NAVOR
PROJEKTIRANJE, STORITVE IN RAZISKAVE, D.O.O.

PROJEKTNA DOKUMENTACIJA ZA IZVEDBO GRADNJE
PZI

2.1	**NAČRT GRADBENIH KONSTRUKCIJ**

za objekt:	**RAZŠIRITEV JEDILNICE V OŠ PODČETRTEK**

investitor:	**Občina Podčetrtek Trška cesta 59 3254 Podčetrtek**		
številka:	**14/24-GK**	datum:	**januar 2025**

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III.	Tehnični prikazi Obvezno pri prijavi gradnje
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1.0 UVOD

1.1 Splošno

Investitor, Občina Podčetrtek, želi zaradi premajhnih prostorskih kapacitet in porasta števila učencev povečati šolsko jedilnico ter na obstoječem podestu ob jedilnici urediti dvonamenski prostor, ki bi v času pouka služil kot glasbena učilnica, v času šolskih prireditev pa kot oder.

Projekt deloma obsega rekonstrukcijo obstoječih prostorov jedilnice, pisarne računovodstva in sejne sobe ter deloma **prizidavo jedilnice**.

Osnovna šola Podčetrtek se nahaja na obrobju naselja Podčetrtek. Zemljišče, na katerem stoji šola, se nahaja v mirnem okolju, ki omogoča primerne pogoje za izobraževalno dejavnost. V bližini se nahajajo zelenice in parkovne površine, kar ustvarja prijetno okolje za učence in zaposlene.

Obstoječa stavba je grajena s kombinacijo armiranobetonske konstrukcije in opečnih zidakov. Zaradi dvigovanja terena je šola deloma podkletena, ponekod pa je na stiku s terenom. Temelji so armiranobetonski narejeni kot kombinacija točkovnih in pasovnih temeljev, ki so stopničasto povezani med sabo. Stropovje je narejeno iz montažnih nosilcev med katerimi so opečna polnila zalita z betonom – monta strop. Fasada je kontaktna, ometana. Leta 2014 je bila izvedena energetska sanacija šolske stavbe. Strešna kritina poševnih streh je iz trapezne pločevine, kritina ravnih streh pa iz FPO membrane.

1.2 Lokacija objekta

Lokacija objekta je v Podčetrtku. Osnovna šola, Stara šola in vrtec se nahajajo v katastrski občini 1229 – Podčetrtek. Šolsko območje obsega parcele št.: 198/8 (2125,0 m2), 198/2 (328,0 m2), 198/10 (271,0 m2), 202/1 (2256,0 m2), 190/4 (4170,8 m2), 190/1 (1100,0 m2), 198/9 (1163 m2).



Del OŠ, ki je predmet obravnave, je bil grajen po načrtih št. 129/70, ki jih je izdelal Zavod za napredek gospodarstva v decembru 1970.

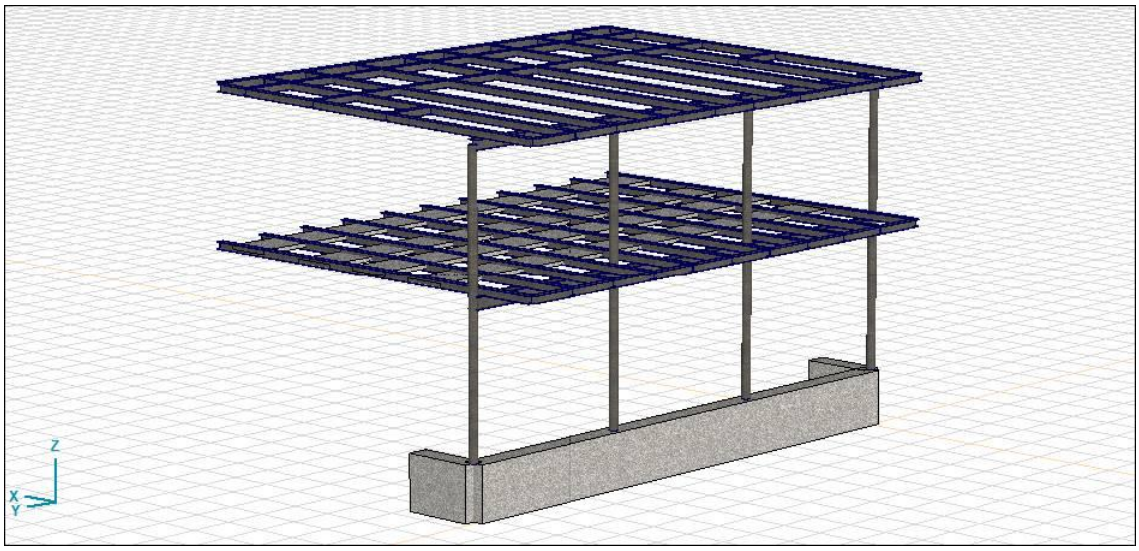
2.0 ANALIZA OBJEKTA

2.1 Dimenzije objekta

2.1.1 Prizidek za razširitev jedilnice

Obstoječi stavbi se v treh rastrih glavnih stebrov v jedilnici prizida lahka montažna jeklena nosilna konstrukcija in sicer tako, da se pritličnega dela objekta, kjer so levo od vhoda v objekt garderobe, ne obremenjuje dodatno. Ta del objekta je namreč klasična zidana konstrukcija temeljena na pasovnih temeljih in zidana z MO. Stene so ojačane s protipotresnimi vezmi. Strop (streha) nad pritličjem je izvedena kot »Super strop« 20+5cm.
Prizidek se zato postavi na lastni pasovni temelj in nad pritličjem ter nad etažo pripne na obstoječo masivno monolitno AB konstrukcijo. Osnovna konstrukcija večnamenskega dela objekta, kjer je jedilnica je monolitna AB okvirna konstrukcija, ki jo sestavljajo stebri dim 30/50cm in grede 50/60cm (nad pritličjem) in 40/60cm (nad etažo). AB okvir je iz betona C25/30 (MB30).

Osne dimenzije prizidka objekta so 820cm ter konzola 160cm in vzdolžno 3x 450cm. Tlorisna dimenzija je tako 9.90 / 13.50 m. Po višini je prizidek etažen in sicer je konstrukcijska osna višina pritličja 3,70m in etaže 3.20m. Temelj pod stebri je pasoven monoliten, izveden na globino obstoječega temelja garderobnega zidu. Dimenzija temelja je 50/130cm in je iz betona C25/30. V pasovni temelj so vpeti jekleni stebri fi 219/10mm, ki jih na nivoju stropa nad pritličjem povezuje nosilec HEA 300. Na nosilec se naslanjajo sekundarni nosilci novega stropa nad pritličjem HEB 180, ki so na obstoječi objekt usidrani v AB gredo dim 50/60cm. HEB nosilci so medsebojno zavetrovani z AB ploščo debeline 10cm izvedeno preko slepega opaža.
Stebri etaže fi 219/10mm v medsebojnem rastru 4,50m, podpirajo vezno gredo HEA 240, na katero se naslanjajo sekundarni nosilci HEA 180, ki nosijo streho prizidka. Stebri so v obstoječi objekt usidrani v AB gredo dim 40/60cm.



2.2 Analiza nosilne konstrukcije

2.2.1 Veljavni predpisi

Po veljavni zakonodaji (Pravilnik o mehanski odpornosti in stabilnosti objektov, UL RS, št. 101/05) se morajo za projektiranje, gradnjo in vzdrževanje novih objektov, uporabljati pravila navedena v standardih Evrokod. Za analizo obstoječega objekta so bili uporabljeni relevantni Evrokod standardi.

2.2.2 Vhodni podatki za analizo nosilne konstrukcije

- *Podatki, ki izhajajo iz lokacije objekta*

- Podatki za izračun potresne obremenitve

Podatek o projektrivnem pospešku tal je javno dostopen v obliki Karte potresne ogroženosti Slovenije (vir ARSO), ki prikazuje pospeške temeljnih tal v odstotku gravitacijskega pospeška za posamezna območja v Sloveniji za potres s povratno dobo 475 let. Za Podčetrtek je ta pospešek 20% težnostnega pospeška g. Potresna obtežba je bila določena na podlagi standarda SIST EN 1998-1 in SIST EN 1998-1:2005/A 101.

- Podatki za izračun obtežbe s snegom:

Obtežba s snegom je bila določena na podlago standarda SIST EN 1991-1-3.

- Podatki za izračun obtežbe z vetrom:

Obtežba z vetrom je bila določena na podlagi standarda SIST EN 1991-1-4.

- *Podatki, ki izhajajo iz zasnove objekta*

Objekt je predviden iz armiranega betona z upoštevano gostoto $\rho=2500kg/m^3$ in jekla z upoštevano gostoto $\rho=7850kg/m^3$.
Sestave sten, tal in strehe so povzete v načrtu arhitekture. Geometrija konstrukcije je opisana v zgornji točki in prikazana v načrtu arhitekture.

V skladu s točko 4.2.3 SIST EN 1998-1 je bil preverjen kriterij enakomernosti konstrukcije. Ker objekt ne zadošča kriteriju enakomernosti je bila izvedena statična analiza na prostorskem modelu objekta.

- *Podatki, ki izhajajo iz Geološko geomehanskega poročila o sestavi in nosilnosti tal ter pogojih temeljenja objektov, ki je bilo izdelana v fazi izgradnje prizidka Vrtec (glej Poročilo št. 1065/2010 GPROCOM d.o.o., Sokolska ulica 22, 2000 MARIBOR)*
  - Dopustna nosilnost temeljnih tal 250,0 kPa
  - Redukcijski faktor nosilnosti 0,80
  - Tip tal za potresno analizo C
  - Prostorninska teža $\gamma = 20,00\ kN/m^3$
  - Modul reakcija tal $K=16666,66\ 70\ kN/m^3$

2.2.3 Določitev lastne teže objekta

Lastno težo nosilnih konstrukcijskih elementov (konstrukcije) upošteva program za analizo, glede na podane geometrijske lastnosti elementov.

- *Določitev stalne teže sklopov*

- Streha nad etažo

Masa sestava:

- FPO folija	$m=2,5\ kg/m^2$
- Toplotna izolacija 20cm	$m= 30\ kg/m^2$
- HI bond 55mm	$m=11,5\ kg/m^2$
- Podkonstrukcija za spuščen strop	$m=2\ kg/m^2$
- Zvočna izolacija	$m=7,5\ kg/m^2$
- Strop	$m=14\ kg/m^2$
- Razvodi ogrevanja	$m= 50\ kg/m^2$
- Svetila, etc	$m=10\ kg/m^2$
	$\Sigma m=127,50\ kg/m^2$
Lastna teža sestava strehe:	$g=1,28kN/m^2$

- Etažna plošča nad garderobo

Masa sestava:

- Finalna obloga Noraplan acoustic	$m= 5kg/m^2$
- Mikroarmiran cementni estrih 5cm	$m= 120kg/m^2$
- Zvočna izolacija WF plošča 2cm	$m= 3kg/m^2$

- Betonska plošča d=10cm m= 250kg/m^2

Σm=378 kg/m^2
Lastna teža sestava : g=3,78 kN/m^2

- Etažna plošča nadstrešek

Masa sestava:

- Finalna obloga Noraplan acoustic m= 5kg/m^2
- Mikroarmiran cementni estrih 5cm m= 120kg/m^2
- Zvočna izolacija WF plošča 2cm m= 3kg/m^2
- Betonska plošča d=10cm m= 250kg/m^2
- Toplotna izolacija d=18cm m= 27kg/m^2
- Tipska podkonstrukcija za prez. fasado m= 5kg/m^2
- Cementna vezana plošča 1,5cm m= 26kg/m^2
- Zaključni silikonski sloj 2cm m= 2kg/m^2

Σm= 438kg/m^2
Lastna teža sestava: g=4,38kN/m^2

- Fasade bočne

Masa sestava:

- Al kompozit d=6mm m= 8kg/m^2
- Podkonstrukcija za AL kompozit m= 5kg/m^2
- Fasadni panel d=240mm m= 35kg/m^2
- Podk. za fas.panel HOP 80/80/5mm / 2,5m m= 15kg/m^2
- Pokonstrukcija za mavčno oblogo m= 5kg/m^2
- Mavčna obloga 2,5cm m= 25kg/m^2

Σm=93 kg/m^2
Lastna teža sestava fasade: g=0,93kN/m^2
Lastna teža sestava fasade: 0,93 x 4,3m g=4,00kN/m^1

- Fasada steklo

Masa sestava:

- Maska zgoraj 0,93 x 0,80 m= 75kg/m^1
- Okno 50 x 3,10 m= 155kg/m^1
- Maska spodaj 0,93 x 0,70 m= 65kg/m^1

Σm=295 kg/m^1
Lastna teža sestava fasade: g=3,00kN/m^1

2.2.4 Določitev koristne obtežbe

Koristna obtežba za analizo objekta je bila določena na podlagi EC1
Predviden objekt je namenjen šolsko dejavnost
Obtežba po kategoriji: C2: q=4,00kN/m^2 .

2.2.5 Določitev obtežbe s snegom

Predviden objekt se nahaja v coni A2 za določitev obtežbe s snegom na nadmorski višini H=220m.
Izraz za izračun karakteristične obtežbe s snegom:

$$s_k = 1.293 \times [1 + (H/728)^2]$$
$$s_k = 1.293 \times [1 + (220/728)^2] = 1.41 kN/m^2$$

Predviden objekt ima streho z naklonom 2^0, kar pomeni oblikovni faktor obtežbe s snegom μ_1=0.8. (μ_2=0).

Faktor izpostavljenosti C_e=1.0, ker je predvideni objekt v bližnji okolici obkrožen s stavbami in tako zaščiten pred vplivi vetra, ki bi odpihnili sneg. Temperaturni faktor je privzeto C_t=1.0.

- Projektna obtežba s snegom na strehi:

$$s = \mu_1 C_e C_t s_k$$
$$s = 0.8 \times 1.0 \times 1.0 \times 1.41 = 1.13 kN/m^2$$

kjer je
- Oblikovni koeficient za ravo streho μ_1=0.8
- Faktor izpostavljenosti C_e=1.0
- Temperaturni faktor C_t=1.0

- Zamet

Prizidani del objekta je 0.5m nižji od strehe obstoječega objekta, zato je za izračun obtežbe s snegom potrebno upoštevati tudi možnost nastanka zametov zaradi vetra in zdrsa snega z zgornje strehe.

