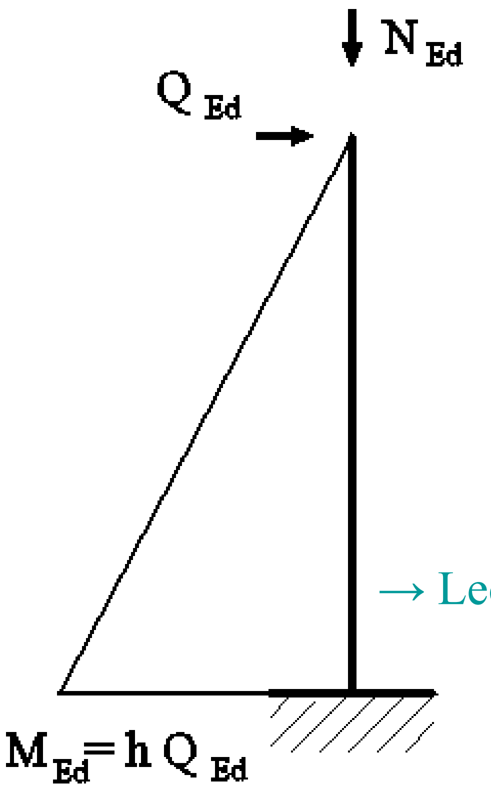
Metal Structures II

Design project II

Crane supporting structures

Example of calculation part III

General information about cross-sectional forces:



→ Lec #4 / 54

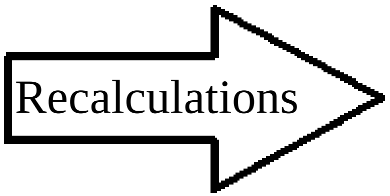
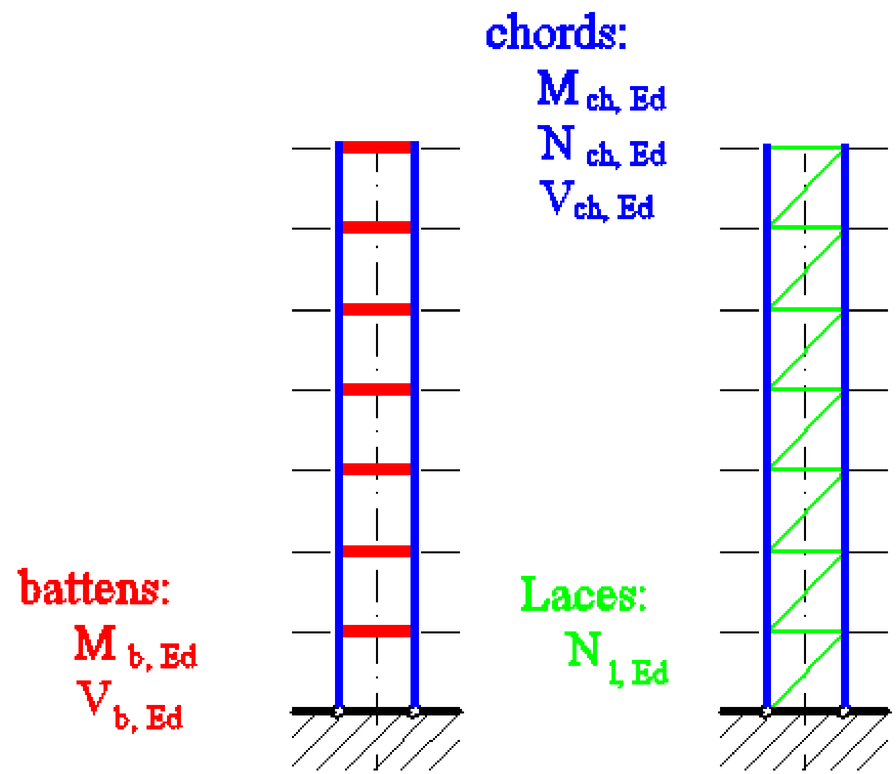


