STEEL BUILDINGS IN EUROPE

Single-Storey Steel Buildings
Part 6: Detailed Design of
Built-up Columns

FOREWORD

This publication is part six of the design guide, *Single-Storey Steel Buildings*.

The 11 parts in the *Single-Storey Steel Buildings* guide are:

Part 1: Architect's guide
Part 2: Concept design
Part 3: Actions
Part 4: Detailed design of portal frames
Part 5: Detailed design of trusses
Part 6: Detailed design of built-up columns
Part 7: Fire engineering
Part 8: Building envelope
Part 9: Introduction to computer software
Part 10: Model construction specification
Part 11: Moment connections

Single-Storey Steel Buildings is one of two design guides. The second design guide is *Multi-Storey Steel Buildings.*

The two design guides have been produced in the framework of the European project "Facilitating the market development for sections in industrial halls and low rise buildings (SECHALO) RFS2-CT-2008-0030".

The design guides have been prepared under the direction of Arcelor Mittal, Peiner Träger and Corus. The technical content has been prepared by CTICM and SCI, collaborating as the Steel Alliance.

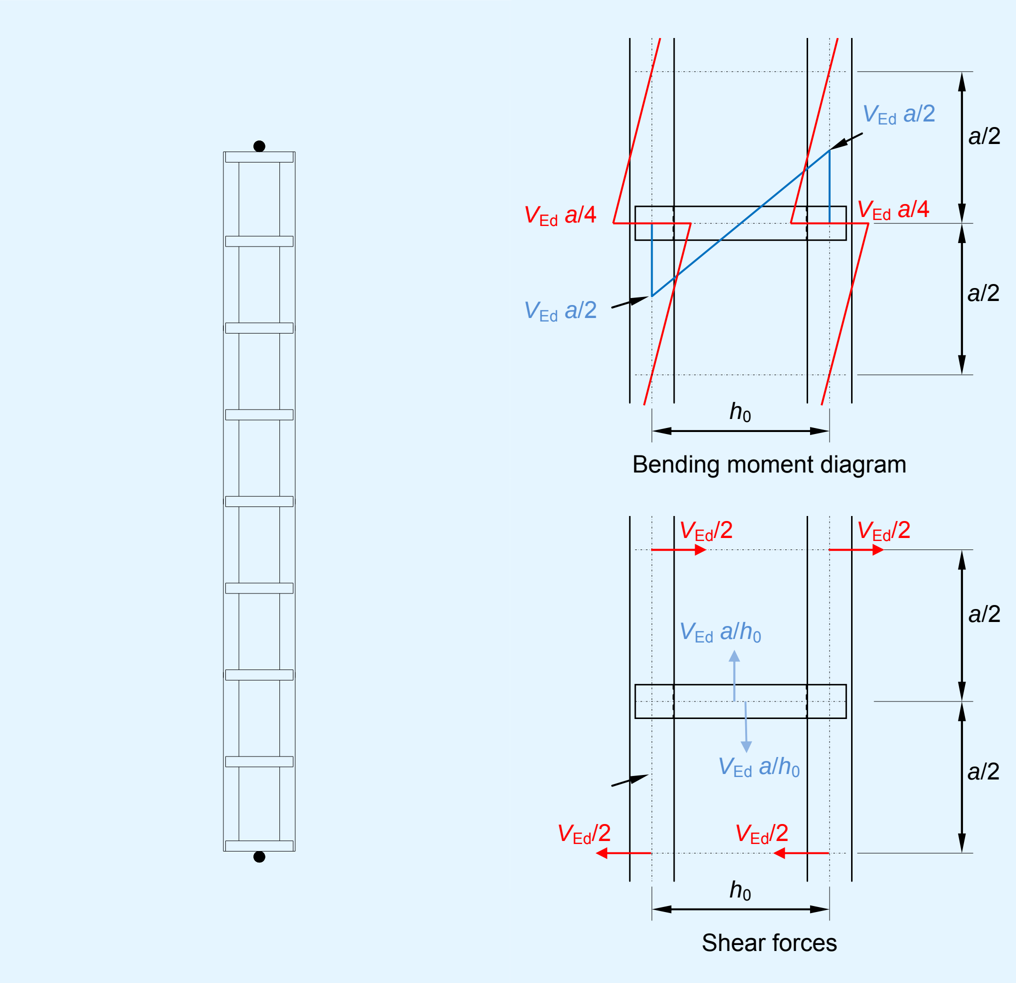


Figure 3.3 Bending moments and shear forces in a panel of a battened built-up column

Initial bow imperfection

The initial bow imperfection e_0 is:

$$e_0 \quad = L/500$$

where:

L is the length of the built-up member

Maximum axial compressive force in the chords

The maximum axial compression $N_{\mathrm{ch,Ed}}$ in the chords is calculated from the expression given in 3.2.1.