- Projektna obtežba s snegom na ravno streho:

Oblikovni faktor ob višjem delu objekta:
$\mu_2 = \mu_w + \mu_s$

Zdrs:
Oblikovni faktor na robu strehe: μ_1=0.8
Zgornja streha ima naklon 19° : μ_s=50% x μ_2 ; μ_s = 0,50 x 2,00 = 1.00
μ_2 = 0,20 + 10 h/l = 0,20 + 10 x 3,90 x 18,60 = 2,296 <= 2,00

Veter (zamet):

$$\mu_w = \frac{(b_1 + b_2)}{2h} \leq \frac{\gamma h}{s_k}$$

Kjer je
- b_1 širina višjega dela objekta
- b_2 širina nižjega dela objekta
- γ prostorninska teža snega, ki se upošteva kot γ=2kN/m^3
- h višinska razlika med višjim in nižjim delom objekta

$$\frac{(b_1 + b_2)}{2h} = \frac{18.60 + 9.5}{2 \times 0.5} = 28.1$$

$$\frac{\gamma h}{s_k} = \frac{2 \times 0.5}{1.41} = 0.71$$

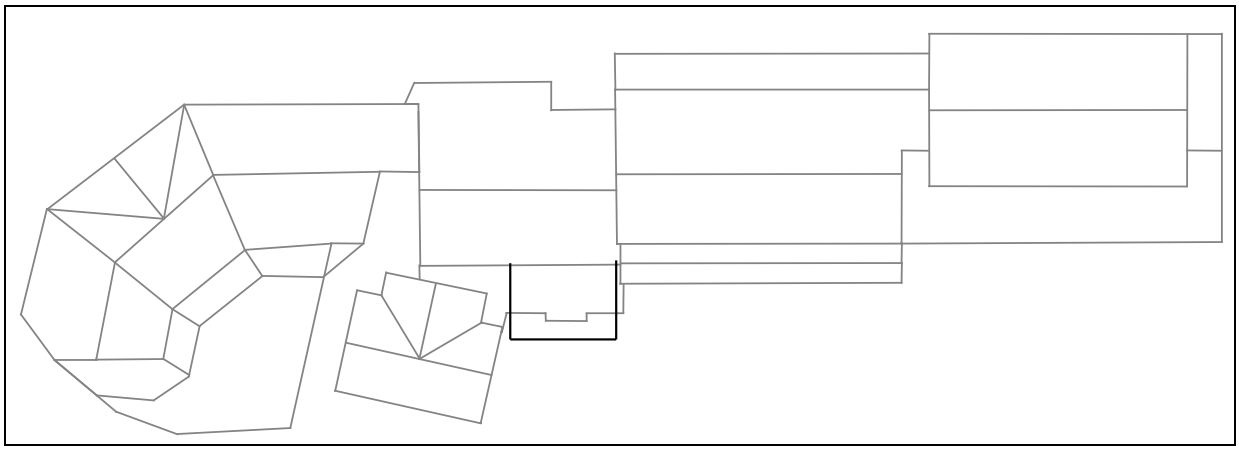
Tako je $\mu_2 = \mu_w + \mu_s$ = 0,71+1,0 = 1,71

Širina zameta je določena po enačbi
ls = 2h = 2×0.5m = 1.00m

$$s = 1.71 \times 1.0 \times 1.0 \times 1.41 = 2.41 kN/m^2$$
s_{dod} = 2,41 - 1,13 = 1.28 kN/m^2

2.2.6 Določitev obtežbe z vetrom po EC1

Obtežba z vetrom je bila določena na podlagi standarda SIST EN 1991-1-4.
- Cona 1 → hitrost vetra $v_b = v_{b,0}$ =20 m/s
  → tlak vetra q_b = 250 Pa
- kategorija terena: IV
- faktor izpostavljenosti
  $c_e(z)$ = 1,52
  $q_p(z) = c_e(z) \times q_b$ = 1.52 x 250 = 380.00 Pa = 0.380 kPa



Smer vetra pravokotno na »sleme« :

- dolžina celotnega objekta b=102,00m
- dolžina prizidka b=14,00m
- širina celotnega objekta d=33,10m
- širina prizidka d=10.00m
- višina objekta h=11,00m
- višina atike h_p=0.00m
  e = b oz. 2h → e = 22,00m
  e/4 = 5,50m
  e/10 =2,20m

površine področij na strehi prizidka:
F: A= 2,2 x 5,5 = 12.10 m^2
G: A= (14,0-2x5,5) x 2.2 = 6.60m^2
H: A= 14,0 x (10,0/2 -2,2) = 39.20m^2
I: A= 14,0x (10,0/2) = 70.00m^2
h_p/h = 0,00 / 8,00 = 0,0

Pritiski na ravno streho :

F: c_{pe} =- 1.8 w_e= 0.380 x (-1,80) = -0,68 kPa
G: c_{pe} =- 2.0+(-1.2-(-2.0))$\log_{10}$ 6.6=-1.34 w_e= 0.380 x (-1.34) = -0,51 kPa
H: c_{pe} =- 0.7 w_e= 0.380 x (-0.70) = -0,27 kPa
I: c_{pe} =$\pm$ 0.2 w_e= 0.380 x (-0.20) = $\pm$0,08 kPa

Smer vetra vzporedno »s slemenom« :

- dolžina objekta b=33.10m
- širina objekta d=14,00m
- višina objekta h=11,00m
- višina atike h_p=0.00m
- e = b oz. 2h → e = 22,00m
  e/4 = 5,50m
  e/10 =2,20m

površine področij na strehi :
F: A= 2.,20 x 5,50 = 12,10 m^2
G: A= (33,10-2x5,50) x 2.20 = 48.62m^2
H: A=33.10 x (14,00/2 -2,2) = 158.88m^2
I: A= 14,00/2x33,10 = 231,70m^2

Pritiski na streho :

F: c_{pe} =-1.8 w_e= 0.380 x (-1,80) = -0.68 kPa

G:	c_{pe} =- 1.2	w_e= 0.380 x (-1.20) = -0,46 kPa
H:	c_{pe} =- 0.7	w_e= 0.380 x (-0.70) = -0,27 kPa
I:	c_{pe} =$\pm$0.2	w_e= 0.380 x (-0.20) = $\pm$0,08 kPa

Pritiski na fasadno steno :

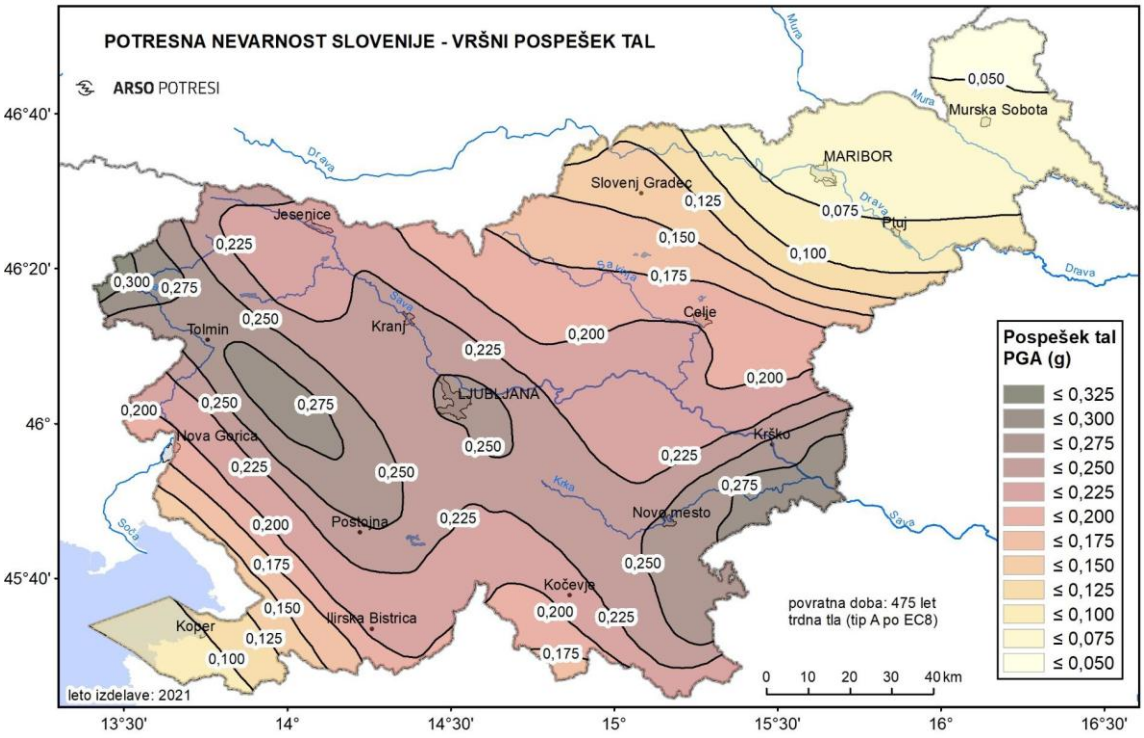
Glede na objekt kot celoto in njegovo tlorisno členjenost privzamem za celotno fasado prizidka :
- za tlake c_{pe} =-1.3
- za sesanje c_{pe} = 1.0

Na bočni fasadi:
w_e= 0.380 x (-1.30) = -0.49 kPa
w_e= 0.380 x (1.00) = 0.38 kPa

Na stekleno fasado :
W_e= 0.380 x (-1.30) x 4,30 /2 = -1,06 kN/m^1
W_e= 0.380 x (1.00) x 4,30 / 2 = 0,82 kN/m^1

2.2.7 Določitev potresne obtežbe po EC8

Določitev potresne obtežbe za analizo objekta je bila izvedena po EC8.
Karta pospeškov:



-Projektni pospešek tal za območje Podčetrtka 0,20 g → a_g=0,2*9,81m/s^2= 1,96m/s^2

Vhodni podatki:
-Tip tal C (glej Geol.-geom. poročilo)

Ground type	S	T_B (s)	T_C (s)	T_D (s)
A	1,0	0,15	0,4	2,0
B	1,2	0,15	0,5	2,0
C	1,15	0,20	0,6	2,0
D	1,35	0,20	0,8	2,0
E	1,4	0,15	0,5	2,0

-Kategorija pomembnosti: III

Importance class	Buildings	Importance factor γ_I (recommended value)
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.	0,8
II	Ordinary buildings, not belonging in the other categories.	1,0
III	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.	1,2
IV	Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.	1,4

-Redukcijski faktor q= 2
Objekt je ena dilatacijska enota.
Potresni vpliv je izračunan s programskim orodjem Axis X6 in upoštevan v dimenzioniranju nosilnih elementov.

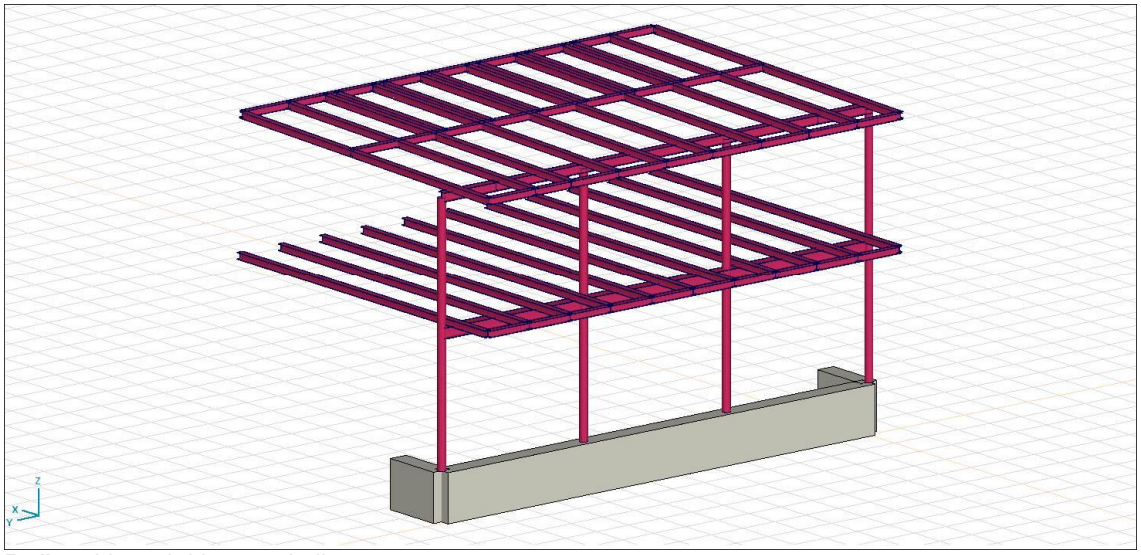
2.2.8 Določitev požarne obtežbe po EC3

V objektu (prizidku) so samostoječi stebri, ki jih ni možno požarno zaščititi oziroma bi bila njihova zaščita izpostavljena mehanskim poškodbam in posledično lahko nefunkcionalna. To so štireje stebri pri vhodu v pritličju in dva stebra v jedilnici.
Iz Načrta požarne varnosti je razvidno, da je potrebna požarna odpornost R60. Zato smo računsko privzeli požarno krivuljo po ISO in sicer za R=60 → T_g=945,34^{0}C; T_{ref} = 20^{0}C; k_{sh} = 1 ter obremenili v sklopu globalne analize prizidka te stebre s privzeto požarno obrermenitvijo.

2.3 Dimenzioniranje

2.3.1 Splošno

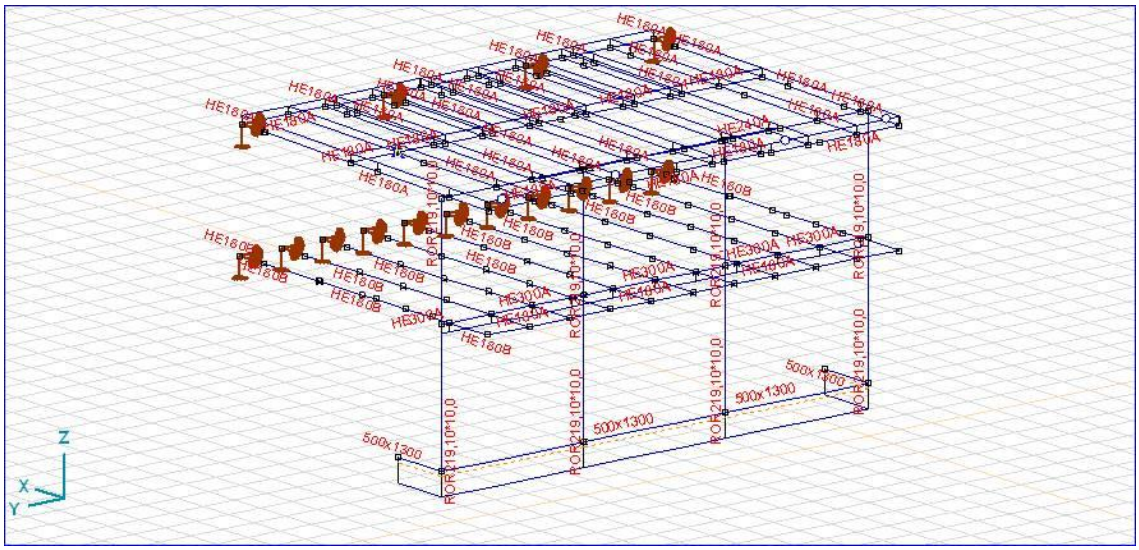
Statična analiza je izvedena po metodi končnih elementov s programsko opremo AxisVM X6. Prikazan je izvleček rezultatov statične analize konstrukcije, rezultati so v celoti arhivirani pri projektantu.