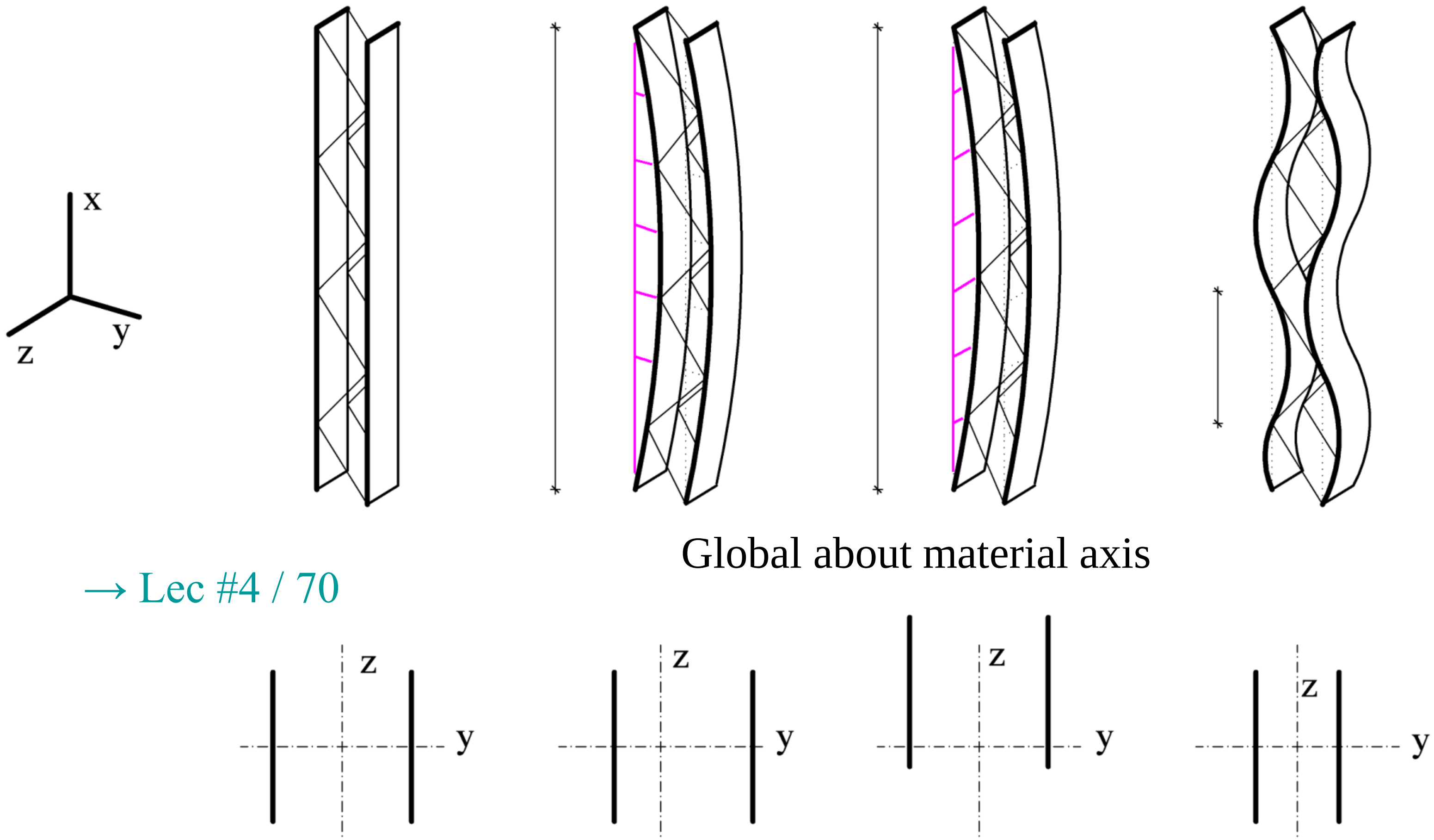
Photo: Author



Calculation as for single-bar member; global values of M_{Ed}, V_{Ed}, N_{Ed}

Local values of $M_{ch, Ed}$, $M_{b, Ed}$, $V_{ch, Ed}$, $V_{b, Ed}$, $N_{ch, Ed}$, $N_{l, Ed}$

Variuos modes of instability must be taken into consideration:



Global about material axis

→ Lec #4 / 70

Photo: Author

Global about immaterial axis

Local

Interaction of lateral buckling and flexural buckling must be analised for member under bending moment and compressive axial force. According to literature, muli-chords members can't be calculated, based on EN 1993-1-1 6.3.3.

→ Lec #4 / 79

$$N_{Ed} / (\chi_y N_{Rk} / \gamma_{M1}) + k_{yy} (M_{y, Ed} + \Delta M_{y, Ed}) / (\chi_{LT} M_{y, Rk} / \gamma_{M1}) + $$
$$+ k_{yz} (M_{z, Ed} + \Delta M_{z, Ed}) / (M_{z, Rk} / \gamma_{M1}) \leq 1,0$$

EN 1993-1-1 (6.61), (6.62)

$$N_{Ed} / (\chi_z N_{Rk} / \gamma_{M1}) + k_{zy} (M_{y, Ed} + \Delta M_{y, Ed}) / (\chi_{LT} M_{y, Rk} / \gamma_{M1}) + $$
$$+ k_{zz} (M_{z, Ed} + \Delta M_{z, Ed}) / (M_{z, Rk} / \gamma_{M1}) \leq 1,0$$

This point is used rather for mono-chord (single-coherent) members. For lateral buckling important is specific geometrical characteristic: warping constant. Calculation of warping constant is possible for single-coherent cross-section. It could be only roughtly evaluated for multi-chord cross-section as mathematical value, with uncertain physical interpretation.

It is suggested, than for such type of member should be calculated rather according to EN 1993-1-1 6.3.4. This point is dedicated to *single members with mono symmetric cross sections*, ***built-up*** *or not*.

Formula according EN 1993-1-1 6.3.4. for interaction between flexural buckling and lateral buckling is as follow (EN 1993-1-1 (6.64)):

→ Lec #4 / 80

$$\chi_{op} \, \alpha_{ult,\,k} / \gamma_{M1} \geq 1{,}0$$

Yes, it's not mistake: ≥ 1,0

$\chi_{op} = \chi(\lambda_{op})$ calculated for lateral buckling or flexural buckling

$\lambda_{op} = \sqrt{(\alpha_{ult,\,k} / \alpha_{cr,\,op})}$

$\alpha_{ult,\,k}$ - the minimum load amplifier of the design loads to reach the characteristic resistance of the most critical cross section of the structural component considering its in plane behaviour without taking lateral or lateral torsional buckling into account however accounting for all effects due to in plane geometrical deformation and imperfections, global and local, where relevant;

$\alpha_{cr,\,op}$ - the minimum amplifier for the in plane design loads to reach the elastic critical load of the structural component with regards to lateral or lateral buckling without accounting for in plane flexural buckling;

Values of $\alpha_{ult,\,k}$ and $\alpha_{cr,\,op}$ should be taken from numerical analysis.