3.3.2 Step 2: In-plane buckling resistance of a chord

Classification of the cross-section of the chord

The cross-section of the chord is classified according to EN 1993-1-1 Table 5.2.

Buckling resistance of a chord about z-z axis

The resistance of the chord has to be verified for bending and axial compression and for buckling in the plane of the built-up member, i.e. about the weak axis of the cross-section of the chord (z-z axis), according to

EN 1993-1-1 § 6.3.3. Depending on the geometry of the battened built-up member, the verifications should be performed for different segments of the chord:

- For an end panel with the maximum shear force and thus the maximum local bending moment
- For a panel located at mid-height where the compression axial force may be maximum in the chord.

3.3.3 Step 3: Out-of-plane buckling resistance of the chords

The out-of-plane buckling resistance is verified using the following criterion:

$$\frac{N_{\mathrm{ch,Ed}}}{N_{\mathrm{b,y,Rd}}} \leq 1$$

where:

$N_{\mathrm{b,y,Rd}}$ is the design buckling resistance of the chord about the strong axis of the cross-section, calculated according to EN 1993-1-1 § 6.3.1.

The buckling length depends on the support conditions of the built-up member for out-of-plane buckling. At the ends of the member, the supports are generally considered as pinned. However intermediate lateral restraints may be provided.

3.3.4 Step 4: Shear force

The shear force V_{Ed} is calculated from the maximum bending moment as for a laced built-up member, according to §3.2.4 of this guide.

3.3.5 Step 5: Resistance of the battens

As shown in Figure 3.3, the battens should be designed to resist the shear force:

$$V_{\mathrm{Ed}} \frac{a}{h_0}$$

And the bending moment:

$$M_{\mathrm{Ed}} = \frac{V_{\mathrm{Ed}} a}{2}$$

The cross-section classification should be determined according to EN 1993-1-1 Table 5.2, for pure bending. The section resistance should be verified using the appropriate criteria given EN 1993-1-1 § 6.2.

3.3.6 Step 5: Resistance of the batten-to-chord connections

The resistance of the connections between the battens and the chords has to be verified according to EN 1993-1-8. This verification depends on the details of the connection: bolted connection or welded connection. This verification is performed using the internal forces calculated in the previous steps.