Računski model konstrukcije

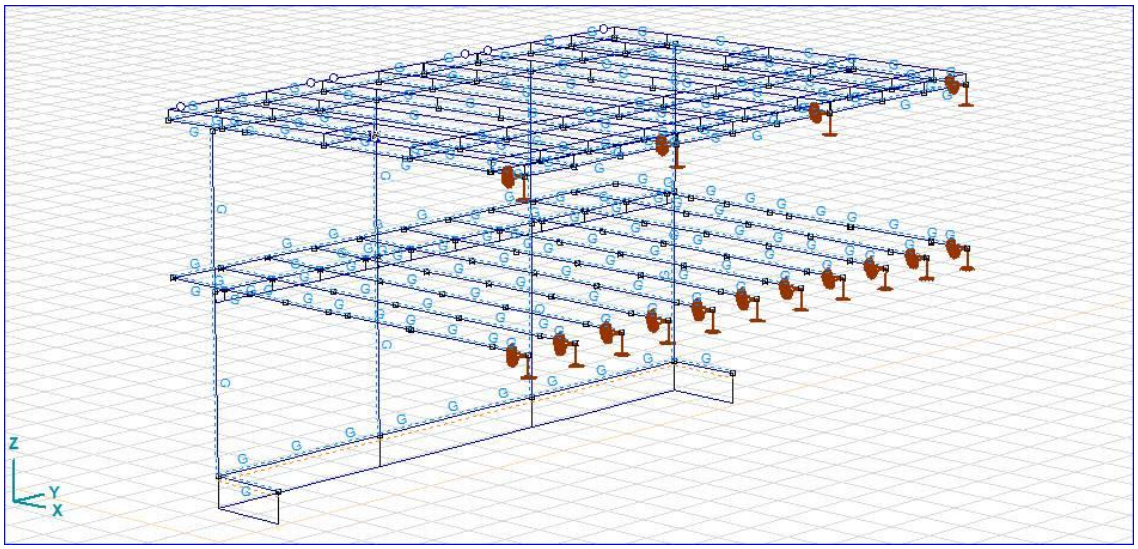
2.3.2 Analiza konstrukcije

- *Računski model*

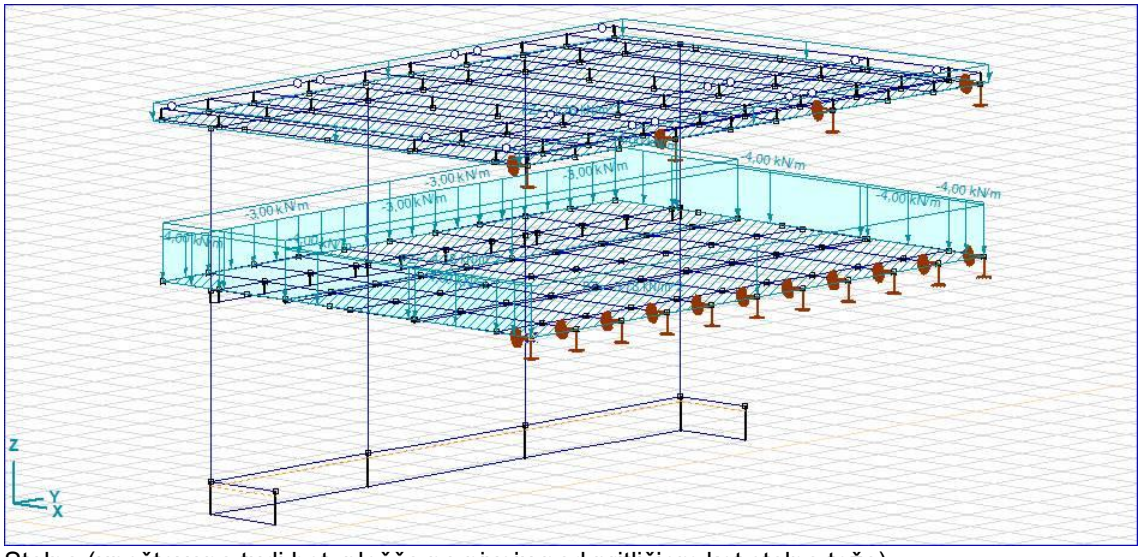


Računski model – dimenzije (tip nosilnih elementov)

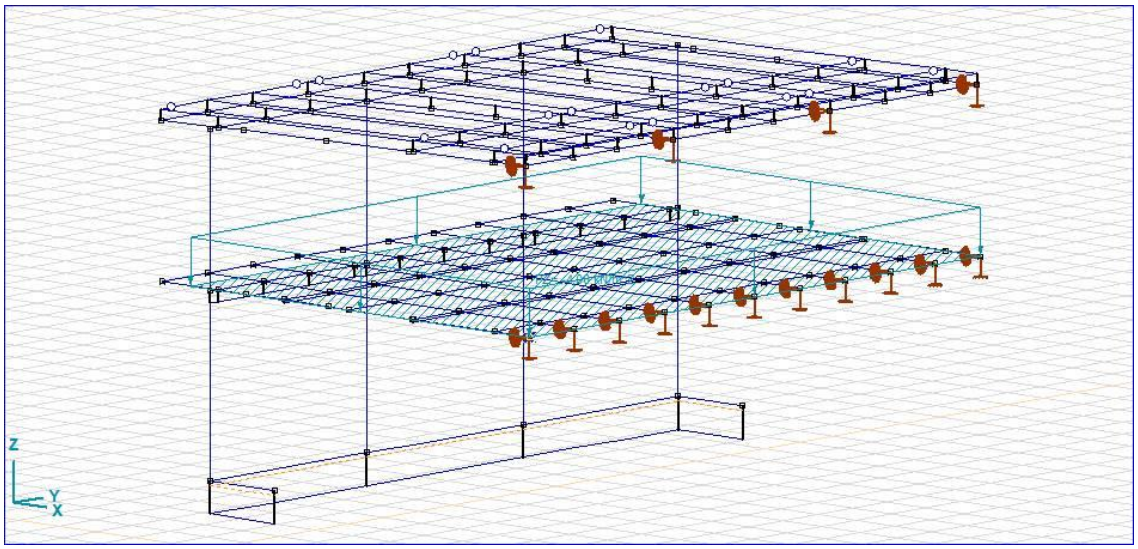
- *Vplivi*



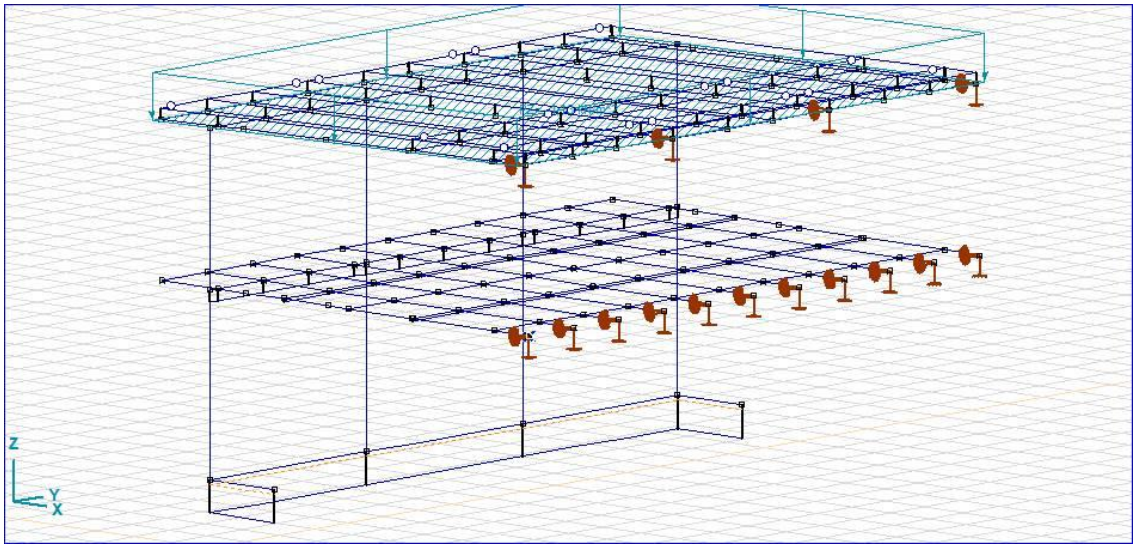
Lastna (upošteva program na osnovi podatkov o materialu)



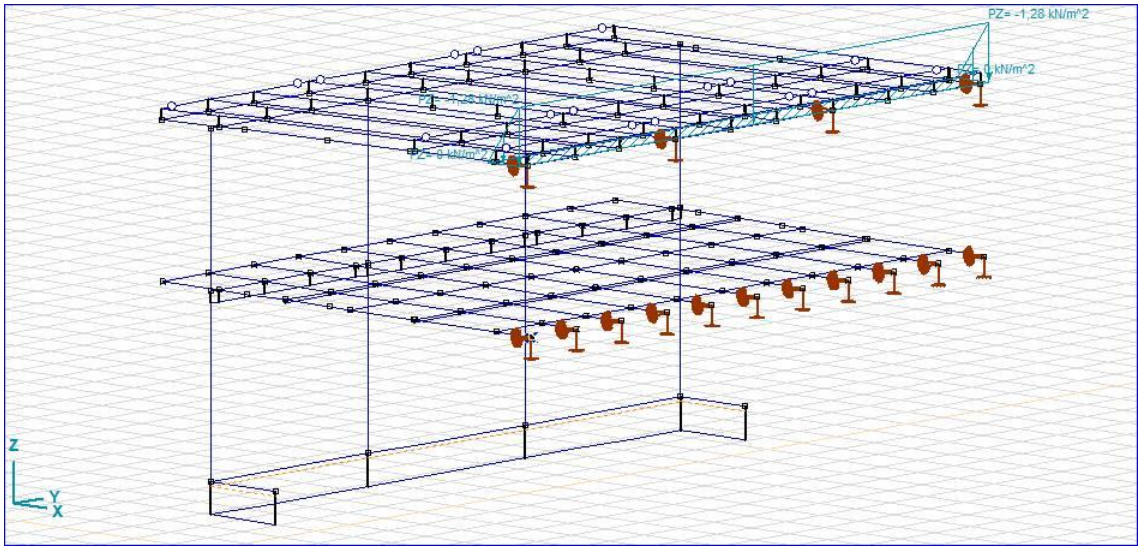
Stalna (upoštevana tudi bet. plošča na nivoju nad pritličjem kot stalna teža)



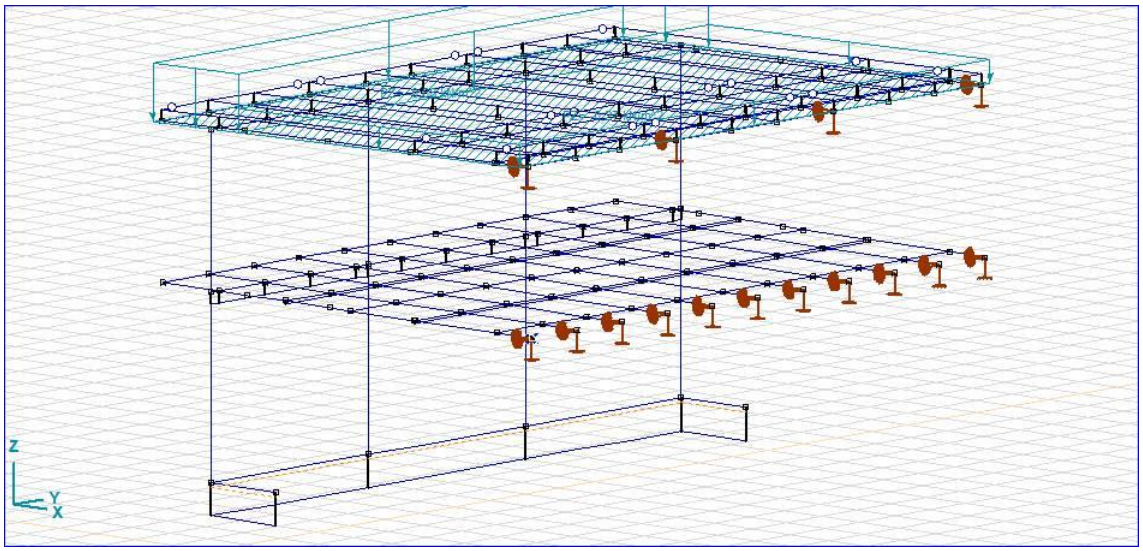
Koristna v etaži



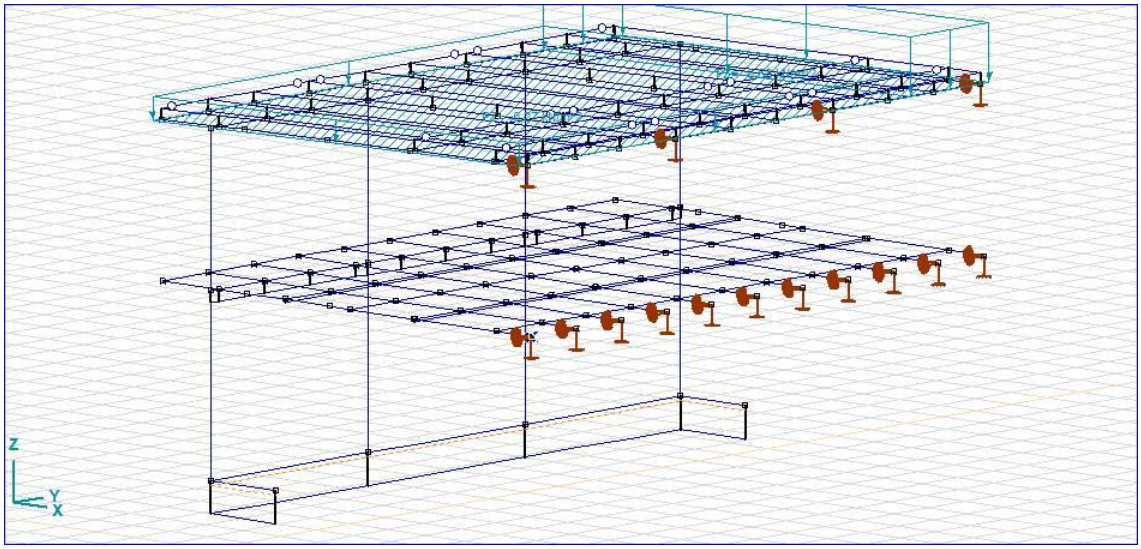
Sneg



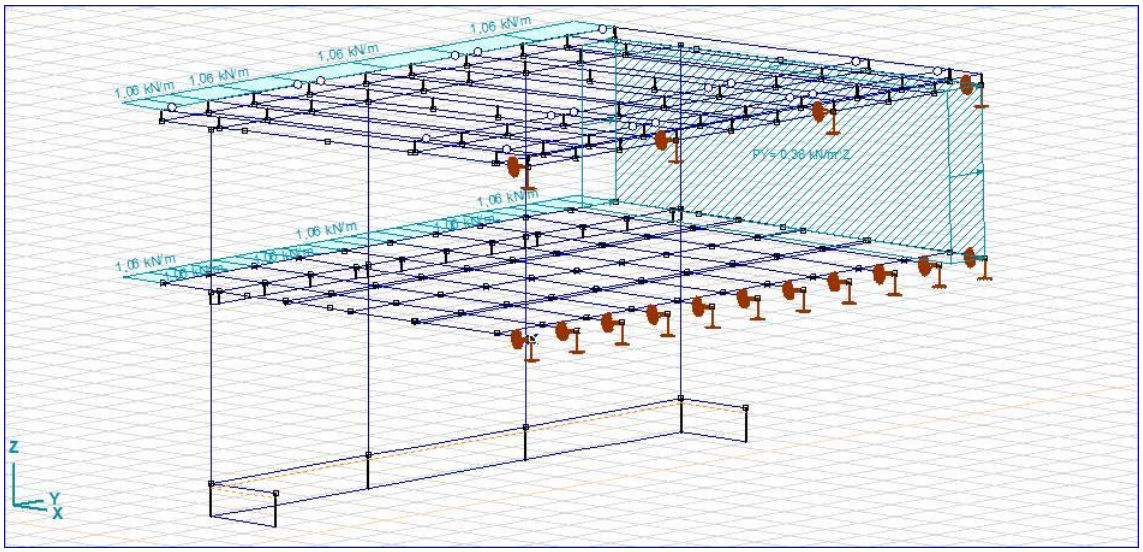
Sneg (zdrs + zamet)



