POSITION 2: EXAMPLE 2

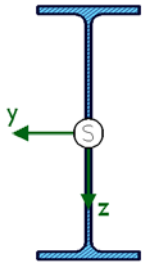
1. Input parameters

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: IPE500
section scale 1:15



1.3. Section properties (refering to centroid S)

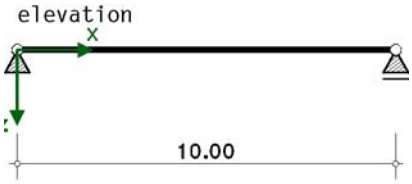
I_y = 48200 cm⁴, I_z = 2140 cm⁴, I_w = 1249000.0 cm⁶, I_t = 89.70 cm⁴
W_y = 1930.00 cm³, W_z = 214.00 cm³, $W_{pl,y}$ = 2194.00 cm³, $W_{pl,z}$ = 336.00 cm³
$z_{m,y}$ = 0 mm, $z_{m,z}$ = 0 mm, A = 11600 mm², cross-section is susceptible to torsional deformations

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 10.000 [m]
no support in z-direction, 1 support in y-direction



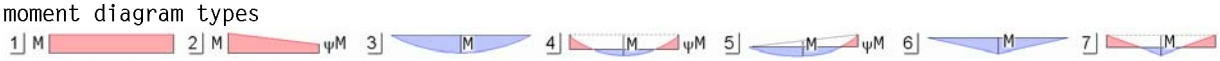
1.6. Buckling factors

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	$M_{0y,d}$ kNm	type -	ψ_y -	$k_{c,y}$ -	ζ_y -	A
1	250.00	2	-0.300	0.700	1.800	

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 2

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	73.9	16.0	4.62	0.814	-61.60	-61.60	ones. 1/1	---	---	---	1
2	73.9	16.0	4.62	0.814	-61.60	-61.60	ones. 1/1	---	---	---	1
3	426.0	10.2	41.76	0.814	-61.60	-59.09	double 3/2	0.727	---	---	2
4	73.9	16.0	4.62	0.814	-59.09	-59.09	ones. 1/1	---	---	---	1
5	73.9	16.0	4.62	0.814	-59.09	-59.09	ones. 1/1	---	---	---	1

verification is done in the predefined class of cross-section 2, U = 0.951

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

I_p = 50340 cm⁴, I_T = 90 cm⁴, i_p^2 = 43397 mm², c^2_y = 99317 mm², c^2_z = 9864 mm², i_m^2 = 43397 mm²
i_y = 203.8 mm, β_y = 1.00 (about the z-axis), $L_{cr,y}$ = 5.000 m, λ_1 = 76.409
i_z = 43.0 mm, β_z = 1.00 (about the y-axis), $L_{cr,z}$ = 10.000 m
λ_y = 0.642, y-buckling curve a ⇒ α_y = 0.21, **λ_z = 1.524**, z-buckling curve b ⇒ α_z = 0.34
Φ_y = 0.753, **χ_y = 0.873, $N_{by,Rd}$ = 3269.43 kN**, Φ_z = 1.886, **χ_z = 0.334, $N_{bz,Rd}$ = 1249.34 kN**

2.2.0.1. Utilizations

Nr	N_d kN	U_y -	U_z -
1	700.00	**0.214**	**0.560**

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

c^2 = 99317 mm², buckling curve c ⇒ α_{LT} = 0.49, N_{cr} = 1774.16 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	1006.42	0.880	0.852	0.908	0.714	250.00	593.21	**0.421**

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	0.480	0.525	0.740	---	**0.474**	---
2	z-z	---	---	0.740	0.886	---	**0.998**

max U = 0.998 ≤ 1 ⇒ verification successful!
the total utilization is: U = 0.998