}{1 - \frac{1}{\alpha_{cr.S}}} M_{S}^{I} \\
N_{ap}^{II} = N_{NS}^{I} + \frac{1}{1 - \frac{1}{\alpha_{cr.S}}} N_{S}^{I} \\
d_{ap}^{II} = d_{NS}^{I} + \frac{1}{1 - \frac{1}{\alpha_{cr.S}}} d_{S}^{I}
\]

- For regular structures, EC3-1-1 (clause 5.2.2), allows the inclusion of secon-order effects associated with vertical loads in a simplified way. Amplification of first-order effects associated with horizontal actions (including imperfections), by:

\[
\frac{1}{(1 - 1/\alpha_{cr})} 
\] if \( \alpha_{cr} \geq 3.0 \)
Global Analysis: structural analysis

**IMPERFECTIONS**

Global imperfections: lack of verticality

Local imperfections: initial curvature

\[ e_0 / L \]

Equivalent horizontal forces

Equivalent geometrical imperfections

Table 2.20 – Initial local bow imperfections

<table>
<thead>
<tr>
<th>Buckling curve</th>
<th>Elastic analysis ( e_0 / L )</th>
<th>Plastic analysis ( e_0 / L )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_0 )</td>
<td>1/350</td>
<td>1/300</td>
</tr>
<tr>
<td>( a )</td>
<td>1/300</td>
<td>1/250</td>
</tr>
<tr>
<td>( b )</td>
<td>1/250</td>
<td>1/200</td>
</tr>
<tr>
<td>( c )</td>
<td>1/200</td>
<td>1/150</td>
</tr>
<tr>
<td>( d )</td>
<td>1/150</td>
<td>1/100</td>
</tr>
</tbody>
</table>
Global Analysis: structural analysis

GLOBAL FRAME ANALYSIS

→ Choice between frame analyses regarding the kind of member design:
  ▪ Design by member buckling checks
  ▪ Design by 2\textsuperscript{nd} order moments + cross-section checks

→ Methods depend on the accounting of
  • 2\textsuperscript{nd} order effects
  • imperfections: global $\Phi$ and/or member $e_0$
Global Analysis: structural analysis

GLOBAL ANALYSIS AND DESIGN WITH MEMBER BUCKLING CHECKS

- Global analysis
  - 1st order analysis
    - Non-sway frame $\alpha_{cr} \geq 10$ resp. 15
    - Sway frame $\alpha_{cr} < 10$ resp. 15
  - 2nd order analysis
    - Amplified sway moment method ($\alpha_{cr} \geq 3$)
    - Sway mode buckling length method
      - No limitation
  - Account for 2nd order P-Δ effects

Joint Research Centre
Global Analysis: structural analysis

GLOBAL ANALYSIS AND DESIGN WITH MEMBER BUCKLING CHECKS

Account for sway imperfection $\phi$

- Yes
- No

Account for local bow imperfection $e_{0,d}$

- Yes
- No

Check of components and frame

- Yes, where the following conditions are met:
  - at least one moment resistant joint at one member end
  - $\lambda > 0.5 \sqrt{A_f / N_L}$

- In plane member stability with non sway buckling length
- In plane member stability with sway buckling length

Cross-section resistances and local stability

Joint resistances

Out-of-plane stability of the members
FRAME DESIGN WITH “FULL” 2. ORDER MOMENTS + CS-CHECKS