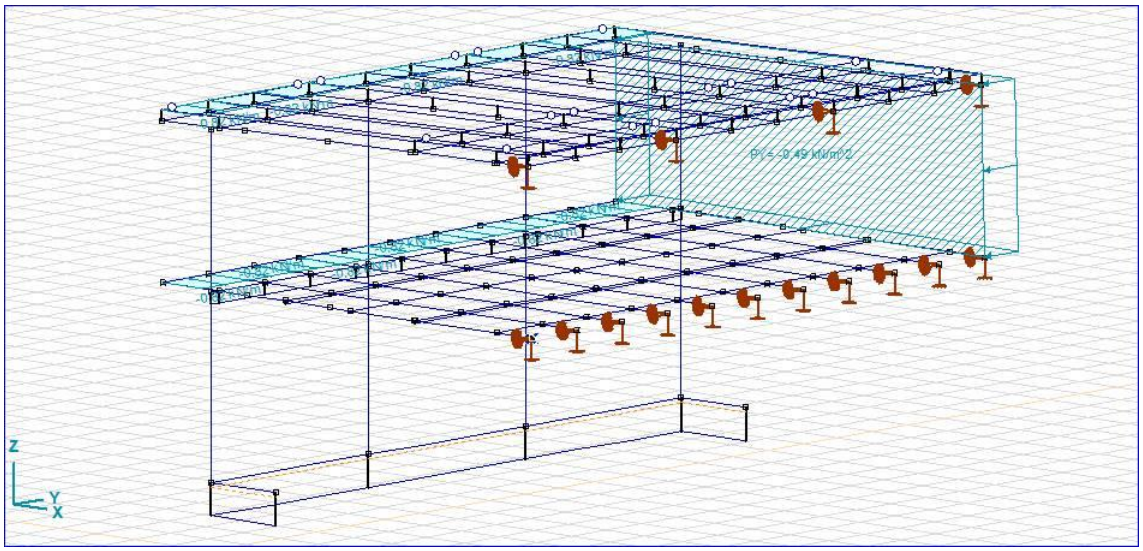
Veter pravokotno na »sleme« - vpliv na streho



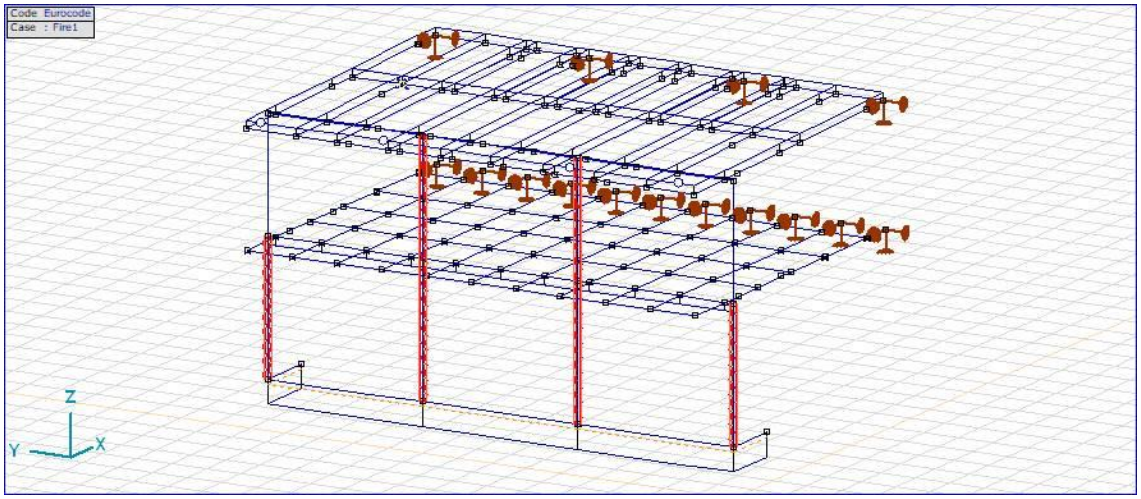
Veter vzporedno na »sleme« - vpliv na streho



Veter vzporedno na »sleme« - vpliv na fasado



Veter pravokotno na »sleme« - vpliv na fasado



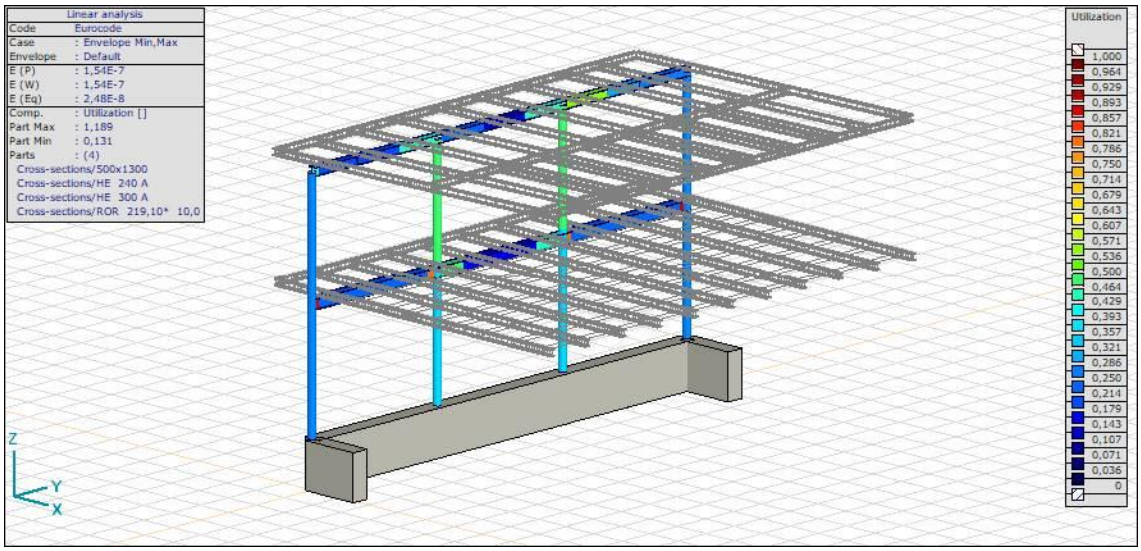
Požar na nezaščitene stebre

- *Obtežne kombinacije*

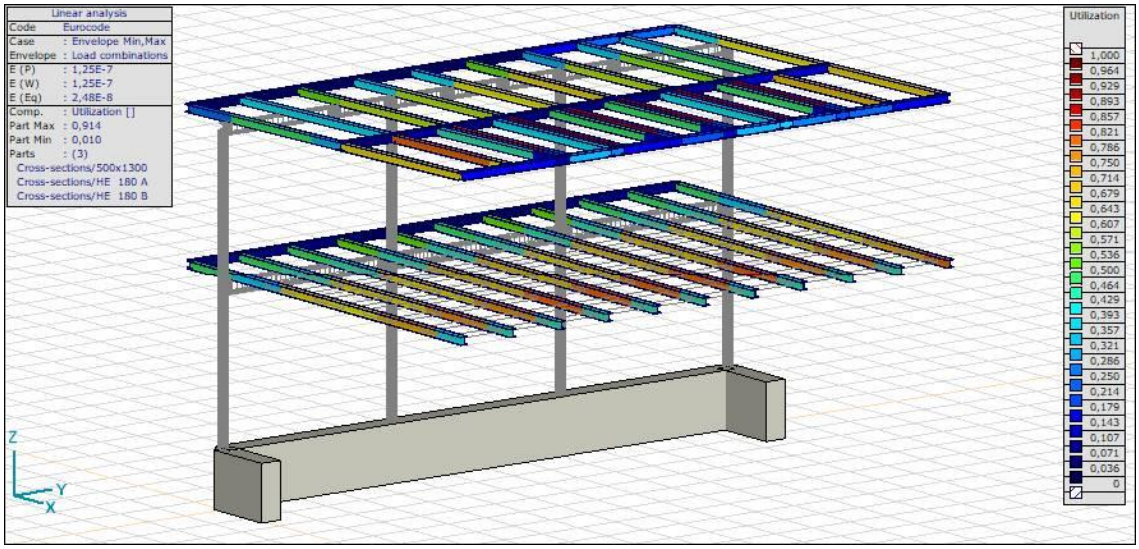
Custom load combinations by load cases

	Type	lastna	stalna	sneg	koristna	sneg_zamet	veter vzpor.	veter prav.	veter fasada 1.smer	veter fasada 2. smer	SM1 X	SM1 Y	SM1 + (SEISMIC1)	SM1 - (SEISMIC1)	Fire1 (FIRE1)
1	ULS	1,35	1,35	1,50	1,50	1,50	1,50	0	1,50	0	0	0	0	0	1,00
2	ULS	1,35	1,35	1,50	1,50	1,50	0	1,50	0	1,50	0	0	0	0	1,00
3	ULS	1,35	1,35	0	1,50	0	1,50	0	1,50	0	0	0	0	0	1,00
4	ULS	1,35	1,35	0	1,50	0	0	1,50	0	1,50	0	0	0	0	1,00
5	ULS	1,35	1,35	1,50	0	1,50	1,50	0	1,50	0	0	0	0	0	1,00
6	ULS	1,35	1,35	1,50	0	1,50	0	1,50	0	1,50	0	0	0	0	1,00
7	ULS	1,35	1,35	0	0	0	1,50	0	1,50	0	0	0	0	0	1,00
8	ULS	1,35	1,35	0	0	0	0	1,50	0	1,50	0	0	0	0	1,00
9	SLS Quasiperm...	1,00	1,00	1,00	1,00	1,00	1,00	0	1,00	0	0	0	0	0	0
10	SLS Quasiperm...	1,00	1,00	1,00	1,00	1,00	0	1,00	0	1,00	0	0	0	0	0
11	SLS Quasiperm...	1,00	1,00	1,00	0,50	1,00	1,00	0	1,00	0	0	0	0	0	0
12	SLS Quasiperm...	1,00	1,00	1,00	0,50	1,00	0	1,00	0	1,00	0	0	0	0	0
13	ULS	1,35	1,35	1,50	0,75	1,50	1,50	0	1,50	0	1,00	0	0	0	1,00
14	ULS	1,35	1,35	1,50	0,75	1,50	0	1,50	0	1,50	0	1,00	0	0	1,00
15	ULS	1,35	1,35	1,50	0,75	1,50	1,50	0	1,50	0	0	0	1,00	0	1,00
16	ULS	1,35	1,35	1,50	0,75	1,50	0	1,50	0	1,50	0	0	0	1,00	1,00
17	SLS Quasiperm...	1,00	1,00	0	0	0	0	0	0	0	0	0	0	0	0

2.3.3 Preveritev dimenzij jeklene konstrukcije



Stebri ; grede HEA 300, HEA 240
Max izkoristek prereza stebra = 47%
Max izkoristek prereza grede HEA300 = 80%
Max izkoristek prereza grede HEA240 =114% (izvedem ojačitev v stiku s stebrom!)