According to EN 1993-1-1 6.3.4.(4) formula could be simplified to form:

$$1 / \alpha_{ult,\ k} = N_{Ed} / N_{Rk} + M_{y,\ Ed} / M_{y,\ Rk}$$

Value of $\alpha_{ult,\ k}$ is calculated for each important cross-section. Final value is min from each cross-sections.

→ Lec #4 / 81

According to EN 1993-1-1 (5.1), $\alpha_{cr,\ op}$ can be presented as:

$$\alpha_{cr,\ op} = N_{cr} / N_{Ed}$$

In analogy to $\alpha_{ult,\ k}$, $\alpha_{cr,\ op}$ is the smallest value for each possible form of instability.

Modes of global instability (Lec. #4):

Reason	Mode	Notices
N_c	Flexural bukling about strong axis	Always
	Flexural bukling about weak axis	
	Torsional buckling	Not for bisymmetrical cross-section
	Flexural (about weak) –torisional buckling	
M	Lateral buckling	Only, if bending moment acts about strong axis
N_c + M	Interaction flexural-lateral buckling	

Modes of instability **for column, considered as one-bar cantilever**; global cross-sectional forces ($N_{Ed, c}$, M_{Ed}) are taken into consideration; critical length comes from total height of column.

Reason	Mode	Notices
$N_{Ed, c}$	Flexural bukling about strong axis	Mode #1
	Flexural bukling about weak axis	Mode #2
	Torsional buckling	Column has bisymmetrical cross-section
	Flexural (about weak) –torisional buckling	
M_{Ed}	Lateral buckling	Interaction recalculated to one cord cross-section
$N_{Ed, c}$ + M_{Ed}	Interaction flexural-lateral buckling	

Modes of instability **for one chord of column**; local cross-sectional forces ($M_{ch,\ Ed}$, $N_{ch,\ Ed}$) are taken into consideration; critical length comes from distances between laces.

Reason	Mode	Notices
$N_{ch,\ Ed}$	Flexural bukling about strong axis	Mode #3
	Flexural bukling about weak axis	Effects calculated in mode #2
	Torsional buckling	Chord has bisymmetrical cross-section
	Flexural (about weak) –torisional buckling	
$M_{ch,\ Ed}$	Lateral buckling	Bending moment acts locally about weak axis of chord
$M_{ch,\ Ed}$ + $N_{ch,\ Ed}$	Interaction flexural-lateral buckling	

Algorithm of analysis:

- General calculation

$$N_{Ed}\ ,\ M_{Ed}\ ,\ V_{Ed}\ ,\ S_v\ ,\ J_{eff}\ ,\ e_0\ ,\ M_{Ed}^{\ II}\ ,\ N_{ch,\ Ed}\ ,\ M_{ch,\ Ed}\ ,\ V_{ch,\ Ed}$$

- Resistance for cross-section of both chords at bottom end of column

$$N_{Ed}\ ,\ M_{Ed}\ ,\ V_{Ed}\ ,\ \alpha_{ult,\ k,\ both}$$

- Resistance for cross-section of one chord at the bottom of column

$$N_{ch,\ Ed}\ ,\ M_{ch,\ Ed}\ ,\ V_{ch,\ Ed}\ ,\ \alpha_{ult,\ k,\ one}$$

- $\alpha_{ult,\ k} = \min\left(\alpha_{ult,\ k,\ both}\ ;\ \alpha_{ult,\ k,\ one}\right)$

→ Lec #4 / 82

- Global flexural stability about material axis

cross-section of both chords , $J_{material}$, $L_{cr} = H$

$$\alpha_{cr,\ op,\ 1} = N_{cr,\ mat} / N_{Ed}$$

- Global flexural stability about immaterial axis

cross-section of both chords , J_{eff} , $L_{cr} = H$

$$\alpha_{cr,\ op,\ 2} = N_{cr,\ immat} / N_{Ed}$$

→ Lec #4 / 83

→ Lec #4 / 84

- Local stability at the end of column

I-section	C-section
cross-section of one chords , J_y , L_{cr} = a $\alpha_{cr, op, 3} = N_{cr, y} / N_{ch, Ed}$ cross-section of one chords , J_z , L_{cr} = a $\alpha_{cr, op, 4} = N_{cr, z} / N_{ch, Ed}$	cross-section of one chords , J_y , L_{cr} = a $\alpha_{cr, op, 3} = N_{cr, y} / N_{ch, Ed}$ cross-section of one chords , J_z , L_{cr} = a $\alpha_{cr, op, 4} = N_{cr, z} / N_{ch, Ed}$ cross-section of one chords , J_w , J_t , L_{cr} = a $\alpha_{cr, op, 5} = N_{cr, T} / N_{ch, Ed}$ cross-section of one chords , J_z , J_w , J_t , L_{cr} = a $\alpha_{cr, op, 5} = N_{cr, T\text{-}z} / N_{ch, Ed}$
local bending moment acts about weak axis → no lateral buckling	

- $\alpha_{cr,\ op} = \min(\alpha_{cr,\ op,\ 1}\ ;\ \alpha_{cr,\ op,\ 2}\ ;\ \ldots)$
- $\lambda_{op} = \sqrt{(\alpha_{ult,\ k} / \alpha_{cr,\ op})}$
- $\chi_{op} = \chi(\lambda_{op})$ calculated for flexural buckling (no lateral buckling)
- $\chi_{op}\ \alpha_{ult,\ k} / \gamma_{M1} \geq 1{,}0$

