POSITION 1: EXAMPLE 1

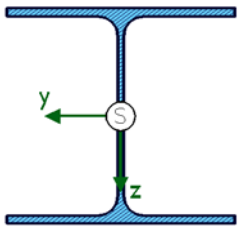
1. Input parameters

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: S355 (St52)
section: HE300AA
section scale 1:10



1.3. Section properties (refering to centroid S)

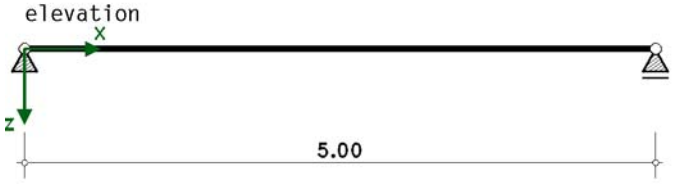
I_y = 13800 cm⁴, I_z = 4734 cm⁴, I_w = 877000.0 cm⁶, I_t = 49.30 cm⁴
W_y = 976.00 cm³, W_z = 316.00 cm³, $W_{pl,y}$ = 1065.00 cm³, $W_{pl,z}$ = 482.00 cm³
$z_{m,y}$ = 0 mm, $z_{m,z}$ = 0 mm, A = 8890 mm², cross-section is susceptible to torsional deformations

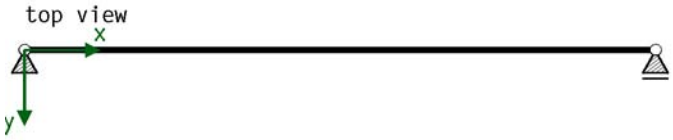
1.4. Load application point (refering to centroid S)

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





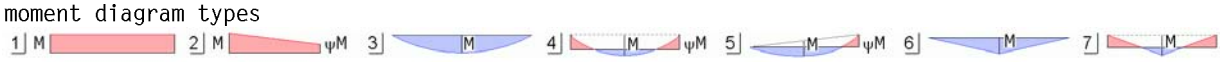
1.6. Buckling factors

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	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	946.80	87.00	2	0.000	0.752	1.770	34.00	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 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	119.3	10.5	11.36	0.814	-108.44	-107.36	ones. 1/3	---	---	---	**3**
2	119.3	10.5	11.36	0.814	-106.28	-107.36	ones. 1/3	---	---	---	3
3	208.0	7.5	27.73	0.814	-107.36	-105.64	double 3/3	1.355	-1.000	---	3
4	119.3	10.5	11.36	0.814	-106.72	-105.64	ones. 1/3	---	---	---	3
5	119.3	10.5	11.36	0.814	-104.57	-105.64	ones. 1/3	---	---	---	3

verification is done in the predefined class of cross-section 3, U = 0.997

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

I_p = 18534 cm⁴, I_T = 49 cm⁴, i_p^2 = 20848 mm, c^2_y = 28700 mm², c^2_z = 9845 mm², i_m^2 = 20851 mm²
i_y = 124.6 mm, β_y = 1.00 (about the z-axis), $L_{cr,y}$ = 5.000 m, λ_1 = 76.409
i_z = 73.0 mm, β_z = 1.00 (about the y-axis), $L_{cr,z}$ = 5.000 m
λ_y = 0.525, y-buckling curve b ⇒ α_y = 0.34, **λ_z = 0.897**, z-buckling curve c ⇒ α_z = 0.49
Φ_y = 0.693, **χ_y = 0.873, $N_{by,Rd}$ = 2504.32 kN**, Φ_z = 1.073, **χ_z = 0.602, $N_{bz,Rd}$ = 1726.71 kN**

2.2.0.1. Utilizations

Nr	N_d kN	U_y -	U_z -
1	946.80	**0.378**	**0.548**

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

c^2 = 28700 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 3924.71 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	1177.10	0.543	0.942	0.635	0.942	87.00	314.98	**0.276**

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

c^2 = 28700 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 11440.85 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	2233.48	0.224	1.000	0.489	1.000	34.00	101.98	**0.333**

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	0.671	0.600	---	---	---	0.777	**0.834**	---
2	z-z	---	---	0.600	0.922	0.600	0.777	---	---	**1.078**

max U = 1.078 > 1 ⇒ verification failed!
the total utilization is: U = 1.078