Grede HEA 180; HEB180
Max izkoristek prereza grede HEA180 = 91%; Max izkoristek prereza grede HEB180 = 82%

Opomba:
Računski model: model 22 = model 21 z dodano požarno obremenitvijo nezaščitenih stebrov (pritličje 4x, nadstropje 2x

STEEL MEMBER DESIGN

Design member **3**
Nodes: **13-28**
Code: **Eurocode**
EN 1993-1-1:2005 + AC:2009, EN 1993-1-5:2006
Material: **S 355**
Cross-section: **ROR 219,10* 10,0**
Load case: **Linear, Envelope (Default)**
Coefficient for seismic forces: **1,0**

1. Axial force-Bending-Shear-Torsion (strength interaction):

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm
$N_{Ed_1} = -163$ kN $V_{y,Ed_1} = 40$ kN $V_{z,Ed_1} = 5{,}8$ kN $M_{y,Ed_1} = -835$ kNcm $= -8{,}353$ kNm $M_{z,Ed_1} = 7370$ kNcm $= 73{,}697$ kNm $M_{x,Ed_1} = 62$ kNcm $= 0{,}625$ kNm

$\eta_{NMV_{pl}} = \max\left(\eta_N ; \eta_{M_{y,pl}} ; \eta_{M_{z,pl}} ; \eta_{V_z} ; \eta_{V_y}\right) = \max(7{,}0 ; 5{,}4 ; 47{,}4 ; 0{,}7 ; 4{,}7) = 47{,}4\ \%$ **passed**

2. Axial Force-Bending-Flexural Buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm
$C_{my} = \max(0{,}2 + 0{,}8 \cdot \alpha_{my}, 0{,}4) = \max(0{,}2 + 0{,}8 \cdot 0{,}01, 0{,}4) = 0{,}4 \geq 0{,}4$ Table B.3
$C_{mz} = \max(0{,}2 + 0{,}8 \cdot \alpha_{mz}, 0{,}4) = \max(0{,}2 + 0{,}8 \cdot 0{,}142, 0{,}4) = 0{,}4 \geq 0{,}4$ Table B.3
$f_{yy} = \min(\lambda_y{}^* - 0{,}2 ; 0{,}8) = \min(0{,}57 - 0{,}2 ; 0{,}8) = 0{,}369$
$f_{zz} = \max(\min(\lambda_z{}^* - 0{,}2 ; 0{,}8) ; 0) = \max(\min(0{,}57 - 0{,}2 ; 0{,}8) ; 0) = 0{,}369$

$$k_{yy} = C_{my} \cdot \left(1 + f_{yy} \cdot \frac{|N_{Ed_1}|}{\frac{\chi_y \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}4 \cdot \left(1 + 0{,}369 \cdot \frac{|(-171)|}{\frac{0{,}90 \cdot 2332}{1}}\right) = 0{,}412$$

$k_{zy} = 0{,}6 \cdot k_{yy} = 0{,}6 \cdot 0{,}412 = 0{,}247$
$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 0{,}412 = 0{,}247$

$$k_{zz} = C_{mz} \cdot \left(1 + f_{zz} \cdot \frac{|N_{Ed_1}|}{\frac{\chi_z \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}4 \cdot \left(1 + 0{,}369 \cdot \frac{|(-171)|}{\frac{0{,}90 \cdot 2332}{1}}\right) = 0{,}412$$

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{}^{*2}}} ; 1\right) = 0{,}90 \quad (6.49)$$

$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{}^{*2}}} ; 1\right) = 0{,}90 \quad (6.49)$$

$$\eta_{NMBuckl_1} = \frac{\left|N_{Ed_1}\right|}{\frac{\chi_y \cdot A \cdot f_y}{\gamma_{M1}}} + k_{yy} \cdot \frac{\left|M_{y,Ed_1}\right|}{\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}}} + k_{yz} \cdot \frac{\left|M_{z,Ed_1}\right|}{\frac{W_{pl,z} \cdot f_y}{\gamma_{M1}}} = \frac{|(-171)|}{\frac{0{,}90 \cdot 66 \cdot 36}{1}} + 0{,}412 \cdot \frac{|(-921)|}{\frac{438 \cdot 36}{1}} + 0{,}247 \cdot \frac{|7370|}{\frac{438 \cdot 36}{1}} = 22{,}3\ \% \quad (6.61)$$

$$\eta_{NMBuckl_2} = \frac{\left|N_{Ed_1}\right|}{\frac{\chi_z \cdot A \cdot f_y}{\gamma_{M1}}} + k_{zy} \cdot \frac{\left|M_{y,Ed_1}\right|}{\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}}} + k_{zz} \cdot \frac{\left|M_{z,Ed_1}\right|}{\frac{W_{pl,z} \cdot f_y}{\gamma_{M1}}} = \frac{|(-171)|}{\frac{0{,}90 \cdot 66 \cdot 36}{1}} + 0{,}247 \cdot \frac{|(-921)|}{\frac{438 \cdot 36}{1}} + 0{,}412 \cdot \frac{|7370|}{\frac{438 \cdot 36}{1}} = 29{,}2\ \% \quad (6.62)$$

$\eta_{NMBuckl} = 29{,}2\ \%$ **passed**

3. Axial force-Bending-Lateral torsional buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2

Disabled

4. Shear(y)-Torsion (strength check):

EN 1993-1-1: 6.2.6, 6.2.7

Critical combination: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm

$$A_{V,y} = \frac{2 \cdot A}{\pi} = 42\ \text{cm}^2$$

$$V_{pl,Rd,y} = \frac{A_{V,y} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{42 \cdot 36}{\sqrt{3} \cdot 1} = 857\ \text{kN} \quad (6.18)$$

$M_{x,Ed_1} = 62$ kNcm

$$V_{pl,T,Rd,y} = \left(1 - \frac{\tau_{T,xy_{Ed}}}{\frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}\right) \cdot V_{pl,Rd,y} = \left(1 - \frac{0{,}1}{\frac{36}{\sqrt{3} \cdot 1}}\right) \cdot 857 = 853\ \text{kN} \quad (6.28)$$

$$\eta_{V_y} = \frac{\left|V_{y,Ed_1}\right|}{V_{pl,T,Rd,y}} = \frac{|40|}{853} = 4{,}7\ \% \quad (6.17) \qquad \textbf{passed}$$

5. Shear web buckling resistance:

EN 1993-1-5: 5.1, 5.2, 5.3, 5.5, Annex A: A.3

Critical combination: **Co #5**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm

User setting: No need to check shear web buckling. →

$$A_{V,z} = \frac{2 \cdot A}{\pi} = 42\ \text{cm}^2$$

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{42 \cdot 36}{\sqrt{3} \cdot 1} = 857\ \text{kN} \quad (6.18)$$

$M_{x,Ed_1} = -5{,}3$ kNcm

$$V_{pl,T,Rd,z} = \left(1 - \frac{\tau_{T,xz_{Ed}}}{\frac{f_y}{\sqrt{3}\cdot\gamma_{M0}}}\right)\cdot V_{pl,Rd,z} = \left(1 - \frac{0{,}0085}{\frac{36}{\sqrt{3}\cdot 1}}\right)\cdot 857 = 857 \text{ kN} \quad (6.28)$$

$$\eta_{V_z} = \frac{\left|V_{z,Ed_1}\right|}{V_{pl,T,Rd,z}} = \frac{|6{,}1|}{857} = 0{,}7\ \% \quad (6.17) \qquad \textbf{passed}$$

6. Web shear-Bending-Axial force

EN 1993-1-1: 6.2.9; EN 1993-1-5: 7.1

Disabled

7. SLS (Serviceability Limit State)

EN 1993-1-1: 7., EN 1990: 3.4, A1.4.

Critical combination: **Co #11**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm

$w_x = |w_{x,i} - w_{x,0}| = |(-0{,}55) - (-0{,}39)| = 0{,}16$ cm

$$w_{x,Limit} = \frac{H_{SLS}}{300{,}0} = \frac{322}{300{,}0} = 1{,}1 \text{ cm}$$

$$\eta_{w_x} = \frac{w_x}{w_{x,Limit}} = \frac{0{,}16}{1{,}1} = 14{,}8\ \%$$

$w_y = |w_{y,i} - w_{y,0}| = |(-0{,}096) - (-0{,}036)| = 0{,}06$ cm

$$w_{y,Limit} = \frac{H_{SLS}}{300{,}0} = \frac{322}{300{,}0} = 1{,}1 \text{ cm}$$

$$\eta_{w_y} = \frac{w_y}{w_{y,Limit}} = \frac{0{,}06}{1{,}1} = 5{,}6\ \%$$

$\eta_{SLS} = \max\left(\eta_{w_x}; \eta_{w_y}\right) = \max(14{,}8; 5{,}6) = 14{,}8\ \%$ **passed**

Partial results

8. Cross-section resistance to axial force:

EN 1993-1-1: 6.2.4

Critical combination: **Co #16**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 322 = 322$ cm

$$N_{pl,Rd} = \frac{A\cdot f_y}{\gamma_{M0}} = \frac{66\cdot 36}{1} = 2332 \text{ kN} \quad (6.10)$$

$$\eta_N = \frac{\left|N_{Ed_{11}}\right|}{N_{pl,Rd}} = \frac{|(-177)|}{2332} = 7{,}6\ \% \quad (6.9) \qquad \textbf{passed}$$

9. Cross-section resistance to bending (yy):

EN 1993-1-1: 6.2.5

Critical combination: **Co #5**

Section class: **1** (Plastic design)
Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 322 = 322$ cm

$$M_{pl,Rd,y} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{438 \cdot 36}{1} = 1{,}5533 \cdot 10^4 \text{ kNcm} = 155{,}334 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{y,pl}} = \frac{|M_{y,Ed_{11}}|}{M_{pl,Rd,y}} = \frac{|1059|}{1{,}5533 \cdot 10^4} = 6{,}8\ \% \quad (6.12) \qquad \textbf{passed}$$

10. Cross-section resistance to bending (zz):

EN 1993-1-1: 6.2.5
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm

$$M_{pl,Rd,z} = \frac{W_{pl,z} \cdot f_y}{\gamma_{M0}} = \frac{438 \cdot 36}{1} = 1{,}5533 \cdot 10^4 \text{ kNcm} = 155{,}334 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{z,pl}} = \frac{|M_{z,Ed_1}|}{M_{pl,Rd,z}} = \frac{|7370|}{1{,}5533 \cdot 10^4} = 47{,}4\ \% \quad (6.12) \qquad \textbf{passed}$$

11. Cross-section resistance to shear (z):

EN 1993-1-1: 6.2.6, 6.2.7
Critical combination: **Co #5**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm

$$A_{V,z} = \frac{2 \cdot A}{\pi} = 42 \text{ cm}^2$$

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{42 \cdot 36}{\sqrt{3} \cdot 1} = 857 \text{ kN} \quad (6.18)$$

$$M_{x,Ed_1} = -5{,}3 \text{ kNcm}$$

$$V_{pl,T,Rd,z} = \left(1 - \frac{\tau_{T,xz_{Ed}}}{\frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}\right) \cdot V_{pl,Rd,z} = \left(1 - \frac{0{,}0085}{\frac{36}{\sqrt{3} \cdot 1}}\right) \cdot 857 = 857 \text{ kN} \quad (6.28)$$

$$\eta_{V_z} = \frac{|V_{z,Ed_1}|}{V_{pl,T,Rd,z}} = \frac{|6{,}1|}{857} = 0{,}7\ \% \quad (6.17) \qquad \textbf{passed}$$

12. Bending-shear interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9
Critical combination for N-M-V strength interaction: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm

$V_{z,Ed_1} = 5{,}8 \text{ kN} \leq V_{pl,T,Rd,z}/2 = 426 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

$V_{y,Ed_1} = 40 \text{ kN} \leq V_{pl,T,Rd,y}/2 = 426 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

13. Bending-axial force interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm

$$n = \frac{\left|N_{Ed_1}\right|}{N_{pl,Rd}} = \frac{163}{2332} = 0{,}07 = 7{,}01\% \le 25\%$$

$M_{N,y,Rd} = M_{y,V,Rd} = 1{,}5533 \cdot 10^4$ kNcm $= 155{,}334$ kNm ENV 1993-1-1:1992 (10) (5.34)

$M_{N,z,Rd} = M_{z,V,Rd} = 1{,}5533 \cdot 10^4$ kNcm $= 155{,}334$ kNm ENV 1993-1-1:1992 (10) (5.34)

$$\eta_{MN,1} = \frac{M_{y,Ed_1}}{M_{N,y,Rd}} = \frac{(-835)}{1{,}5533 \cdot 10^4} = 5{,}4\ \%$$

$$\eta_{MN,2} = \frac{M_{z,Ed_1}}{M_{N,z,Rd}} = \frac{7370}{1{,}5533 \cdot 10^4} = 47{,}4\ \%$$

$\alpha_{MN} = 2$

$\beta_{MN} = 2$

$$\eta_{MN,3} = \left(\frac{M_{y,Ed_1}}{M_{N,y,Rd}}\right)^{\alpha_{MN}} + \left(\frac{M_{z,Ed_1}}{M_{N,z,Rd}}\right)^{\beta_{MN}} = \left(\frac{(-835)}{1{,}5533 \cdot 10^4}\right)^2 + \left(\frac{7370}{1{,}5533 \cdot 10^4}\right)^2 = 22{,}8\ \% \quad (6.41)$$

$\eta_{MN} = \max(\eta_{MN,1}; \eta_{MN,2}; \eta_{MN,3}; \eta_N) = \max(5{,}4; 47{,}4; 22{,}8; 7{,}0) = 47{,}4\ \%$ **passed**

14. Buckling resistance:

EN 1993-1-1: 6.3.1

Critical combination for N-M-Buckling interaction: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 322 = 0$ cm

$K_y = 1$

$K_z = 1$

$L_{cr_y} = K_y \cdot L = 1 \cdot 322 = 322$ cm

$L_{cr_z} = K_z \cdot L = 1 \cdot 322 = 322$ cm

Buckling curve about the y axis: *a* Table 6.2

$\rightarrow \alpha_y = 0{,}21$ Table 6.1

Buckling curve about the z axis: *a* Table 6.2

$\rightarrow \alpha_z = 0{,}21$ Table 6.1

$$\lambda_y{}^* = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{66 \cdot 36}{7207}} = 0{,}57 \quad (6.50)$$

$$\lambda_z{}^* = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{66 \cdot 36}{7207}} = 0{,}57 \quad (6.50)$$

$$\phi_y = \frac{1 + \alpha_y \cdot (\lambda_y{}^* - 0{,}2) + \lambda_y{}^{*2}}{2} = \frac{1 + 0{,}21 \cdot (0{,}57 - 0{,}2) + 0{,}57^2}{2} = 0{,}7005$$

$$\phi_z = \frac{1 + \alpha_z \cdot (\lambda_z{}^* - 0{,}2) + \lambda_z{}^{*2}}{2} = \frac{1 + 0{,}21 \cdot (0{,}57 - 0{,}2) + 0{,}57^2}{2} = 0{,}7005$$

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{}^{*2}}}\,;1\right) = \min\left(\frac{1}{0{,}7005 + \sqrt{0{,}7005^2 - 0{,}57^2}}\,;1\right) = 0{,}90 \quad (6.49)$$

$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{}^{*2}}}\,;1\right) = \min\left(\frac{1}{0{,}7005 + \sqrt{0{,}7005^2 - 0{,}57^2}}\,;1\right) = 0{,}90 \quad (6.49)$$

$\chi_{TF} = 1$ (6.52, 6.49)

$\chi = \min(\chi_y\,;\chi_z\,;\chi_{TF}) = \min(0{,}90\,;0{,}90\,;1) = 0{,}90 \le 1{,}0$

$$N_{b,Rd} = \frac{\chi \cdot A \cdot f_y}{\gamma_{M1}} = \frac{0{,}90 \cdot 66 \cdot 36}{1} = 2102 \text{ kN} \quad (6.47)$$

$$\eta_{N_b} = \frac{|N_{Ed_1}|}{N_{b,Rd}} = \frac{|(-171)|}{2102} = 8{,}1\ \% \quad (6.46) \qquad \textbf{passed}$$

15. Lateral-torsional buckling resistance:

EN 1993-1-1: 6.3.2

Disabled

STEEL MEMBER DESIGN

Design member **50**
Nodes: **12-28**
Code: **Eurocode**
EN 1993-1-1:2005 + AC:2009, EN 1993-1-5:2006
Material: **S 355**
Cross-section: **ROR 219,10* 10,0**
Load case: **Linear, Envelope (Default)**
Coefficient for seismic forces: **1,0**