- For battened column: resistance of baten

→ Lec #4 / 85

$$M_{b,\ Ed}\ ,\ V_{b,\ Ed}$$

- For laced column: resistance of lace

$$N_{l,\ Ed}$$

- Resistance of welds around Lace or batten
- Deformation of column

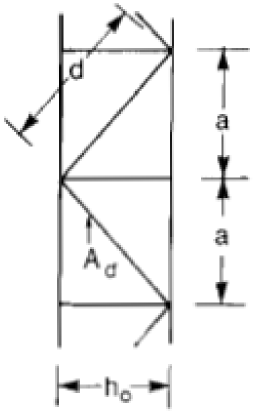
Geometry of column:

Cross-section of column's chord similar to cross-section of run-beam I-part;

Axis distance between chords equal axid distance I-pars and C-part of run-bram;

Webs of chords paralelly to axis of run-beam.

S355



Rys: EN 1993-1-1 fig 6.9

In analised case: 2x HEB 550:

h_0 = 800 mm.

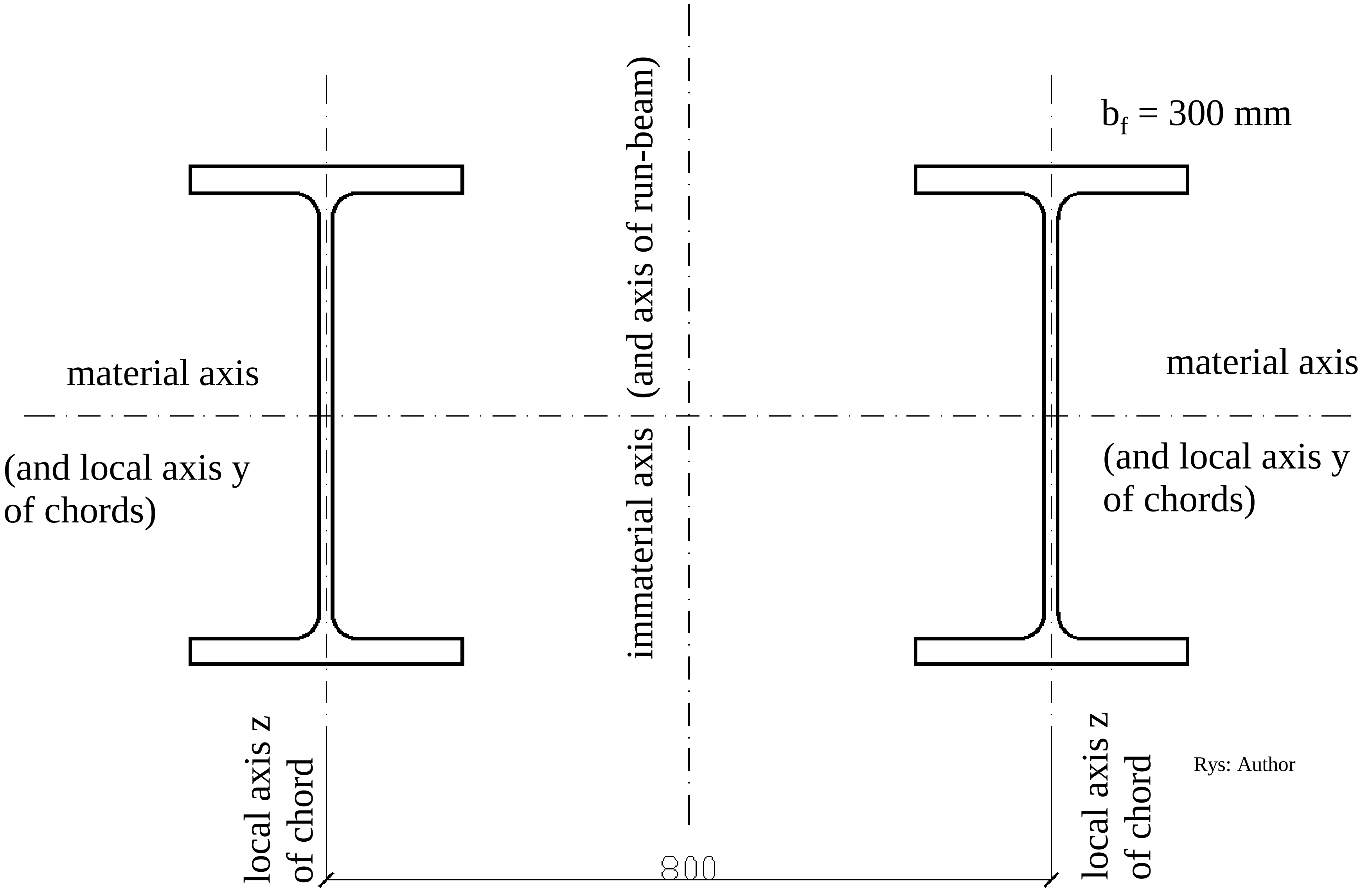
L = 8,000 m

Distance between laces: a = 727 mm (11 spans along column)

Laces the same as for beam, L 60x60x8

A_d = 9,600 cm^2

d = 1,081 m



bf = 300 mm
material axis
(and local axis y
of chords)
material axis
(and local axis y
of chords)
immaterial axis (and axis of run-beam)
local axis z
of chord
local axis z
of chord
800