3.3.7 Flowchart

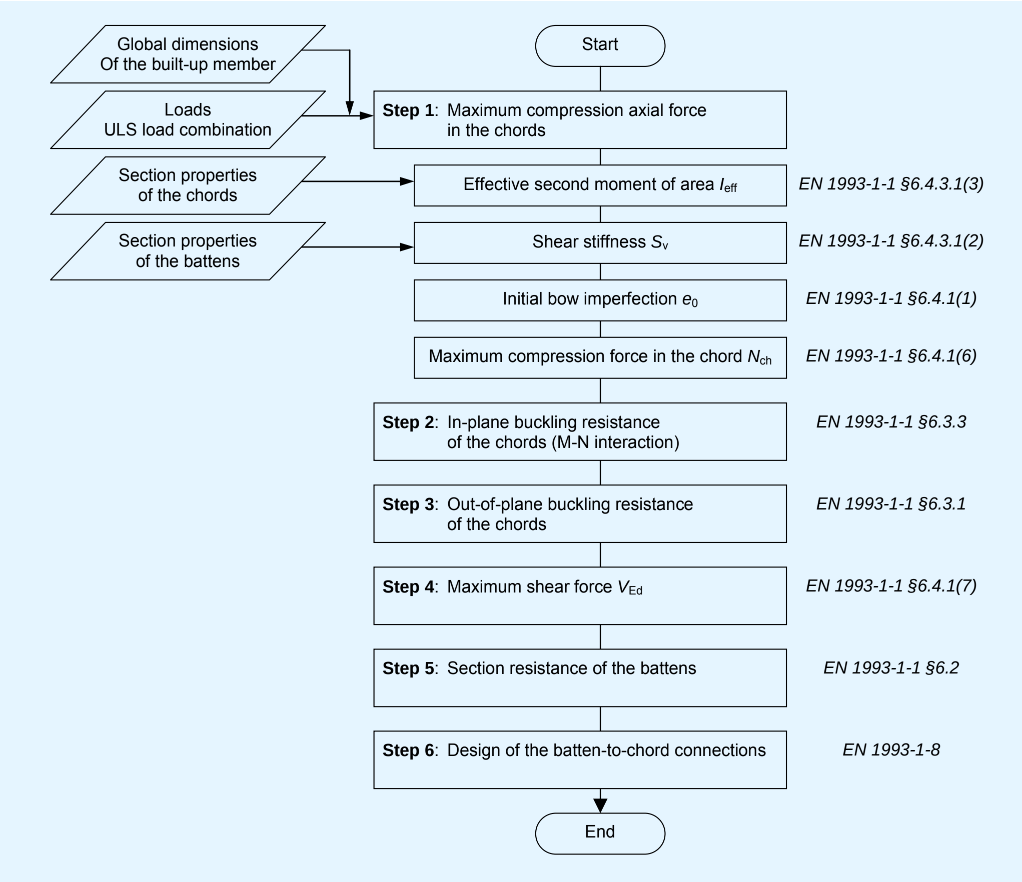


Figure 3.4 Flowchart of the design methodology for battened built-up columns

3.4 Buckling length

3.4.1 Laced compression members

Chords

According to EN 1993-1-1 Annex BB, the buckling length L_{cr} of a rolled I or H section chord member of built-up columns is taken as 0,9L for in-plane buckling and 1,0L for out-of-plane buckling. These values may be reduced if it is justified through detailed analysis.

L is the distance in a given plane between two adjacent points at which a member is braced against displacement in this plane, or between one such point and the end of the member.

Web members

Angles are mostly used as web members.

Provided that the chords supply appropriate end restraint to web members in compression made of angles and the end connections supply appropriate fixity (at least 2 bolts if bolted), the buckling length L_{cr} for in-plane buckling is taken as 0,9L, where L is the system length between joints.

When only one bolt is used for end connections of angle web members, the eccentricity should be taken into account and the buckling length L_{cr} is taken equal to the system length L.

The effective slenderness ratio $\bar{\lambda}_{eff}$ of angle web members is given in EN 1993-1-1 § BB.1.2 as follows:

$$\bar{\lambda}_{eff} = 0,35 + 0,7\bar{\lambda}$$

where:

$\bar{\lambda}$ is the non-dimensional slenderness defined in EN 1993-1-1 § 6.3.

For sections other than angles, the web members may be designed for in-plane buckling using a buckling length smaller than the system length and using the non-dimensional slenderness as defined in EN 1993-1-1 § 6.3, provided that the chords provide appropriate end restraint and the end connections provide appropriate fixity (at least 2 bolts if bolted). In practice, the buckling length L_{cr} of a rolled profile is equal to the distance between joints for in-plane buckling and for out-of-plane buckling.

3.4.2 Battened compression members

For simplicity, any potential restraint at the ends of the columns is neglected and the buckling length of the chords may be taken as the system length.

REFERENCES

1 EN 1993-1-1:2005 Eurocode 3 Design of Steel structures. General rules and rules for buildings

2 EN 1993-1-8:2005 Eurocode 3 Design of Steel structures. Design of joints

APPENDIX A

Worked Example: Design of a laced built-up column

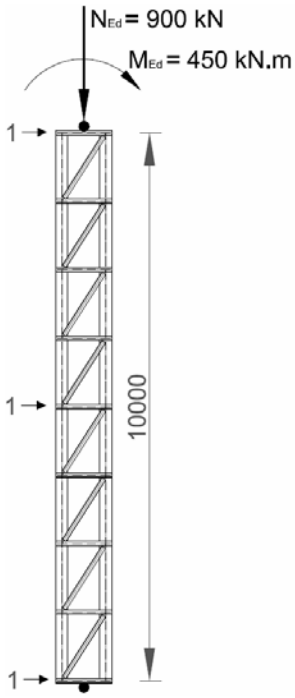
1. Introduction

This worked example deals with the verification of a typical built-up column under compressive axial force and bending moment. The calculations are carried out according to EN 1993-1-1. No National Annex is considered and the recommended values of EN 1993-1-1 are used in the calculations.

The calculations are performed according to the design methodology given in Section 3.2 of this guide.

2. Description

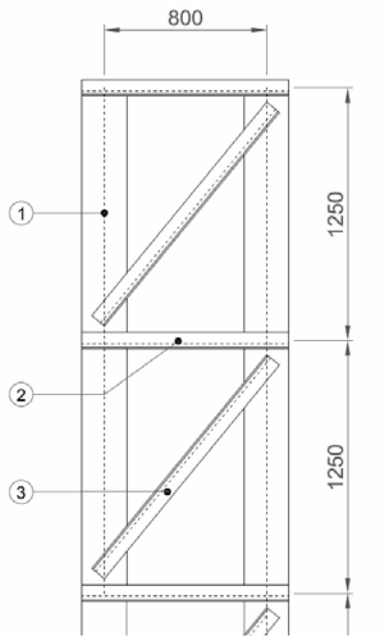
The geometry of the built-up column is described in Figure A.1 and in Figure A.2. For the most unfavourable ULS combination of actions, an axial force and a bending moment about the strong axis of the compound section are applied at the top of the column.