1. Axial force-Bending-Shear-Torsion (strength interaction):

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9
Critical combination: **Co #2**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm
$N_{Ed_1} = -518$ kN $V_{y,Ed_1} = -1{,}1$ kN $V_{z,Ed_1} = 5{,}2$ kN $M_{y,Ed_1} = -2081$ kNcm $= -20{,}812$ kNm $M_{z,Ed_1} = -266$ kNcm $=$
$= -2{,}655$ kNm $M_{x,Ed_1} = -13$ kNcm $= -0{,}134$ kNm

$\eta_{NMV_{pl}} = \max\left(\eta_N ; \eta_{M_{y,pl}} ; \eta_{M_{z,pl}} ; \eta_{V_z} ; \eta_{V_y}\right) = \max\,(22{,}2 ; 13{,}4 ; 1{,}7 ; 0{,}6 ; 0{,}1) = 22{,}2\ \%$ **passed**

2. Axial Force-Bending-Flexural Buckling

EN 1993-1-1: 6.3.3. Annex B: Method 2
Critical combination: **Co #16**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm
$C_{my} = \max\,(0{,}2 + 0{,}8 \cdot \alpha_{my}, 0{,}4) = \max\,(0{,}2 + 0{,}8 \cdot 0{,}427, 0{,}4) = 0{,}542 \geq 0{,}4$ Table B.3
$C_{mz} = \max\,(0{,}2 + 0{,}8 \cdot \alpha_{mz}, 0{,}4) = \max\,(0{,}2 + 0{,}8 \cdot 0{,}043, 0{,}4) = 0{,}4 \geq 0{,}4$ Table B.3
$f_{yy} = \min\,(\lambda_y{}^* - 0{,}2 ; 0{,}8) = \min\,(0{,}66 - 0{,}2 ; 0{,}8) = 0{,}462$
$f_{zz} = \max\,(\min\,(\lambda_z{}^* - 0{,}2 ; 0{,}8) ; 0) = \max\,(\min\,(0{,}66 - 0{,}2 ; 0{,}8) ; 0) = 0{,}462$

$$k_{yy} = C_{my} \cdot \left(1 + f_{yy} \cdot \frac{|N_{Ed_1}|}{\frac{\chi_y \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}542 \cdot \left(1 + 0{,}462 \cdot \frac{|(-456)|}{\frac{0{,}86 \cdot 2332}{1}}\right) = 0{,}598$$

$k_{zy} = 0{,}6 \cdot k_{yy} = 0{,}6 \cdot 0{,}598 = 0{,}359$
$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 0{,}442 = 0{,}265$

$$k_{zz} = C_{mz} \cdot \left(1 + f_{zz} \cdot \frac{|N_{Ed_1}|}{\frac{\chi_z \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}4 \cdot \left(1 + 0{,}462 \cdot \frac{|(-456)|}{\frac{0{,}86 \cdot 2332}{1}}\right) = 0{,}442$$

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{}^{*2}}} ; 1\right) = 0{,}86 \quad (6.49)$$

$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{}^{*2}}} ; 1\right) = 0{,}86 \quad (6.49)$$

$$\eta_{NMBuckl_1} = \frac{\left|N_{Ed_1}\right|}{\frac{\chi_y \cdot A \cdot f_y}{\gamma_{M1}}} + k_{yy} \cdot \frac{\left|M_{y,Ed_1}\right|}{\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}}} + k_{yz} \cdot \frac{\left|M_{z,Ed_1}\right|}{\frac{W_{pl,z} \cdot f_y}{\gamma_{M1}}} = \frac{|(-456)|}{\frac{0{,}86 \cdot 66 \cdot 36}{1}} + 0{,}598 \cdot \frac{|(-1992)|}{\frac{438 \cdot 36}{1}} + 0{,}265 \cdot \frac{|(-2950)|}{\frac{438 \cdot 36}{1}} = 35{,}3\ \%$$

(6.61)

$$\eta_{NMBuckl_2} = \frac{\left|N_{Ed_1}\right|}{\frac{\chi_z \cdot A \cdot f_y}{\gamma_{M1}}} + k_{zy} \cdot \frac{\left|M_{y,Ed_1}\right|}{\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}}} + k_{zz} \cdot \frac{\left|M_{z,Ed_1}\right|}{\frac{W_{pl,z} \cdot f_y}{\gamma_{M1}}} = \frac{|(-456)|}{\frac{0{,}86 \cdot 66 \cdot 36}{1}} + 0{,}359 \cdot \frac{|(-1992)|}{\frac{438 \cdot 36}{1}} + 0{,}442 \cdot \frac{|(-2950)|}{\frac{438 \cdot 36}{1}} = 35{,}6\ \%$$

(6.62)

$\eta_{NMBuckl} = 35{,}6\ \%$ **passed**

3. Axial force-Bending-Lateral torsional buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2

Disabled

4. Cross-section resistance to shear (y):

EN 1993-1-1: 6.2.6, 6.2.7

Critical combination: **Co #16**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm

$$A_{V,y} = \frac{2 \cdot A}{\pi} = 42\ \text{cm}^2$$

$$V_{pl,Rd,y} = \frac{A_{V,y} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{42 \cdot 36}{\sqrt{3} \cdot 1} = 857\ \text{kN} \quad (6.18)$$

$M_{x,Ed_1} = -4{,}6$ kNcm

$$V_{pl,T,Rd,y} = \left(1 - \frac{\tau_{T,xy_{Ed}}}{\frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}\right) \cdot V_{pl,Rd,y} = \left(1 - \frac{0{,}0074}{\frac{36}{\sqrt{3} \cdot 1}}\right) \cdot 857 = 857\ \text{kN} \quad (6.28)$$

$$\eta_{V_y} = \frac{\left|V_{y,Ed_1}\right|}{V_{pl,T,Rd,y}} = \frac{|(-15)|}{857} = 1{,}8\ \% \quad (6.17) \qquad \textbf{passed}$$

5. Shear web buckling resistance:

EN 1993-1-5: 5.1, 5.2, 5.3, 5.5, Annex A: A.3

Critical combination: **Co #5**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm

User setting: No need to check shear web buckling. →

$$A_{V,z} = \frac{2 \cdot A}{\pi} = 42\ \text{cm}^2$$

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{42 \cdot 36}{\sqrt{3} \cdot 1} = 857\ \text{kN} \quad (6.18)$$

$M_{x,Ed_1} = 5{,}6$ kNcm

$$V_{pl,T,Rd,z} = \left(1 - \frac{\tau_{T,xz_{Ed}}}{\frac{f_y}{\sqrt{3}\cdot\gamma_{M0}}}\right)\cdot V_{pl,Rd,z} = \left(1 - \frac{0{,}0089}{\frac{36}{\sqrt{3}\cdot 1}}\right)\cdot 857 = 857 \text{ kN} \quad (6.28)$$

$$\eta_{V_z} = \frac{\left|V_{z,Ed_1}\right|}{V_{pl,T,Rd,z}} = \frac{|7{,}1|}{857} = 0{,}8\ \% \quad (6.17) \qquad \textbf{passed}$$

6. Web shear-Bending-Axial force

EN 1993-1-1: 6.2.9; EN 1993-1-5: 7.1

Disabled

7. SLS (Serviceability Limit State)

EN 1993-1-1: 7., EN 1990: 3.4, A1.4.

Critical combination: **Co #10**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}700\cdot L = 0{,}700\cdot 375 = 262$ cm

$w_x = |w_{x,i} - w_{x,0}| = |(-0{,}58) - (-0{,}22)| = 0{,}36$ cm

$$w_{x,Limit} = \frac{H_{SLS}}{300{,}0} = \frac{375}{300{,}0} = 1{,}2 \text{ cm}$$

$$\eta_{w_x} = \frac{w_x}{w_{x,Limit}} = \frac{0{,}36}{1{,}2} = 28{,}7\ \%$$

$w_y = |w_{y,i} - w_{y,0}| = |(-0{,}016) - 0{,}0028| = 0{,}019$ cm

$$w_{y,Limit} = \frac{H_{SLS}}{300{,}0} = \frac{375}{300{,}0} = 1{,}2 \text{ cm}$$

$$\eta_{w_y} = \frac{w_y}{w_{y,Limit}} = \frac{0{,}019}{1{,}2} = 1{,}5\ \%$$

$\eta_{SLS} = \max\left(\eta_{w_x}; \eta_{w_y}\right) = \max(28{,}7; 1{,}5) = 28{,}7\ \%$ **passed**

Partial results

8. Cross-section resistance to axial force:

EN 1993-1-1: 6.2.4

Critical combination: **Co #2**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000\cdot L = 0{,}000\cdot 375 = 0$ cm

$$N_{pl,Rd} = \frac{A\cdot f_y}{\gamma_{M0}} = \frac{66\cdot 36}{1} = 2332 \text{ kN} \quad (6.10)$$

$$\eta_N = \frac{\left|N_{Ed_1}\right|}{N_{pl,Rd}} = \quad ?2{,}2\ \% \quad (6.9) \qquad \textbf{passed}$$

9. Cross-se nce to bending (yy):

EN 1993-1-1: 6.2.5

Critical combi

Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm

$$M_{pl,Rd,y} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{438 \cdot 36}{1} = 1{,}5533 \cdot 10^4 \text{ kNcm} = 155{,}334 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{y,pl}} = \frac{|M_{y,Ed_1}|}{M_{pl,Rd,y}} = \frac{|(-2081)|}{1{,}5533 \cdot 10^4} = 13{,}4\ \% \quad (6.12) \qquad \textbf{passed}$$

10. Cross-section resistance to bending (zz):

EN 1993-1-1: 6.2.5
Critical combination: **Co #16**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm

$$M_{pl,Rd,z} = \frac{W_{pl,z} \cdot f_y}{\gamma_{M0}} = \frac{438 \cdot 36}{1} = 1{,}5533 \cdot 10^4 \text{ kNcm} = 155{,}334 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{z,pl}} = \frac{|M_{z,Ed_1}|}{M_{pl,Rd,z}} = \frac{|(-2950)|}{1{,}5533 \cdot 10^4} = 19{,}0\ \% \quad (6.12) \qquad \textbf{passed}$$

11. Cross-section resistance to shear (z):

EN 1993-1-1: 6.2.6, 6.2.7
Critical combination: **Co #5**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm

$$A_{V,z} = \frac{2 \cdot A}{\pi} = 42 \text{ cm}^2$$

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \qquad = 857 \text{ kN} \quad (6.18)$$

$$M_{x,Ed_1} = 5{,}6 \text{ kNcm}$$

$$V_{pl,T,Rd,z} = \left(1 - \frac{\tau_{T,xz_{Ed}}}{\frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}\right) \cdot V_{pl,Rd,z} = \left(1 - \frac{0{,}0089}{\frac{36}{\sqrt{3} \cdot 1}}\right) \cdot 857 = 857 \text{ kN} \quad (6.28)$$

$$\eta_{V_z} = \frac{|V_{z,Ed_1}|}{V_{pl,T,Rd,z}} = \frac{|7{,}1|}{857} = 0{,}8\ \% \quad (6.17) \qquad \textbf{passed}$$

12. Bending-shear interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9
Critical combination for N-M-V strength interaction: **Co #2**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm

$V_{z,Ed_1} = 5{,}2 \text{ kN} \leq V_{pl,T,Rd,z}/2 = 428 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

$V_{y,Ed_1} = -1{,}1 \text{ kN} \leq V_{pl,T,Rd,y}/2 = 428 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

13. Bending-axial force interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #2**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm

$$n = \frac{\left|N_{Ed_1}\right|}{N_{pl,Rd}} = \frac{518}{2332} = 0{,}22 = 22{,}23\% \leq 25\%$$

$M_{N,y,Rd} = M_{y,V,Rd} = 1{,}5533 \cdot 10^4$ kNcm $= 155{,}334$ kNm ENV 1993-1-1:1992 (10) (5.34)

$M_{N,z,Rd} = M_{z,V,Rd} = 1{,}5533 \cdot 10^4$ kNcm $= 155{,}334$ kNm ENV 1993-1-1:1992 (10) (5.34)

$$\eta_{MN,1} = \frac{M_{y,Ed_1}}{M_{N,y,Rd}} = \frac{(-2081)}{1{,}5533 \cdot 10^4} = 13{,}4\ \%$$

$$\eta_{MN,2} = \frac{M_{z,Ed_1}}{M_{N,z,Rd}} = \frac{(-266)}{1{,}5533 \cdot 10^4} = 1{,}7\ \%$$

$\alpha_{MN} = 2$

$\beta_{MN} = 2$

$$\eta_{MN,3} = \left(\frac{M_{y,Ed_1}}{M_{N,y,Rd}}\right)^{\alpha_{MN}} + \left(\frac{M_{z,Ed_1}}{M_{N,z,Rd}}\right)^{\beta_{MN}} = \left(\frac{(-2081)}{1{,}5533 \cdot 10^4}\right)^2 + \left(\frac{(-266)}{1{,}5533 \cdot 10^4}\right)^2 = 1{,}8\ \%$$ (6.41)

$\eta_{MN} = \max(\eta_{MN,1}; \eta_{MN,2}; \eta_{MN,3}; \eta_N) = \max(13{,}4; 1{,}7; 1{,}8; 22{,}2) = 22{,}2\ \%$ **passed**

14. Buckling resistance:

EN 1993-1-1: 6.3.1

Critical combination for N-M-Buckling interaction: **Co #16**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 375 = 0$ cm

$K_y = 1$

$K_z = 1$

$L_{cr_y} = K_y \cdot L = 1 \cdot 375 = 375$ cm

$L_{cr_z} = K_z \cdot L = 1 \cdot 375 = 375$ cm

Buckling curve about the y axis: *a* Table 6.2

$\rightarrow \alpha_y = 0{,}21$ Table 6.1

Buckling curve about the z axis: *a* Table 6.2

$\rightarrow \alpha_z = 0{,}21$ Table 6.1

$$\lambda_y{}^* = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{66 \cdot 36}{5316}} = 0{,}66$$ (6.50)

$$\lambda_z{}^* = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{66 \cdot 36}{5316}} = 0{,}66$$ (6.50)

$$\phi_y = \frac{1 + \alpha_y \cdot (\lambda_y{}^* - 0{,}2) + \lambda_y{}^{*2}}{2} = \frac{1 + 0{,}21 \cdot (0{,}66 - 0{,}2) + 0{,}66^2}{2} = 0{,}7679$$

$$\phi_z = \frac{1 + \alpha_z \cdot (\lambda_z{}^* - 0{,}2) + \lambda_z{}^{*2}}{2} = \frac{1 + 0{,}21 \cdot (0{,}66 - 0{,}2) + 0{,}66^2}{2} = 0{,}7679$$

