POSITION 5: EXAMPLE 4

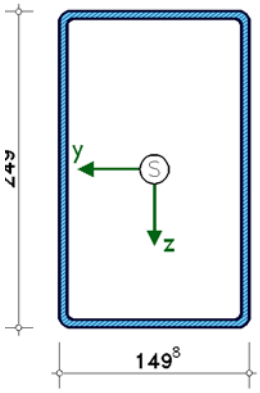
1. Input parameters

1.1. General statements

results acc. to DIN EN 1993:2010, Germany
verification of classification of the cross-section (width to thickness ratio)
torsional-flexural buckling by the method of fictitious bars acc. to EN 1993-1-1 6.3.3 with N+My+Mz

1.2. Cross-section

material: S275 (St44)
designation: RSH 250x150x6 cold formed, b = 150.00 mm, h = 250.00 mm, t = 6.00 mm
section scale 1:60



1.3. Section properties (refering to centroid S)

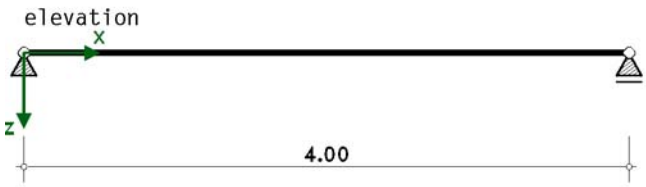
I_y = 4028 cm⁴, I_z = 1819 cm⁴, I_w = 7954.5 cm⁶, I_t = 3818.16 cm⁴
W_y = 322.22 cm³, W_z = 242.52 cm³, $W_{pl,y}$ = 389.42 cm³, $W_{pl,z}$ = 273.02 cm³
$z_{m,y}$ = 0 mm, $z_{m,z}$ = 0 mm, A = 4656 mm², cross-section ist verdrehsteif

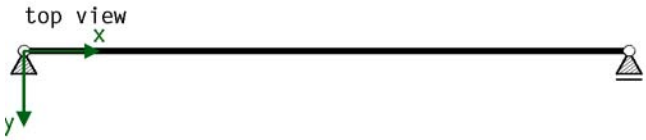
1.4. Load application point (refering to centroid S)

z_{load} = 0 mm (centroid),

1.5. Structural system

all supports with fork conditions, beam length 4.000 [m]
no support in z-direction, no support in y-direction





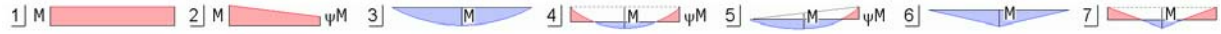
1.6. Buckling factors

about the y-axis: β_z = 1.000, about the z-axis: β_y = 1.000
warping restraint intensity β_0 = 1.000

1.7. Combinations of design internal forces

Nr	N_d kN	$M_{0y,d}$ kNm	type -	ψ_y -	$k_{c,y}$ -	ζ_y -	$M_{0z,d}$ kNm	type -	ψ_z -	$k_{c,z}$ -	ζ_z -	A
1	376.50	32.00	2	0.000	0.752	1.770	21.00	2	0.000	0.752	1.770	

moment diagram types



2. Verifications acc. to DIN EN 1993, Germany

DIN EN 1993-1-1 (EC 3)

chapter	value	definition
6.1(1)	permanent/transient sit.	partial factors for structural steel
	γ_{M0} = 1.00	Cross-section failure
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension
	accidental situation	partial factors for structural steel
	γ_{M0} = 1.00	Cross-section failure
	γ_{M1} = 1.00	instability
	γ_{M2} = 1.15	fracture cross-sections in tension
6.3.2.2(2)	factor f for modifying	buckling curve torsional-flexural buckling
	of χ_{LT}: setting	general case

2.1. Classification of cross-sections acc. to DIN EN 1993-1-1, 5.5.2

2.1.1. Load combination 1 ⇒ class of cross-section 1

Nr	c mm	t mm	c/t -	ε -	σ_1 N/mm²	σ_2 N/mm²	Tab 5.2	α -	ψ -	k_σ -	class -
1	1260.0	60.0	21.00	0.924	-80.73	-79.06	double 3/1	0.509	---	---	1
2	2260.0	60.0	37.67	0.924	-79.06	-81.00	double 3/1	0.505	---	---	1
3	1260.0	60.0	21.00	0.924	-81.00	-82.66	double 3/1	0.509	---	---	1
4	2260.0	60.0	37.67	0.924	-82.66	-80.73	double 3/1	0.505	---	---	1

verification is done in the predefined class of cross-section 2, U = 0.497

2.2. Torsional-flexural buckling acc. to DIN EN 1993-1-1, 6.3.3

I_p = 5847 cm⁴, I_T = 3818 cm⁴, i_p^2 = 12557 mm, c^2_y = 1313029 mm², c^2_z = 592950 mm², i_m^2 = 12558 mm²
i_y = 93.0 mm, β_y = 1.00 (about the z-axis), $L_{cr,y}$ = 4.000 m, λ_1 = 86.815
i_z = 62.5 mm, β_z = 1.00 (about the y-axis), $L_{cr,z}$ = 4.000 m
λ_y = 0.495, y-buckling curve c ⇒ α_y = 0.49, **λ_z = 0.737**, z-buckling curve c ⇒ α_z = 0.49
Φ_y = 0.695, **χ_y = 0.846, $N_{by,Rd}$ = 984.24 kN**, Φ_z = 0.903, **χ_z = 0.702, $N_{bz,Rd}$ = 816.62 kN**

2.2.0.1. Utilizations

Nr	N_d kN	U_y -	U_z -
1	376.50	**0.383**	**0.461**

2.2.1. Torsional-flexural buckling acc. to DIN EN 1993-1-1 6.3.2 about the y-y-axis

c^2 = 1313029 mm², buckling curve c ⇒ α_{LT} = 0.49, N_{cr} = 2356.19 kN

2.2.1.1. Utilizations

Nr	M_{cr} kNm	λ_{LT} -	f -	Φ_{LT} -	χ_{LT} -m	M_{Ed} kNm	$M_{b,Rd}$ kNm	U -
1	4779.81	0.150	1.000	0.447	1.000	32.00	97.36	**0.329**

2.2.2. Torsional-flexural buckling acc. to DIN EN 1993-1-1 6.3.2 about the z-z-axis

c^2 = 1313029 mm^2, buckling curve c $\Rightarrow \alpha_{LT}$ = 0.49, N_{cr} = 5217.54 kN

2.2.2.1. Utilizations

Nr	M_{cr} kNm	λ_{LT} -	f -	Φ_{LT} -	χ_{LT} -m	M_{Ed} kNm	$M_{b,Rd}$ kNm	U -
1	10584.40	0.084	1.000	0.425	1.000	21.00	68.26	**0.308**

2.2.3. Utilizations interaction

Nr	axis	C_{my} -	k_{yy} -	C_{mLT} -	k_{zy} -	C_{mz} -	k_{zz} -	k_{yz} -	U Gl.(6.61) -	U Gl.(6.62) -
1	y-y	0.600	0.668	0.600	---	---	---	0.449	**0.740**	---
2	z-z	---	---	0.600	0.401	0.600	0.749	---	---	**0.823**

max U = 0.823 ≤ 1 ⇒ verification successful!
the total utilization is: U = 0.823