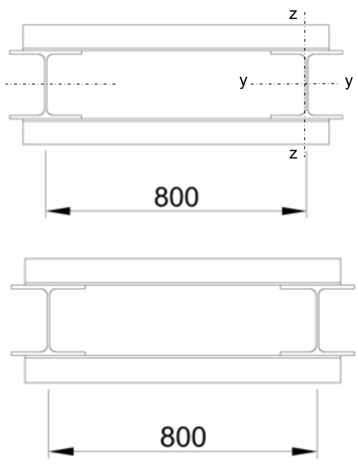


1 Lateral restraints

Figure A.1 Design model

The built-up column is restrained against out-of-plane buckling at both ends and at mid-height.





1 Chords HEA 200
2 Posts Angles 90 × 9
3 Diagonals Angles 80 × 8

Figure A.2 Geometry of the built-up column

Section properties

Note that the y-y axis and the z-z axis refer to the strong axis and the weak axis respectively, of the cross-section of each component.

Chords: HEA 220 – S355

$A_{ch} = 64,3\ \text{cm}^2$

$i_y = 9,17$ cm $\quad i_z = 5,51$ cm

Diagonals: Equal angles L 90 × 90 × 9 – S355

$A_d = 15,52\ \text{cm}^2$

$i_y = i_z = 2,73$ cm $\quad i_u = 3,44$ cm $\quad i_v = 1,75$ cm

Posts: Equal angles L 80 × 80 × 8 – S355

$A_v = 12,27\ \text{cm}^2$

$i_y = i_z = 2,43$ cm $\quad i_u = 3,06$ cm $\quad i_v = 1,56$ cm

3. Step 1: Maximum compressive axial force in the chords

3.1. Effective second moment of area

The effective second moment of area of the built-up section about the strong axis is calculated using the following expression:

EN 1993-1-1 § 6.4.2.1

$I_{eff} = 0,5\ h_0^{\ 2} A_{ch}$

where:

A_{ch} is the section area of a chord

h_0 is the distance between the centroids of the chords

The value of the effective second moment of area is:

$I_{eff} = 0,5 \times 80^2 \times 64,3 = 205800\ \text{cm}^4$

3.2. Shear stiffness

For N-shaped arrangement of lacings, the expression of shear stiffness is:

EN 1993-1-1 Figure 6.9

$$S_v = \frac{nEA_d a h_0^2}{d^3 \left[1 + \dfrac{A_d h_0^3}{A_v d^3}\right]}$$

where:

$d = \sqrt{h_0^2 + a^2} = \sqrt{0,8^2 + 1,25^2} = 1,48$ m

n is the number of planes of lacings ($n = 2$)

A_d is the section area of the diagonals

A_v is the section area of the posts.

Therefore:

$$S_v = \frac{2 \times 210000 \times 1552 \times 1250 \times 800^2}{1480^3 \left[1 + \dfrac{1552 \times 800^3}{1227 \times 1480^3}\right]} \times 10^{-3}$$

$S_v = 134100$ kN

3.3. Initial bow imperfection

The initial bow imperfection is taken equal to:

$e_0 = L/500 = 10000/500 = 20$ mm

EN 1993-1-1 § 6.4.1(1)

3.4. Maximum axial compressive force in the chords

The maximum compressive axial force in the chords, $N_{\mathrm{ch,Ed}}$, is determined at mid height of the built-up column as follows:

$$N_{\mathrm{ch,Ed}} = \frac{N_{\mathrm{Ed}}}{2} + \frac{M_{\mathrm{Ed}} h_0 A_{\mathrm{ch}}}{2 I_{\mathrm{eff}}}$$

EN 1993-1-1 § 6.4.1(6)

where:

$$M_{\mathrm{Ed}} = \frac{N_{\mathrm{Ed}} e_0 + M_{\mathrm{Ed}}^{\mathrm{I}}}{1 - \dfrac{N_{\mathrm{Ed}}}{N_{\mathrm{cr}}} - \dfrac{N_{\mathrm{Ed}}}{S_{\mathrm{v}}}}$$

N_{cr} is the effective critical axial force of the built up member:

$$N_{\mathrm{cr}} = \frac{\pi^2 E I_{\mathrm{eff}}}{L^2} = \frac{\pi^2 \times 210000 \times 205800 \times 10^4}{10000^2} \times 10^{-3} = 42650 \text{ kN}$$

The maximum bending moment, including the bow imperfection and the second order effects is:

$$M_{\mathrm{Ed}} = \frac{900 \times 0{,}02 + 450}{1 - \dfrac{900}{42650} - \dfrac{900}{134100}} = 481{,}4 \text{ kNm}$$