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{}^{*2}}}\,;1\right) = \min\left(\frac{1}{0{,}7679 + \sqrt{0{,}7679^2 - 0{,}66^2}}\,;1\right) = 0{,}86 \quad (6.49)$$

$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{}^{*2}}}\,;1\right) = \min\left(\frac{1}{0{,}7679 + \sqrt{0{,}7679^2 - 0{,}66^2}}\,;1\right) = 0{,}86 \quad (6.49)$$

$\chi_{TF} = 1$ (6.52, 6.49)

$\chi = \min(\chi_y\,;\chi_z\,;\chi_{TF}) = \min(0{,}86\,;0{,}86\,;1) = 0{,}86 \le 1{,}0$

$$N_{b,Rd} = \frac{\chi \cdot A \cdot f_y}{\gamma_{M1}} = \frac{0{,}86 \cdot 66 \cdot 36}{1} = 2016 \text{ kN} \quad (6.47)$$

$$\eta_{N_b} = \frac{|N_{Ed_1}|}{N_{b,Rd}} = \frac{|(-456)|}{2016} = 22{,}6\,\% \quad (6.46) \qquad \textbf{passed}$$

15. Lateral-torsional buckling resistance:

EN 1993-1-1: 6.3.2

Disabled

STEEL MEMBER DESIGN

Design member **30**
Nodes: **28-49**
Code: **Eurocode**
EN 1993-1-1:2005 + AC:2009, EN 1993-1-5:2006
Material: **S 355**
Cross-section: **HE 300 A**
Load case: **Linear, Envelope (Default)**
Coefficient for seismic forces: **1,0**

1. Axial force-Bending-Shear-Torsion (strength interaction):

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9
Critical combination: **Co #1**
Section class: **3** (Elastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm
Effect of warping torsion is disregarded

$$\sigma_{N,Ed} = \frac{N_{Ed_1}}{A_{net}} = \frac{(-3{,}9)}{113} = -0{,}034 \text{ kN/cm}^2 = -0{,}34 \text{ N/mm}^2$$

$$\sigma_{My,b,n,Ed} = \frac{-M_{y,Ed_1}}{I_y} \cdot (z_c - t_f 2) = \frac{-1{,}4358 \cdot 10^4}{1{,}8268 \cdot 10^4} \cdot (14 - 1{,}42) = -10 \text{ kN/cm}^2 = -102{,}96 \text{ N/mm}^2$$

$$\sigma_{Mz,n,Ed} = \frac{M_{z,Ed_1}}{I_z} \cdot \frac{t_w}{2} = \frac{(-98)}{6310} \cdot \frac{0{,}85}{2} = -0{,}0066 \text{ kN/cm}^2 = -0{,}07 \text{ N/mm}^2$$

$$\tau_{Vz,xz,b,n,Ed} = \frac{V_{z,Ed_1}}{I_y \cdot t_w} \cdot (b_2 \cdot t_{f,2} \cdot (z_c - t_f/2)) = \frac{(-205)}{1{,}8268 \cdot 10^4 \cdot 0{,}85} \cdot (30 \cdot 1{,}4 \cdot (14 - 1{,}4/2)) = -7{,}7 \text{ kN/cm}^2 = -76{,}62 \text{ N/mm}^2$$

$$\tau_{T,xz,Ed} = \frac{M_{x,Ed_1}}{I_t} \cdot t_w = \frac{757}{85} \cdot 0{,}85 = 7{,}5 \text{ kN/cm}^2 = 75{,}46 \text{ N/mm}^2$$

$$\sigma_{vonMises} = \sqrt{\left((\sigma_{N,Ed} + \sigma_{My,b,n,Ed} + \sigma_{Mz,n,Ed})^2 + 3 \cdot (|\tau_{Vz,xz,b,n,Ed}| + \tau_{T,xz,Ed})^2\right)} =$$

$$= \sqrt{(((-0{,}034) + (-10) + (-0{,}0066))^2 + 3 \cdot (|(-7{,}7)| + 7{,}5)^2)} = 28 \text{ kN/cm}^2 = 282{,}97 \text{ N/mm}^2$$

$$\eta_{NMV} = \eta_{vonMises} = \frac{\sigma_{vonMises}}{\frac{f_y}{\gamma_{M0}}} = \frac{28}{\frac{36}{1}} = 79{,}7\ \% \quad (14) \qquad \text{p} \qquad \text{1}$$

2. Axial Force-Bending-Flexural Buckling

EN 1993-1-1: 6.3.3
Critical combination: **Co #15**
Section class: **3** (Elastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm
N_{Ed_1} = 0,95 kN (Beam in tension)

$\eta_{NMBuckl} = \eta_{NMV} = 67{,}8\ \%$ **passed**

3. Axial force-Bending-Lateral torsional buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2

Disabled

4. Cross-section resistance to shear (y):

EN 1993-1-1: 6.2.6, 6.2.7

Critical combination: **Co #15**

Section class: **3** (Elastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm

$$V_{el,Rd,y} = \frac{\frac{I \cdot t}{S} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{A_{V,el,y} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}}$$

$$\rho_I = \frac{I_{z,1}}{I_{z,1} + I_{z,2}} = 0{,}5$$

$$A_{V,el,y} = \frac{I_{z,1} \cdot t_{f,1}}{\frac{b_1^2 \cdot t_{f,1}}{8} \cdot \rho_I} = 56 \text{ cm}^2$$

$$V_{el,Rd,y} = \frac{A_{V,el,y} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{56 \cdot 36}{\sqrt{3} \cdot 1} = 1148 \text{ kN}$$

$$\eta_{V_y} = \frac{\left|V_{y,Ed_1}\right|}{V_{el,Rd,y}} = \frac{|(-17)|}{1148} = 1{,}5\ \% \qquad \textbf{passed}$$

5. Shear web buckling resistance:

EN 1993-1-5: 5.1, 5.2, 5.3, 5.5, Annex A: A.3

Critical combination: **Co #3**

Section class: **3** (Elastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm

User setting: No need to check shear web buckling. →

$$V_{el,Rd,z} = \frac{\frac{I \cdot t}{S} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{A_{V,el,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}}$$

$$A_{V,el,z} = \frac{I_y \cdot t_w}{(b \cdot t_f) \cdot \left(h - z_c - \frac{t_f}{2}\right) + (h - z_c - t_f)^2 \cdot \frac{t_w}{2}} = 24 \text{ cm}^2$$

$$V_{el,Rd,z} = \frac{A_{V,el,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{24 \cdot 36}{\sqrt{3} \cdot 1} = 488 \text{ kN}$$

$$\eta_{V_z} = \frac{\left|V_{z,Ed_1}\right|}{V_{el,Rd,z}} = \frac{|(-206)|}{488} = 42{,}3\ \% \qquad \textbf{passed}$$

6. Web shear-Bending-Axial force

EN 1993-1-1: 6.2.9; EN 1993-1-5: 7.1

Disabled

7. SLS (Serviceability Limit State)

EN 1993-1-1: 7., EN 1990: 3.4, A1.4.

Critical combination: **Co #9**
Section class: **3** (Elastic design)
Critical section: $x = 0{,}500 \cdot L = 0{,}500 \cdot 35 = 18$ cm

$$e_z = \left| e_{z,i} - e_{i,z} \cdot \left(1 - \frac{x}{L}\right) - e_{j,z} \cdot \frac{x}{L} + u_z \right| = \left| (-1{,}1) - (-1{,}1) \cdot \left(1 - \frac{18}{35}\right) - (-1{,}1) \cdot \frac{18}{35} + 0 \right| = 0{,}0028 \text{ cm}$$

$$e_{z,Limit} = \frac{L}{300{,}0} = \frac{35}{300{,}0} = 0{,}12 \text{ cm}$$

$$\eta_{e_z} = \frac{e_z}{e_{z,Limit}} = \frac{0{,}0028}{0{,}12} = 2{,}4\ \%$$

$$\eta_{SLS} = \max\left(\eta_{e_z}\right) = \max(2{,}4) = 2{,}4\ \% \qquad \textbf{passed}$$

Partial results

8. Cross-section resistance to axial force:

EN 1993-1-1: 6.2.4
Critical combination: **Co #15**
Section class: **3** (Elastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm

$$N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{113 \cdot 36}{1} = 3996 \text{ kN} \quad (6.10)$$

$$\eta_N = \frac{|N_{Ed_1}|}{N_{pl,Rd}} = \frac{|(-11)|}{3996} = 0{,}3\ \% \quad (6.9) \qquad \textbf{passed}$$

9. Cross-section resistance to bending (yy):

EN 1993-1-1: 6.2.5
Critical combination: **Co #15**
Section class: **3** (Elastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm

$$M_{el,Rd,y} = \frac{W_{el,y} \cdot f_y}{\gamma_{M0}} = \frac{1260 \cdot 36}{1} = 4{,}4725 \cdot 10^4 \text{ kNcm} = 447{,}246 \text{ kNm} \quad (6.14)$$

$$\eta_{M_{y,el}} = \frac{|M_{y,Ed_1}|}{M_{el,Rd,y}} = \frac{|1{,}4779 \cdot 10^4|}{4{,}4725 \cdot 10^4} = 33{,}0\ \% \quad (6.12) \qquad \textbf{passed}$$

10. Cross-section resistance to bending (zz):

EN 1993-1-1: 6.2.5
Critical combination: **Co #15**
Section class: **3** (Elastic design)
Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 35 = 35$ cm

$$M_{el,Rd,z} = \frac{W_{el,z} \cdot f_y}{\gamma_{M0}} = \frac{421 \cdot 36}{1} = 1{,}4933 \cdot 10^4 \text{ kNcm} = 149{,}328 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{z,el}} = \frac{|M_{z,Ed_{11}}|}{M_{el,Rd,z}} = \frac{|643|}{1{,}4933 \cdot 10^4} = 4{,}3\ \% \quad (6.12) \qquad \textbf{passed}$$

11. Cross-section resistance to shear (z):

EN 1993-1-1: 6.2.6, 6.2.7

Critical combination: **Co #3**

Section class: **3** (Elastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm

$$V_{el,Rd,z} = \frac{\frac{I \cdot t}{S} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{A_{V,el,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}}$$

$$A_{V,el,z} = \frac{I_y \cdot t_w}{(b \cdot t_f) \cdot \left(h - z_c - \frac{t_f}{2}\right) + (h - z_c - t_f)^2 \cdot \frac{t_w}{2}} = 24 \text{ cm}^2$$

$$V_{el,Rd,z} = \frac{A_{V,el,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{24 \cdot 36}{\sqrt{3} \cdot 1} = 488 \text{ kN}$$

$$\eta_{V_z} = \frac{\left|V_{z,Ed_1}\right|}{V_{el,Rd,z}} = \frac{|(-206)|}{488} = 42{,}3\ \% \qquad \textbf{passed}$$

13. Bending-axial force interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #1**

Section class: **3** (Elastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm

$$\eta_{MN} = \frac{N_{Ed_1}}{A \cdot \frac{f_y}{\gamma_{M0}}} + \frac{\left|M_{y,Ed_1}\right|}{W_{el,y} \cdot \frac{f_y}{\gamma_{M0}}} + \frac{\left|M_{z,Ed_1}\right|}{W_{el,z} \cdot \frac{f_y}{\gamma_{M0}}} = \frac{(-3{,}9)}{113 \cdot \frac{36}{1}} + \frac{|1{,}4358 \cdot 10^4|}{1260 \cdot \frac{36}{1}} + \frac{|(-98)|}{421 \cdot \frac{36}{1}} = 32{,}9\ \% \qquad \textbf{passed}$$

14. Buckling resistance:

EN 1993-1-1: 6.3.1

Critical combination for N-M-Buckling interaction: **Co #15**

Section class: **3** (Elastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 35 = 0$ cm

N_{Ed_1} = 0,95 kN (Beam in tension)

$\eta_{N_b} = \eta_N = 0\ \%$

15. Lateral-torsional buckling resistance:

EN 1993-1-1: 6.3.2

Disabled

STEEL MEMBER DESIGN

Design member **128**
Nodes: **13-187**
Code: **Eurocode**
EN 1993-1-1:2005 + AC:2009, EN 1993-1-5:2006
Material: **S 355**
Cross-section: **HE 240 A**
Load case: **Linear, Envelope (Default)**
Coefficient for seismic forces: **1,0**

1. Axial force-Bending-Shear-Torsion (strength interaction):

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm

$N_{Ed_1} = -11$ kN $V_{y,Ed_1} = 6{,}8$ kN $V_{z,Ed_1} = -125$ kN $M_{y,Ed_1} = 1{,}5492 \cdot 10^4$ kNcm $= 154{,}921$ kNm $M_{z,Ed_1} = -48$ kNcm $=$
$= -0{,}479$ kNm $M_{x,Ed_1} = 847$ kNcm $= 8{,}475$ kNm

Effect of warping torsion is disregarded

$$\tau_{T,xy,Ed} = \frac{|M_{x,Ed_1}|}{I_t} \cdot t_f = \frac{|847|}{42} \cdot 1{,}2 = 24 \text{ kN/cm}^2$$

$$\tau_{T,xz,Ed} = \frac{|M_{x,Ed_1}|}{I_t} \cdot t_w = \frac{|847|}{42} \cdot 0{,}75 = 15 \text{ kN/cm}^2$$

$$\tau_{T,Ed} = \max(\tau_{T,xy,Ed}; \tau_{T,xz,Ed}) = \max(24; 15) = 24 \text{ kN/cm}^2$$

$$\eta_{M_x} = \frac{\tau_{T,Ed}}{\frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}} = \frac{24}{\frac{36}{\sqrt{3} \cdot 1}} = 118{,}9\ \%$$

$$\eta_{NMV_{pl}} = \max\left(\eta_N; \eta_{M_{y,pl}}; \eta_{M_{z,pl}}; \eta_{V_z}; \eta_{V_y}; \eta_{M_x}\right) = \max(0{,}4; 58{,}6; 0{,}4; 38{,}1; 2{,}6; 118{,}9) = 118{,}9\ \%$$ **not passed**

OJACAM TORZIJSKO STR STEBER HEA; DODATNE "LEDVICE".

