POSITION 6: EXAMPLE 5

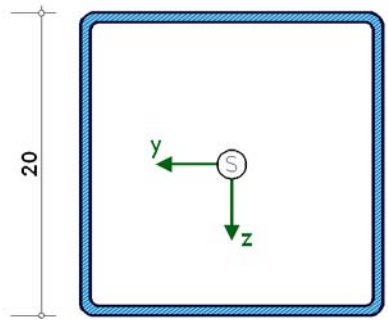
1. Input parameters

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

1.2. Cross-section

material: S355 (St52)
section: MSH200X200X6.3
section scale 1: 5



1.3. Section properties (refering to centroid S)

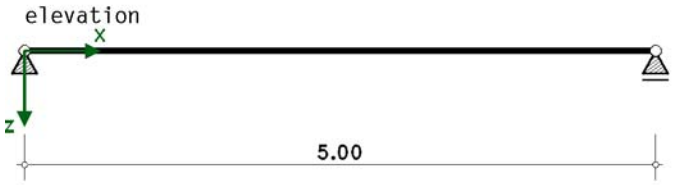
I_y = 2960 cm^4, I_z = 2960 cm^4, I_w = 0.0 cm^6, I_t = 4660.00 cm^4
W_y = 296.00 cm^3, W_z = 296.00 cm^3, $W_{pl,y}$ = 345.00 cm^3, $W_{pl,z}$ = 345.00 cm^3
$z_{m,y}$ = 0 mm, $z_{m,z}$ = 0 mm, A = 4780 mm^2, cross-section ist verdrehsteif

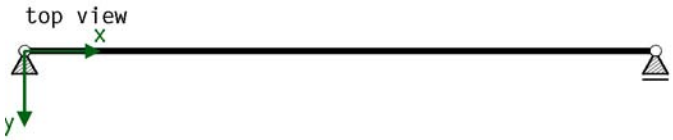
1.4. Load application point (refering to centroid S)

z_{load} = 0 mm (centroid),

1.5. Structural system

all supports with fork conditions, beam length 5.000 [m]
no support in z-direction, no support in y-direction





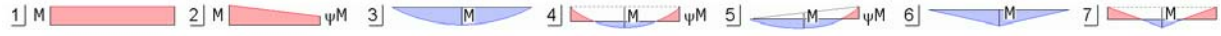
1.6. Buckling factors

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	$M_{Oy,d}$ kNm	type -	ψ_y -	$k_{c,y}$ -	ζ_y -	A
1	27.81	3	0.000	0.940	1.128	

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 of χ_{LT}: setting	buckling curve torsional-flexural buckling 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 3

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	96.8	6.3	15.37	0.814	-140.20	-140.20	double 2/1	---	---	---	1
2	96.8	6.3	15.37	0.814	-140.20	-142.02	double 3/3	2.057	-1.000	---	**3**
3	96.8	6.3	15.37	0.814	-142.02	-142.02	double 2/1	---	---	---	1
4	96.8	6.3	15.37	0.814	-142.02	-140.20	double 3/3	2.057	-1.000	---	3

verification is done in the predefined class of cross-section 2, U = 1.067
Attention! verification of classification of cross-sections failed!

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

I_p = 5920 cm⁴, I_T = 4660 cm⁴, i_p^2 = 12385 mm, c^2_y = 1538155 mm², c^2_z = 1538155 mm², i_m^2 = 12385 mm²
i_y = 78.7 mm, β_y = 1.00 (about the z-axis), $L_{cr,y}$ = 5.000 m, λ_1 = 76.409
i_z = 78.7 mm, β_z = 1.00 (about the y-axis), $L_{cr,z}$ = 5.000 m
λ_y = 0.832, y-buckling curve c ⇒ α_y = 0.49, **λ_z = 0.832**, z-buckling curve c ⇒ α_z = 0.49
Φ_y = 1.000, **χ_y = 0.642, $N_{by,Rd}$ = 990.92 kN**, Φ_z = 1.000, **χ_z = 0.642, $N_{bz,Rd}$ = 990.92 kN**

2.2.0.1. Utilizations

Nr	N_d kN	U_y -	U_z -
1	674.50	**0.681**	**0.681**

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

c^2 = 1538155 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 2453.98 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	3433.23	0.189	1.000	0.477	1.000	27.81	111.34	**0.250**

2.2.2. Utilizations interaction

Nr	axis	C_{my} -	k_{yy} -	C_{mLT} -	k_{zy} -	U Gl.(6.61) -	U Gl.(6.62) -
1	y-y	0.950	1.358	0.950	---	**1.020**	---
2	z-z	---	---	0.950	0.815	---	**0.884**

max U = 1.020 > 1 ⇒ verification failed!
the total utilization is: U = 1.067