In the most compressed chord, the axial force is:

$$N_{\mathrm{ch,Ed}} = \frac{900}{2} + \frac{481{,}4 \times 0{,}8 \times 64{,}34 \times 10^{-4}}{2 \times 205800 \times 10^{-8}} = 1052 \text{ kN}$$

4. Step 2: In-plane buckling resistance of the chord

4.1. Classification of the cross-section of the chord

ε = 0,81 for steel grade S355

Flange slenderness: $c/t_{\mathrm{f}} = 88{,}5 / 11 = 8{,}05 < 10\,\varepsilon = 8{,}10$ Class 2

Web slenderness: $c/t_{\mathrm{w}} = 152 / 7 = 21{,}7 < 33\,\varepsilon = 26{,}73$ Class 1

Therefore the cross-section is Class 2 for pure compression.

4.2. Buckling resistance of a chord

The buckling resistance of the most compressed chord is verifed according to EN 1993-1-1 § 6.3.1 for buckling about the weak axis of the cross-section, i.e. about the z-z axis.

The buckling length of a hot-rolled H-section member can be taken equal to 0,9 *a* for in-plane buckling, where *a* is the system length between two nodes of the built-up column.

Buckling length of chords:

$L_{cr,z} = 0,9\ a = 0,9 \times 1,25 = 1,125$ m

EN 1993-1-1 BB.1.1(2)B

The slenderness is:

$$\lambda_z = \frac{L_{cr,z}}{i_z}$$

where

i_z is the radius of gyration of the gross cross-section, about the weak axis.

therefore: $\lambda_z = \frac{1125}{55,1} = 20,42$

$$\lambda_1 = \pi \sqrt{\frac{E}{f_y}} = 93,9\,\varepsilon \qquad \text{With: } \varepsilon = 0,81 \text{ for steel grade S355}$$

$$\lambda_1 = 93,9 \times 0,81 = 76,06$$

The non-dimensional slenderness is:

$$\bar{\lambda}_z = \frac{\lambda_z}{\lambda_1} = \frac{20,42}{76,06} = 0,268$$

Buckling curve *c* for buckling about the weak axis, since:

EN 1993-1-1 Table 6.2

Steel grade S355

$h/b < 1,2$

$t_f < 100$ mm

The imperfection factor is: $\alpha_z = 0,49$

The reduction factor χ_z can be calculated from the following expressions:

EN 1993-1-1 § 6.3.1.2(1)

$$\phi_z = 0,5\left[1 + \alpha_z\left(\bar{\lambda}_z - 0,2\right) + \bar{\lambda}_z^2\right] = 0,5\left[1 + 0,49 \times \left(0,268 - 0,2\right) + 0,268^2\right] = 0,553$$

$$\chi_z = \frac{1}{\phi_z + \sqrt{\phi_z^2 + \bar{\lambda}_z^2}} = \frac{1}{0,553 + \sqrt{0,553^2 - 0,268^2}} = 0,965$$

The design buckling resistance is equal to:

$$N_{b,z,Rd} = \frac{\chi_z A_{ch} f_y}{\gamma_{M1}} = \frac{0,965 \times 6430 \times 355}{1,0} \times 10^{-3} = 2203\,\text{kN}$$

The resistance criterion is:

$$\frac{N_{ch,Ed}}{N_{b,z,Rd}} = \frac{1052}{2203} = 0,477 < 1 \qquad \text{OK}$$

5. Step 3: Out-of-plane buckling resistance of the chords

The built-up column is pinned at both ends and is laterally supported at mid-height. Therefore the buckling length for buckling about the strong axis of the chords is taken equal to:

$L_{cr,y} = L/2 = 10000/2 = 5000$ mm

The slenderness is:

$$\lambda_y = \frac{L_{cr,y}}{i_y}$$

where

i_y is the radius of gyration of the gross cross-section, about the strong axis.

Therefore:

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{5000}{91{,}7} = 54{,}53$$

$$\lambda_1 = 93{,}9\,\varepsilon = 76{,}06$$

The non-dimensional slenderness is:

$$\bar{\lambda}_y = \frac{\lambda_y}{\lambda_1} = \frac{54{,}53}{76{,}06} = 0{,}717$$

Buckling curve *b* for buckling about the strong axis, since:

Steel grade S355

$h/b < 1{,}2$

$t_f < 100$ mm

The imperfection factor is: $\alpha_y = 0{,}34$

The reduction factor χ_y can be calculated from the following expressions: — EN 1993-1-1 § 6.3.1.2(1)

$$\phi_y = 0{,}5\left[1 + \alpha_y\left(\bar{\lambda}_y - 0{,}2\right) + \bar{\lambda}_y^2\right] = 0{,}5\left[1 + 0{,}34 \times \left(0{,}717 - 0{,}2\right) + 0{,}717^2\right] = 0{,}845$$

$$\chi_y = \frac{1}{\phi_y + \sqrt{\phi_y^{\,2} + \bar{\lambda}_y^2}} = \frac{1}{0{,}845 + \sqrt{0{,}845^2 - 0{,}717^2}} = 0{,}774$$

The design buckling resistance is equal to:

$$N_{b,y,Rd} = \frac{\chi_y A_{ch} f_y}{\gamma_{M1}} = \frac{0{,}774 \times 6430 \times 355}{1{,}0} \times 10^{-3} = 1767\ \text{kN}$$

The resistance criterion is:

$$\frac{N_{ch,Ed}}{N_{b,y,Rd}} = \frac{1052}{1767} = 0{,}595 < 1 \quad \text{OK}$$

6. Step 4: Maximum shear force

The maximum compressive axial force is obtained in the diagonals of the end panels of the built-up column. It depends on the shear force in this panel. The shear force can be assessed by the following expression:

$$V_{\mathrm{Ed}} = \frac{1}{L}\left(4-(4-\pi)\frac{e_{\mathrm{o}}N_{\mathrm{Ed}}}{e_{\mathrm{o}}N_{\mathrm{Ed}}+M_{\mathrm{Ed}}^{I}}\right)M_{\mathrm{Ed}}^{II}$$

where:

L = 10 m

e_0 = 0,02 m

N_{Ed} = 900 kN

$M_{\mathrm{Ed}}^{\mathrm{I}}$ = 450 kNm

$M_{\mathrm{Ed}}^{\mathrm{II}}$ = 482 kNm

Therefore:

$$V_{\mathrm{Ed}} = \frac{1}{10}\left(4-(4-\pi)\frac{0{,}02\times 900}{0{,}02\times 900+450}\right)\times 482 = 191{,}2 \text{ kN}$$

7. Step 5: Buckling resistance of the web members in compressive

7.1. Diagonals

7.1.1. Maximum compression axial force

The expression of the compression axial force $N_{\mathrm{d,Ed}}$ in a diagonal is derived from the shear force as follows:

$$N_{\mathrm{d,Ed}} = \frac{V_{\mathrm{Ed}}\cos\varphi}{n} = \frac{V_{\mathrm{Ed}}d}{nh_0}$$

where:

h_0 = 800 mm

d = 1480 mm

n is the number of plans of lacings: $n = 2$

then:

$$N_{\mathrm{d,Ed}} = \frac{191{,}2\times 1480}{2\times 800} = 176{,}86 \text{ kN}$$

7.1.2. Classification of a diagonal in compression

$h/t = 90 / 9 = 10 \qquad < 15\ \varepsilon = 12{,}15$

$(b+h) / (2t) = (90+90) / (2 \times 9) = 10 \qquad > 11{,}5\ \varepsilon = 9{,}31$ Class 4

EN 1993-1-1 Table 5.2 Sheet 3

Although the cross-section is Class 4, according to EN 1993-1-1 Table 5.2 Sheet 3, the calculation of the effective section area leads to no reduction. The section area is therefore fully effective and the calculation is the same as for a Class 3 Section.

7.1.3. Buckling resistance of a diagonal

The non dimensional slenderness can be calculated according to EN 1993-1-1 § BB.1.2 in so far as the diagonals are welded at both ends and the chords are stiff enough to ensure that the ends are clamped.

Slenderness about the weakest axis:

$$\lambda_{\mathrm{v}} = \frac{d}{i_{\mathrm{v}}} = \frac{1480}{17{,}5} = 84{,}57$$

Non dimensional slenderness

$$\bar{\lambda}_{\mathrm{v}} = \frac{\lambda}{93{,}9\varepsilon} = \frac{84{,}57}{93{,}9 \times 0{,}81} = 1{,}112$$

Effective non dimensional slenderness

EN 1993-1-1 § BB.1.2

$$\bar{\lambda}_{\mathrm{eff,v}} = 0{,}35 + 0{,}7\bar{\lambda}_{\mathrm{v}} = 0{,}35 + 0{,}7 \times 1{,}112 = 1{,}128$$

Buckling curve *b* is used for the determination of the reduction factor:

$\alpha_{\mathrm{v}} = 0{,}34$

Therefore:

EN 1993-1-1 § 6.3.1

$$\phi_{\mathrm{v}} = 0{,}5\left[1 + \alpha\left(\bar{\lambda}_{\mathrm{eff,v}} - 0{,}2\right) + \bar{\lambda}_{\mathrm{eff,v}}^{2}\right] = 0{,}5 \times \left[1 + 0{,}34 \times (1{,}128 - 0{,}2) + 1{,}128^{2}\right] = 1{,}294$$

$$\chi_{\mathrm{v}} = \frac{1}{\phi_{\mathrm{v}} + \sqrt{\phi_{\mathrm{v}}^{2} + \bar{\lambda}_{\mathrm{eff,v}}^{2}}} = \frac{1}{1{,}294 + \sqrt{1{,}294^{2} - 1{,}128^{2}}} = 0{,}519$$

The design buckling resistance of a compression member is equal to:

$$N_{\mathrm{b\text{-}d,Rd}} = \frac{\chi_{\mathrm{v}} A_{\mathrm{d}} f_{\mathrm{y}}}{\gamma_{\mathrm{M1}}} = \frac{0{,}519 \times 1552 \times 355}{1{,}0} \times 10^{-3} = 285{,}9\ \mathrm{kN}$$

The resistance criterion is:

$$\frac{N_{\mathrm{d,Ed}}}{N_{\mathrm{b\text{-}d,Rd}}} \leq 1 \Leftrightarrow \frac{176{,}8}{285{,}9} = 0{,}62 < 1 \qquad \text{OK}$$

7.2. Posts

7.2.1. Maximum compressive axial force

The maximum compressive axial force is:

$N_{h,Ed} = V_{Ed} = 191{,}2$ kN

7.2.2. Classification of the cross-section

$h/t = 80 / 8 = 10 \quad < 15\ \varepsilon = 12{,}15$

$(b+h) / (2t) = (80+80) / (2 \times 8) = 10 \quad > 11{,}5\ \varepsilon = 9{,}31$ Class 4

EN 1993-1-1 Table 5.2 Sheet 3

Although the cross-section is Class 4, according to EN 1993-1-1 Table 5.2 Sheet 3, the calculation of the effective section area leads to no reduction. The section area is therefore fully effective and the calculation is the same as for a Class 3 section.

7.2.3. Buckling resistance

The buckling length is equal to:

$L_{cr} = h_0 = 800$ mm

Slenderness about the weakest axis:

$$\lambda_v = \frac{L_{h,y}}{i_v} = \frac{800}{15{,}6} = 51{,}28$$

Non dimensional slenderness:

$$\bar{\lambda}_v = \frac{\lambda_v}{93{,}9\varepsilon} = \frac{51{,}28}{93{,}9 \times 0{,}81} = 0{,}674$$

Effective non dimensional slenderness:

$$\bar{\lambda}_{eff,v} = 0{,}35 + 0{,}7\bar{\lambda}_v = 0{,}35 + 0{,}7 \times 0{,}674 = 0{,}822$$

EN 1993-1-1 § BB.1.2

The buckling curve **b** is used for the determination of the reduction factor:

$\alpha = 0{,}34$

Therefore:

$$\phi_v = 0{,}5\left[1 + \alpha\left(\bar{\lambda}_{eff,v} - 0{,}2\right) + \bar{\lambda}^2_{eff,v}\right] = 0{,}5 \times \left[1 + 0{,}34 \times (0{,}822 - 0{,}2) + 0{,}822^2\right] = 0{,}943$$

$$\chi_v = \frac{1}{\phi_v + \sqrt{\phi_v^2 + \bar{\lambda}^2_{eff,v}}} = \frac{1}{0{,}943 + \sqrt{0{,}943^2 - 0{,}822^2}} = 0{,}712$$

The design buckling resistance of a compression member is equal to:

$$N_{b,Rd} = \frac{\chi_v A_h f_y}{\gamma_{M1}} = \frac{0{,}712 \times 1227 \times 355}{1{,}0} \times 10^{-3} = 310 \text{ kN}$$

The resistance criterion is:

$$\frac{N_{\mathrm{h,Ed}}}{N_{\mathrm{b,Rd}}} = \frac{191{,}2}{310} = 0{,}62 < 1 \qquad \text{OK}$$

8. Step 6: Resistance of the web members in tension

It is necessary to verify the resistance of the diagonals in tension, even if this situation is generally less critical than compression.

The verification of these members includes the verification of the resistance of the cross-section and the verification of the resistance of the net section for bolted connections.