Rys: Author

Chord:

$A_{ch} = 254{,}1 \text{ cm}^2$

$J_{y,\,ch} = 136\,700{,}0 \text{ cm}^4$

$J_{z,\,ch} = 13\,080{,}0 \text{ cm}^4$

Recalculation to cross-sectional forces in chord:

$e_0 = 8{,}000 / 500 = 0{,}016 \text{ m}$

$S_V = n\,E\,A_d\,a\,h_0^2 / d^3 = 148\,510{,}728 \text{ kN}$

$J_{immat,\,full} = 0{,}5\,h_0^2\,A_{ch} + 2\,J_{z,\,ch} = 839\,280{,}0 \text{ cm}^4$

μ = (cantilever) = 2

$L = 8{,}000 \text{ m}$

$N_{cr} = \pi^2\,E\,J_{immat,\,eff} / (\mu\,L)^2 = 83\,819{,}263 \text{ kN}$

$z_s = h_0 / 2 = 400 \text{ mm}$

Total column:

$A = 2\,A_{ch} = 508{,}2 \text{ cm}^2$

$J_{mat} = 2\,J_{y,\,ch} = 273\,400{,}0 \text{ cm}^4$

$J_{immat,\,eff} = 2\,A_{ch}\,z_s^2 = 813\,120{,}0 \text{ cm}^4$

$W_{eff} = J_{immat,\,eff} / (z_s + b_f / 2)\ 14\,784{,}0 \text{ cm}^3$

Loads applicated to column:

Force H for beam produces shear force and bending moment in column; force V produces axial force in column.

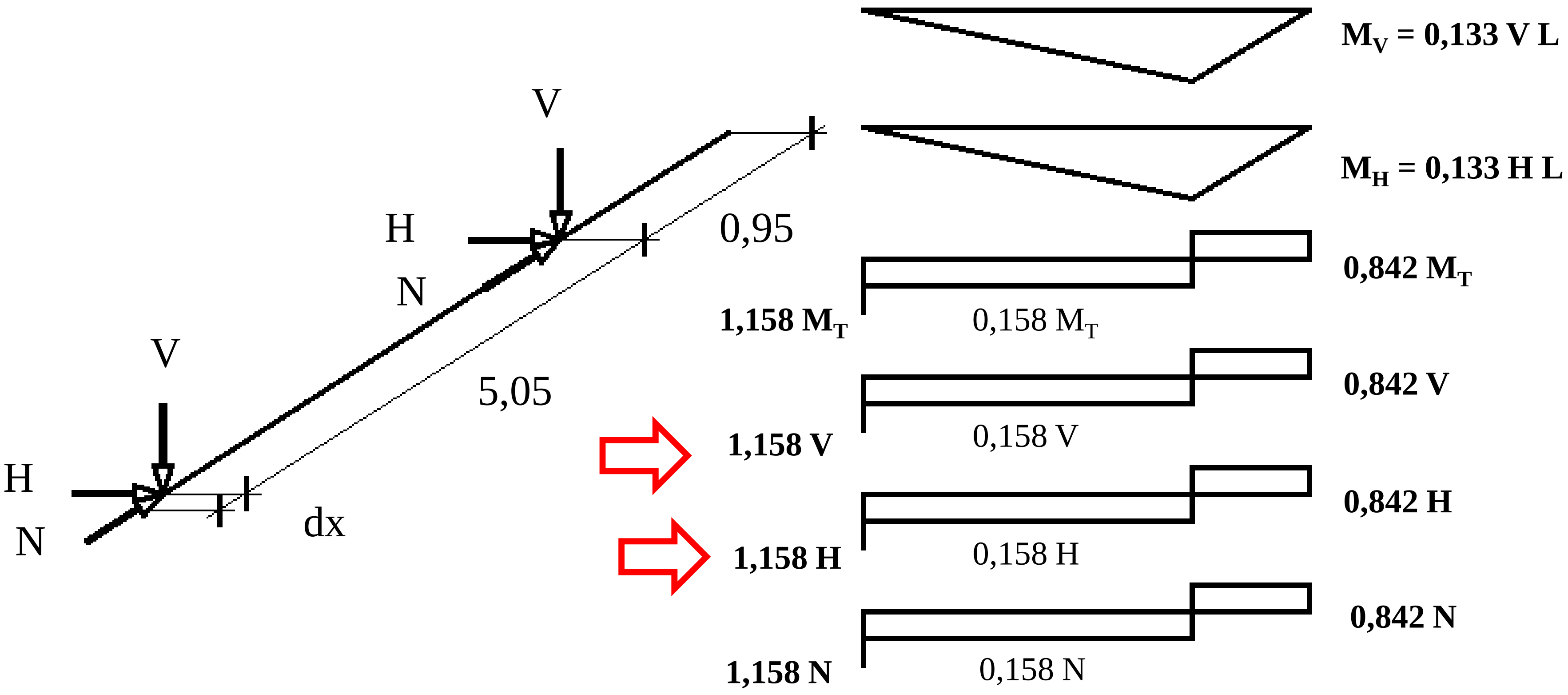


Photo: Author

Additionally, effect of wind acton on column must be considerated.