Maximum design value of the tensile axial force:

$N_{\mathrm{t,Ed}} = 176{,}8$ kN

The resistance criterion is:

EN 1993-1-1 §6.2.3

$$\frac{N_{\mathrm{t,Ed}}}{N_{\mathrm{t,Rd}}} \leq 1{,}0$$

The design tension resistance $N_{\mathrm{t,Rd}}$ is taken as the design plastic resistance of the gross cross-section:

$$N_{\mathrm{t,Rd}} = N_{\mathrm{pl,Rd}} = \frac{A_{\mathrm{d}}\, f_{\mathrm{y}}}{\gamma_{\mathrm{M_0}}} = \frac{1552 \times 355}{1{,}0} \times 10^{-3} = 551\,\mathrm{kN}$$

The resistance criterion is:

$$\frac{N_{\mathrm{Ed}}}{N_{\mathrm{t,Rd}}} = \frac{176{,}8}{551{,}0} = 0{,}32 < 1{,}0 \quad \text{OK}$$

9. Step 7: Resistance of the diagonal-to-chord welded connection

The diagonals (L90 × 90 × 9) are welded to the chord (HEA 220) by fillet welds, see Figure A.3.

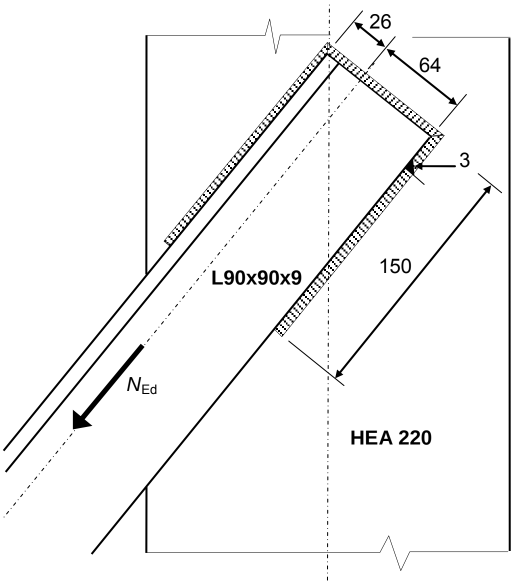


Figure A.3 Welded connection of a diagonal to the chord

Throat thickness:	a	= 3 mm
Effective longitudinal length of the fillet weld:	$l_{\text{eff-L}}$	= 150 mm
Effective transverse length of the fillet weld:	$l_{\text{eff-T}}$	= 90 mm
Axial force in the diagonal:	$N_{\text{d,Ed}}$	= 176,8 kN

The design resistance of a fillet weld is determined using the simplified method given in EN 1993-1-8 § 4.5.3.3.

At every point along the length of the fillet weld, the resultant of all the forces per unit length transmitted by the weld should satisfy the following criterion:

$$F_{\text{w,Ed}} \leq F_{\text{w,Rd}}$$

where:

$F_{\text{w,Ed}}$ is the design value of the force per unit length

$F_{\text{w,Rd}}$ is the design weld resistance per unit length

The design resistance is independent of the orientation of the weld throat plane and it is determined from:

$$F_{\text{w,Rd}} = f_{\text{vw,d}}\, a$$

where: EN1993-1-8

$f_{\text{vw,d}}$ is the design shear strength of the weld § 4.5.3.3

$$f_{\text{vw,d}} = \frac{f_{\text{u}} / \sqrt{3}}{\beta_{w} \gamma_{\text{M2}}}$$

f_u is the ultimate tensile strength of the weaker part:

f_u = 510 N/mm^2

EN 1993-1-1 Table 3.1

β_w is the appropriate correlation factor:

β_w = 0,9 for steel grade S355

EN1993-1-8 Table 4.1

γ_{M2} = 1,25

therefore:

$$f_{vw,d} = \frac{f_u / \sqrt{3}}{\beta_w \gamma_{M2}} = \frac{510/\sqrt{3}}{0,9 \times 1,25} = 261,7 \text{ N/mm}^2$$

$$F_{w,Rd} = f_{vw,d} a = 261,7 \times 5 = 785,2 \text{ N/mm}$$

$$F_{w,Ed} = \frac{N_{d,Ed}}{\sum l_{eff}} = \frac{176800}{(2 \times 150 + 90)} = 453,3 \text{ N/mm}$$

Therefore:

$F_{w,Ed}$ = 453,3 N/mm^2 < $F_{w,Rd}$ =785,2 N/mm^2 OK

The minimum throat thickness a_{min} = 3 mm is acceptable.

To prevent corrosion, the diagonal may be welded all around in one pass (a = 3 mm).

To account for eccentricity a 5 mm (2 passes) throat fillet weld is recommended on the unconnected leg side, as shown in Figure A.4.

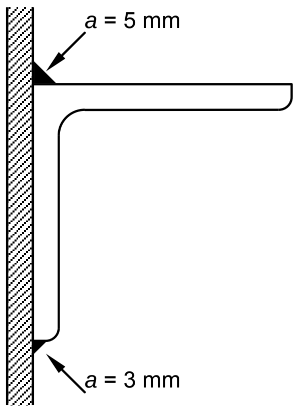


Figure A.4 Throat thickness of the weld fillets