→ Des #1 part I / 71

Max V, over support

Force	Combination			
	5, wind longitudinal	5, wind transversal	8, wind longitudinal	8, wind transversal
M_V [kNm]	0,000	0,000	0,000	0,000
M_H [kNm]	0,000	0,000	0,000	0,000
M_T [kNm]	72,704	76,335	13,473	17,102
V_V [kN]	409,143	409,143	557,810	557,810
V_H [kN]	159,361	170,701	0,000	11,337
N [kN]	32,637	0,000	91,360	58,723

Combitnation, which must be analised:

- extremelly V_V and average wind (A – max N_{Ed});
- extremelly V_H and average wind (A – max V_{Ed});
- no action (B);
- max wind only (C).

Combination	Effect			
	N_{ED} [kN]	M_{ED} [kNm]	V_{ED} [kN]	$\delta_{H, accept}$
A – max N_{ED}	557,810	97,642	13,074	For A: h_c / 400 = = 20 [mm] For difference between A and B = = L / 600 = 10 [mm]
A – max V_{ED}	409,143	1372,555	172,438	
B	Case important for deformation olny			
C	Case important for deformation olny			L / 400 = 15 [mm]

Resistance of total column in support:

A – max N_{ED}

$N_{Rd} = A\,f_y = 18\,041{,}100$ kN

$M_{Rd} = W_{eff}\,f_y = 5\,248{,}323$ kNm

V_{Rd} = |resistance of 4x HEB 550 flange| = 7 132,591 kN

$V_{Ed} / V_{Rd} = 0{,}002 < 1{,}0$ **OK**

$V_{Ed} / V_{Rd} < 0{,}5 \rightarrow$ No interaction between shear force and bending moment

$N_{Ed} / N_{Rd} = 0{,}031 < 1{,}0$ **OK**

Very small value, there is assumed no interaction between axial force and bending moment withoud further calculation

$M_{Ed} / M_{Rd} = 0{,}019 < 1{,}0$ **OK**

$$\alpha_{ult,\,k,\,both} = 1 / (N_{Ed} / N_{Rd} + M_{Ed} / M_{Rd}) = 20{,}000$$

$A – \max N_{ED}$

$$S_1 = 1 - (N_{Ed} / N_{cr}) - (N_{Ed} / S_V)] = 0{,}990$$

$$N_{ch,\,Ed,\,max} = N_{Ed} / 2 + M_{Ed}\, z_s\, A_{ch} / (S_1\, J_{eff}) = 283{,}836 \text{ kN}$$

$$V_{ch,\,Ed,\,max} = (\pi\, N_{Ed}\, e_0 + M_{Ed}) / (2\, L\, n\, S_1) = 3{,}967 \text{ kN}$$

$$M_{ch,\,Ed,\,max} = a\, (\pi\, N_{Ed}\, e_0 + M_{Ed}) / (4\, L\, n\, S_1) = 1{,}442 \text{ kNm}$$

Resistance of one chord in support:

$N_{ch,\,Rd} = A_{ch}\, f_y = 9\,020{,}550$ kN

A – max N_{ED}

$M_{ch,\,Rd} = W_{z,\,ch}\, f_y = 309{,}489$ kNm

$V_{ch,\,Rd}$ = |resistance of 2x HEB 550 flange| = 3 556,293 kN

$V_{ch,\,Ed} / V_{ch,\,Rd} = 0{,}001 < 1{,}0$ **OK**

$V_{Ed} / V_{Rd} < 0{,}5 \rightarrow$ No interaction between shear force and bending moment

$N_{ch,\,Ed} / N_{ch,\,Rd} = 0{,}031 < 1{,}0$ **OK**

Very small value, there is assumed no interaction between axial force and bending moment withoud further calculation

$M_{ch,\,Ed} / M_{ch,\,N,\,Rd} = 0{,}004 < 1{,}0$ **OK**

$\alpha_{ult,\,k,\,one} = 1 / (N_{ch,\,Ed} / N_{ch,\,Rd} + M_{ch,\,Ed} / M_{ch,\,N,\,Rd}) = 28{,}571$

$A – \max N_{ED}$

$$\alpha_{ult, k, both} = 1 / (N_{Ed} / N_{Rd} + M_{Ed} / M_{Rd}) = 20{,}000$$

$$\alpha_{ult, k, one} = 1 / (N_{ch, Ed} / N_{ch, Rd} + M_{ch, Ed} / M_{ch, N, Rd}) = 28{,}571$$

$$\alpha_{ult, k} = \min (\alpha_{ult, k, both} \quad ; \quad \alpha_{ult, k, one}) = \mathbf{20{,}000}$$

A – max N_{ED}

Global flexural bucklind about material axis

$J_{mat} = 2\ J_{y,\ ch} = 273\ 400{,}0\ cm^4$

$N_{cr,\ mat} = \pi^2\ E\ J_{mat}\ /\ (\mu\ L)^2 = 22\ 134{,}901\ kN$

$$\alpha_{cr,\ op,\ 1} = N_{cr,\ mat}\ /\ N_{Ed} = 31{,}682$$

Global flexural buckling about immaterial axis

$N_{cr,\ immat} = \pi^2\ E\ \ J_{eff}\ /\ (\mu\ L)^2 = 65\ 831{,}495\ kN$

$$\alpha_{cr,\ op,\ 2} = N_{cr,\ immat}\ /\ N_{Ed} = 118{,}018$$

A – max N_{ED}

Local flexural buckling for one chord between laces, about local axis z:

$N_{cr, z} = \pi^2 E J_{z, ch} / (a)^2 = 512\ 929{,}837$ kN

$$\alpha_{cr, op, 3} = N_{cr, y} / N_{ch, Ed} = 1\ 807{,}135$$

$\alpha_{cr, op} = \min(\alpha_{cr, op, 1} ; \alpha_{cr, op, 2} ; \alpha_{cr, op, 3}) =$ **31,682**

$$\lambda_{op} = \sqrt{(\alpha_{ult, k} / \alpha_{cr, op})} = 0{,}795 \rightarrow \text{(flexural buckling, buckling curve c)}\ \Phi_{op} = 0{,}964 \rightarrow$$

$$\rightarrow \chi_{op} = 0{,}798$$

$\chi_{op}\ \alpha_{ult, k} / \gamma_{M1} = 0{,}798 \cdot 20{,}000 / 1{,}0 = 15{,}960 \geq 1{,}0$ **OK**

Resistance of total column in support:

A – max V_{ED}

$N_{Rd} = A\ f_y = 18\ 041{,}100$ kN

$M_{Rd} = W_{eff}\ f_y = 5\ 248{,}323$ kNm

V_{Rd} = |resistance of 4x HEB 550 flange| = 7 132,591 kN

$V_{Ed} / V_{Rd} = 0{,}024 < 1{,}0$ **OK**

$V_{Ed} / V_{Rd} < 0{,}5 \rightarrow$ No interaction between shear force and bending moment

$N_{Ed} / N_{Rd} = 0{,}023 < 1{,}0$ **OK**

Very small value, there is assumed no interaction between axial force and bending moment withoud further calculation

$M_{Ed} / M_{Rd} = 0{,}262 < 1{,}0$ **OK**

$\alpha_{ult,\ k,\ both} = 1 / (N_{Ed} / N_{Rd} + M_{Ed} / M_{Rd}) = 3{,}509$

A – max V_{ED}

$$S_1 = 1 - (N_{Ed} / N_{cr}) - (N_{Ed} / S_V)] = 0{,}992$$

$$N_{ch,\ Ed,\ max} = N_{Ed} / 2 + M_{Ed}\ z_s\ A_{ch} / (S_1\ J_{eff}) = 1934{,}101\ kN$$

$$V_{ch,\ Ed,\ max} = (\pi\ N_{Ed}\ e_0 + M_{Ed}) / (2\ L\ n\ S_1) = 43{,}886\ kN$$

$$M_{ch,\ Ed,\ max} = a\ (\pi\ N_{Ed}\ e_0 + M_{Ed}) / (4\ L\ n\ S_1) = 15{,}953\ kNm$$

Resistance of one chord in support:

A – max V_{ED}

$N_{ch,\,Rd} = A_{ch}\, f_y = 9\,020{,}550$ kN

$M_{ch,\,Rd} = W_{z,\,ch}\, f_y = 309{,}489$ kNm

$V_{ch,\,Rd}$ = |resistance of 2x HEB 550 flange| = 3 556,293 kN

$V_{ch,\,Ed} / V_{ch,\,Rd} = 0{,}0012 < 1{,}0$ **OK**

$V_{Ed} / V_{Rd} < 0{,}5 \rightarrow$ No interaction between shear force and bending moment

$N_{ch,\,Ed} / N_{ch,\,Rd} = 0{,}214 < 1{,}0$ **OK**

EN 1993-1-1, (6.33), (6.34), (6.35)→ Interaction between axial force and bending moment

$M_{ch,\,Ed} / M_{ch,\,N,\,Rd} = 0{,}052 < 1{,}0$ **OK**

$\alpha_{ult,\,k,\,one} = 1 / (N_{ch,\,Ed} / N_{ch,\,Rd} + M_{ch,\,Ed} / M_{ch,\,N,\,Rd}) = 3{,}759$

A – max V_{ED}

$$\alpha_{ult,\,k,\,both} = 1 / (N_{Ed} / N_{Rd} + M_{Ed} / M_{Rd}) = 3{,}509$$

$$\alpha_{ult,\,k,\,one} = 1 / (N_{ch,\,Ed} / N_{ch,\,Rd} + M_{ch,\,Ed} / M_{ch,\,N,\,Rd}) = 3{,}759$$

$$\alpha_{ult,\,k} = \min(\alpha_{ult,\,k,\,both} \;;\; \alpha_{ult,\,k,\,one}) = \mathbf{3{,}509}$$

A – max V_{ED}

Global flexural bucklind about material axis

$J_{mat} = 2\ J_{y,\ ch} = 273\ 400{,}0\ cm^4$

$N_{cr,\ mat} = \pi^2\ E\ J_{mat} / (\mu\ L)^2 = 22\ 134{,}901\ kN$

$$\alpha_{cr,\ op,\ 1} = N_{cr,\ mat} / N_{Ed} = 54{,}101$$

Global flexural buckling about immaterial axis

$N_{cr,\ immat} = \pi^2\ E\ J_{eff} / (\mu\ L)^2 = 65\ 831{,}495\ kN$

$$\alpha_{cr,\ op,\ 2} = N_{cr,\ immat} / N_{Ed} = 160{,}901$$

$A - \max V_{ED}$

Local flexural buckling for one chord between laces, about local axis z:

$N_{cr,\,z} = \pi^2\, E\, J_{z,\,ch} \,/\, (a)^2 = 512\ 929{,}837\ kN$

$$\alpha_{cr,\,op,\,3} = N_{cr,\,y} \,/\, N_{ch,\,Ed} = 265{,}203$$

$\alpha_{cr,\,op} = \min\,(\alpha_{cr,\,op,\,1}\,;\,\alpha_{cr,\,op,\,2}\,;\,\alpha_{cr,\,op,\,3}) = \mathbf{54{,}101}$

$$\lambda_{op} = \sqrt{(\alpha_{ult,\,k} \,/\, \alpha_{cr,\,op})} = 0{,}065 < 0{,}200 \;\rightarrow\; \chi_{op} = 1{,}000$$

$$\chi_{op}\, \alpha_{ult,\,k} \,/\, \gamma_{M1} = 1{,}000 \cdot 3{,}509 \,/\, 1{,}0 = 3{,}509 \;\geq 1{,}0$$ **OK**

Resistance of laces

$$N_{l,\,Ed,\,max} = \max V_{ch,\,Ed,\,max} / \cos\alpha = 59{,}300\ kN$$

$$N_{l,\,Rd} = A_d\, f_y = 340{,}800\ kN$$

$$N_{l,\,Ed,\,max} / N_{l,\,Rd} = 0{,}174 < 1$$ **OK**

Buckling:

$A_d = 9{,}6\ cm^2$

$J_u = 46{,}1\ cm^4$

$J_v = 12{,}1\ cm^4$

$J_t \approx 2{,}0\ cm^4$

$J_w \approx 73{,}7\ cm^6$

$\mu_v = \mu_u = \mu_T = 1{,}0$

$z_s = 0{,}0$

$i_s = 2{,}54\ cm$

$N_{cr, u} = 938{,}507$ kN

$N_{cr, v} = 246{,}333$ kN

$N_{cr, T} = 2\,747{,}771$ kN

$N_{cr, vT} = 246{,}333$ kN

$\lambda_u = 0{,}603$

$\lambda_v = 1{,}176$

$\lambda_T = 0{,}124$

$\lambda_{vT} = 1{,}176$

$\chi_u = 0{,}783$; $\chi_v = 0{,}445$; $\chi_T = 1{,}000$; $\chi_{vT} = 0{,}446$

$\chi = \min(0{,}783 ; 0{,}445 ; 1{,}000 ; 0{,}445) = 0{,}445$

$\chi N_{l, Rd} = 151{,}656$ kN

$N_{l, Ed, max} / \chi N_{l, Rd} = 0{,}391 < 1$ **OK**

Resistance of welds

Rys: Autor

$e_1 = 1{,}77$ cm

$e_2 = 4{,}23$ cm

$l_1 / l_2 = 2{,}390$

$N_{Ed} = 59{,}300$ kN

Weld a = 5 mm

$\tau = N_{Ed} / (a\, l_1 + a\, l_2)$

$\sqrt{(3\, \tau^2)} \leq f_u / (\beta_w\, \gamma_{M2}) = 453{,}333$ MPa

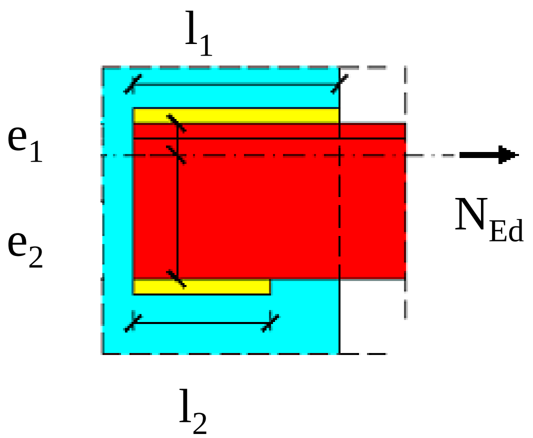
$(l_1 + l_2) \geq 45$ mm

$\min (l_1 + l_2) \geq 30$ mm;

$\min (l_1 + l_2) \geq 6a = 30$ mm

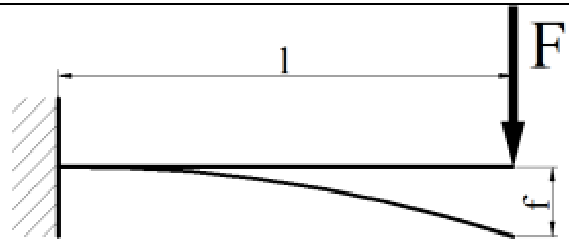
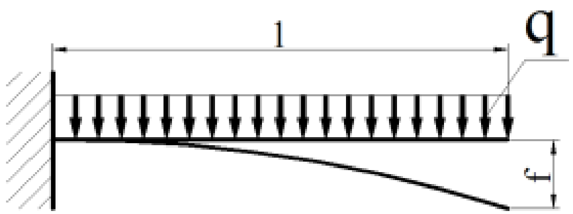
$l_1 = 30$ mm

$l_2 = 70$ mm



$e_1\, l_1 = e_2\, l_2$

Rys: agh.edu.pl

	$f = \frac{F \cdot l^3}{3EJ}$
	$f = \frac{q \cdot l^4}{8EJ}$

$J = J_{immat,\ eff}$ (⟶ #t / 16)

- Characteristic values of loads must be taken into consideration (without safety factors);
- Effective moment of inertia J_{eff} is adopted:

Case	Accepted value	Characteristic value
Max sway for working conditions (A)	20 mm	11,5 mm
Difference of sways for two neighbour columns for working conditions (A-B)	10 mm	11,5 mm
Difference of sways for two neighbour columns for max wind (C)	15 mm	0,8 mm

More massive I-sections must be applied. For HEM 550, second condition is equal 8,2 mm.

Thank you for attention

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