2. Axial Force-Bending-Flexural Buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm
$C_{my} = \max(0{,}2 + 0{,}8 \cdot \alpha_{my}, 0{,}4) = \max(0{,}2 + 0{,}8 \cdot 0{,}947, 0{,}4) = 0{,}958 \geq 0{,}4$ Table B.3
$C_{mz} = \max(0{,}2 + 0{,}8 \cdot \alpha_{mz}, 0{,}4) = \max(0{,}2 + 0{,}8 \cdot 0{,}93, 0{,}4) = 0{,}944 \geq 0{,}4$ Table B.3
$f_{yy} = \min(\lambda_y^* - 0{,}2; 0{,}8) = \min(0{,}02 - 0{,}2; 0{,}8) = 0$
$f_{zz} = \min(2 \cdot \lambda_z^* - 0{,}6; 1{,}4) = \min(2 \cdot 0{,}03 - 0{,}6; 1{,}4) = 0$

$$k_{yy} = C_{my} \cdot \left(1 + f_{yy} \cdot \frac{|N_{Ed_1}|}{\frac{\chi_y \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}958 \cdot \left(1 + 0 \cdot \frac{|(-26)|}{\frac{1{,}00 \cdot 2728}{1}}\right) = 0{,}958$$

$k_{zy} = 0{,}6 \cdot k_{yy} = 0{,}6 \cdot 0{,}958 = 0{,}575$ Table Annex B.1

$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 0{,}944 = 0{,}566$

$$k_{zz} = C_{mz} \cdot \left(1 + f_{zz} \cdot \frac{|N_{Ed_1}|}{\frac{\chi_z \cdot N_{pl,Rd}}{\gamma_{M1}}} \right) = 0{,}944 \cdot \left(1 + 0 \cdot \frac{|(-26)|}{\frac{1{,}00 \cdot 2728}{1}} \right) = 0{,}944$$ Table Annex B.1

$$\chi_y = \min \left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{}^{*2}}} ; 1 \right) = 1{,}00 \quad (6.49)$$

$$\chi_z = \min \left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{}^{*2}}} ; 1 \right) = 1{,}00 \quad (6.49)$$

$$\eta_{NMBuckl_1} = \frac{|N_{Ed_1}|}{\frac{\chi_y \cdot A \cdot f_y}{\gamma_{M1}}} + k_{yy} \cdot \frac{|M_{y,Ed_1}|}{\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}}} + k_{yz} \cdot \frac{|M_{z,Ed_1}|}{\frac{W_{pl,z} \cdot f_y}{\gamma_{M1}}} = \frac{|(-26)|}{\frac{1{,}00 \cdot 77 \cdot 36}{1}} + 0{,}958 \cdot \frac{|1{,}5492 \cdot 10^4|}{\frac{745 \cdot 36}{1}} + 0{,}566 \cdot \frac{|(-535)|}{\frac{352 \cdot 36}{1}} = 59{,}5\ \%$$

(6.61)

$$\eta_{NMBuckl_2} = \frac{|N_{Ed_1}|}{\frac{\chi_z \cdot A \cdot f_y}{\gamma_{M1}}} + k_{zy} \cdot \frac{|M_{y,Ed_1}|}{\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}}} + k_{zz} \cdot \frac{|M_{z,Ed_1}|}{\frac{W_{pl,z} \cdot f_y}{\gamma_{M1}}} = \frac{|(-26)|}{\frac{1{,}00 \cdot 77 \cdot 36}{1}} + 0{,}575 \cdot \frac{|1{,}5492 \cdot 10^4|}{\frac{745 \cdot 36}{1}} + 0{,}944 \cdot \frac{|(-535)|}{\frac{352 \cdot 36}{1}} = 38{,}7\ \%$$

(6.62)

$\eta_{NMBuckl} = 59{,}5\ \%$ **passed**

3. Axial force-Bending-Lateral torsional buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2

Disabled

4. Shear(y)-Torsion (strength check):

EN 1993-1-1: 6.2.6, 6.2.7

Critical combination: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 13 = 13$ cm

$A_{V,y} = 2 \cdot b \cdot t_f = 58$ cm²

$$V_{pl,Rd,y} = \frac{A_{V,y} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{58 \cdot 36}{\sqrt{3} \cdot 1} = 1181\ \text{kN} \quad (6.18)$$

$M_{x,Ed_{11}} = 847$ kNcm

$$V_{pl,T,Rd,y} = \left(\sqrt{1 - \frac{\tau_{T,xy_{Ed}}}{1.25 \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}} \right) \cdot V_{pl,Rd,y} = \left(\sqrt{1 - \frac{24}{1.25 \cdot \frac{36}{\sqrt{3} \cdot 1}}} \right) \cdot 1181 = 261\ \text{kN} \quad (6.26)$$

$$\eta_{V_y} = \frac{|V_{y,Ed_{11}}|}{V_{pl,T,Rd,y}} = \frac{|6{,}8|}{261} = 2{,}6\ \% \quad (6.17)$$ **passed**

5. Shear web buckling resistance:

EN 1993-1-5: 5.1, 5.2, 5.3, 5.5, Annex A: A.3
Critical combination: **Co #16**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm
User setting: No need to check shear web buckling. →
$A_{V,z} = A - 2 \cdot b \cdot t_f + (t_w + 2 \cdot r) \cdot t_f = 25$ cm²

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{25 \cdot 36}{\sqrt{3} \cdot 1} = 516 \text{ kN} \quad (6.18)$$

$M_{x,Ed_1} = 813$ kNcm

$$V_{pl,T,Rd,z} = \left(\sqrt{1 - \frac{\tau_{T,xz_{Ed}}}{1.25 \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}} \right) \cdot V_{pl,Rd,z} = \left(\sqrt{1 - \frac{15}{1.25 \cdot \frac{36}{\sqrt{3} \cdot 1}}} \right) \cdot 516 = 338 \text{ kN} \quad (6.26)$$

$$\eta_{V_z} = \frac{|V_{z,Ed_1}|}{V_{pl,T,Rd,z}} = \frac{|(-126)|}{338} = 37{,}1\ \% \quad (6.17) \qquad \textbf{passed}$$

6. Web shear-Bending-Axial force
EN 1993-1-1: 6.2.9; EN 1993-1-5: 7.1
Disabled

Partial results

8. Cross-section resistance to axial force:
EN 1993-1-1: 6.2.4
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm

$$N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{77 \cdot 36}{1} = 2728 \text{ kN} \quad (6.10)$$

$$\eta_N = \frac{|N_{Ed_1}|}{N_{pl,Rd}} = \frac{|(-26)|}{2728} = 1{,}0\ \% \quad (6.9) \qquad \textbf{passed}$$

9. Cross-section resistance to bending (yy):
EN 1993-1-1: 6.2.5
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm

$$M_{pl,Rd,y} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{745 \cdot 36}{1} = 2{,}6434 \cdot 10^4 \text{ kNcm} = 264{,}341 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{y,pl}} = \frac{|M_{y,Ed_1}|}{M_{pl,Rd,y}} = \frac{|1{,}5492 \cdot 10^4|}{2{,}6434 \cdot 10^4} = 58{,}6\ \% \quad (6.12) \qquad \textbf{passed}$$

10. Cross-section resistance to bending (zz):

EN 1993-1-1: 6.2.5

Critical combination: **Co #16**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 13 = 13$ cm

$$M_{pl,Rd,z} = \frac{W_{pl,z} \cdot f_y}{\gamma_{M0}} = \frac{352 \cdot 36}{1} = 1{,}2485 \cdot 10^4 \text{ kNcm} = 124{,}851 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{z,pl}} = \frac{|M_{z,Ed_{11}}|}{M_{pl,Rd,z}} = \frac{|(-644)|}{1{,}2485 \cdot 10^4} = 5{,}2\ \% \quad (6.12) \qquad \textbf{passed}$$

11. Shear(z)-Torsion (strength check):

EN 1993-1-1: 6.2.6, 6.2.7

Critical combination: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm

$A_{V,z} = A - 2 \cdot b \cdot t_f + (t_w + 2 \cdot r) \cdot t_f = 25$ cm²

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{25 \cdot 36}{\sqrt{3} \cdot 1} = 516 \text{ kN} \quad (6.18)$$

$M_{x,Ed_1} = 847$ kNcm

$$V_{pl,T,Rd,z} = \left(\sqrt{1 - \frac{\tau_{T,xz_{Ed}}}{1.25 \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}} \right) \cdot V_{pl,Rd,z} = \left(\sqrt{1 - \frac{15}{1.25 \cdot \frac{36}{\sqrt{3} \cdot 1}}} \right) \cdot 516 = 329 \text{ kN} \quad (6.26)$$

$$\eta_{V_z} = \frac{|V_{z,Ed_1}|}{V_{pl,T,Rd,z}} = \frac{|(-125)|}{329} = 38{,}1\ \% \quad (6.17) \qquad \textbf{passed}$$

12. Bending-shear interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm

$V_{z,Ed_1} = -125 \text{ kN} \le V_{pl,T,Rd,z}/2 = 164 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

$V_{y,Ed_1} = 6{,}8 \text{ kN} \le V_{pl,T,Rd,y}/2 = 131 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

13. Bending-axial force interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm

$$\eta = \frac{|N_{Ed_1}|}{N_{pl,Rd}} = \frac{11}{2728} = 0 = 0{,}38\% \le 25\%$$

$$|N_{Ed_1}| = 11 \text{ kN} \le N_{lim,y} = \frac{h_w \cdot t_w \cdot f_y}{2 \cdot \gamma_{M0}} = \frac{23_w \cdot 0{,}75 \cdot 36}{2 \cdot 1} = 274 \text{ kN}$$

$$\left|N_{Ed_1}\right| = 11 \text{ kN} \le N_{lim,z} = \frac{h_w \cdot t_w \cdot f_y}{\gamma_{M0}} = \frac{23_w \cdot 0{,}75 \cdot 36}{1} = 548 \text{ kN}$$

$M_{N,y,Rd} = M_{y,V,Rd} = 2{,}6434 \cdot 10^4$ kNcm = 264,341 kNm

$M_{N,z,Rd} = M_{z,V,Rd} = 1{,}2485 \cdot 10^4$ kNcm = 124,851 kNm

$$\eta_{MN,1} = \frac{M_{y,Ed_1}}{M_{N,y,Rd}} = \frac{1{,}5492 \cdot 10^4}{2{,}6434 \cdot 10^4} = 58{,}6\ \%$$

$$\eta_{MN,2} = \frac{M_{z,Ed_1}}{M_{N,z,Rd}} = \frac{(-48)}{1{,}2485 \cdot 10^4} = 0{,}4\ \%$$

$\alpha_{MN} = 2$

$\beta_{MN} = \max(5 \cdot n\,;\,1) = \max(5 \cdot 0\,;\,1) = 1$

$$\eta_{MN,3} = \left(\frac{M_{y,Ed_1}}{M_{N,y,Rd}}\right)^{\alpha_{MN}} + \left(\frac{M_{z,Ed_1}}{M_{N,z,Rd}}\right)^{\beta_{MN}} = \left(\frac{1{,}5492 \cdot 10^4}{2{,}6434 \cdot 10^4}\right)^2 + \left(\frac{(-48)}{1{,}2485 \cdot 10^4}\right)^1 = 34{,}7\ \% \quad (6.41)$$

$\eta_{MN} = \max(\eta_{MN,1}\,;\,\eta_{MN,2}\,;\,\eta_{MN,3}\,;\,\eta_N) = \max(58{,}6\,;\,0{,}4\,;\,34{,}7\,;\,0{,}4) = 58{,}6\ \%$ **passed**

14. Buckling resistance:

EN 1993-1-1: 6.3.1

Critical combination for N-M-Buckling interaction: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 13 = 0$ cm

$K_y = 1$

$K_z = 1$

$L_{cr_y} = K_y \cdot L = 1 \cdot 13 = 13$ cm

$L_{cr_z} = K_z \cdot L = 1 \cdot 13 = 13$ cm

Buckling curve about the y axis: *b* Table 6.2

$\rightarrow \alpha_y = 0{,}34$ Table 6.1

Buckling curve about the z axis: *c* Table 6.2

$\rightarrow \alpha_z = 0{,}49$ Table 6.1

$$\lambda_y{}^* = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{77 \cdot 36}{9{,}5227 \cdot 10^6}} = 0{,}02 \quad (6.50)$$

$$\lambda_z{}^* = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{77 \cdot 36}{3{,}3957 \cdot 10^6}} = 0{,}03 \quad (6.50)$$

$$\phi_y = \frac{1 + \alpha_y \cdot (\lambda_y{}^* - 0{,}2) + \lambda_y{}^{*2}}{2} = \frac{1 + 0{,}34 \cdot (0{,}02 - 0{,}2) + 0{,}02^2}{2} = 0{,}469$$

$$\phi_z = \frac{1 + \alpha_z \cdot (\lambda_z{}^* - 0{,}2) + \lambda_z{}^{*2}}{2} = \frac{1 + 0{,}49 \cdot (0{,}03 - 0{,}2) + 0{,}03^2}{2} = 0{,}4583$$

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{}^{*2}}}\,;\,1\right) = \min\left(\frac{1}{0{,}469 + \sqrt{0{,}469^2 - 0{,}02^2}}\,;\,1\right) = 1{,}00 \quad (6.49)$$

$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{}^{*2}}}; 1\right) = \min\left(\frac{1}{0{,}4583 + \sqrt{0{,}4583^2 - 0{,}03^2}}; 1\right) = 1{,}00 \quad (6.49)$$

$$\chi = \min(\chi_y; \chi_z) = \min(1{,}00; 1{,}00) = 1{,}00 \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi \cdot A \cdot f_y}{\gamma_{M1}} = \frac{1{,}00 \cdot 77 \cdot 36}{1} = 2728 \text{ kN} \quad (6.47)$$

$$\eta_{N_b} = \frac{|N_{Ed_1}|}{N_{b,Rd}} = \frac{|(-26)|}{2728} = 1{,}0\ \% \quad (6.46) \qquad \textbf{passed}$$

15. Lateral-torsional buckling resistance:

EN 1993-1-1: 6.3.2

Disabled

STEEL MEMBER DESIGN

Design member **165**
Nodes: **171-176**
Code: **Eurocode**
EN 1993-1-1:2005 + AC:2009, EN 1993-1-5:2006
Material: **S 355**
Cross-section: **HE 180 A**
Load case: **Linear, Envelope (Default)**
Coefficient for seismic forces: **1,0**

1. Axial force-Bending-Shear

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 427 = 427$ cm
$N_{Ed_{13}} = 0{,}63$ kN $V_{y,Ed_{13}} = 4{,}6$ kN $V_{z,Ed_{13}} = -6$ kN $M_{y,Ed_{13}} = -5368$ kNcm $= -53{,}682$ kNm $M_{z,Ed_{13}} = 722$ kNcm $=$
$= 7{,}217$ kNm $M_{x,Ed_{13}} = -1{,}2$ kNcm $= -0{,}012$ kNm

$\eta_{NMV_{pl}} = \max\left(\eta_N ; \eta_{M_{y,pl}} ; \eta_{M_{z,pl}} ; \eta_{V_z} ; \eta_{V_y}\right) = \max(0 ; 46{,}5 ; 13{,}0 ; 2{,}0 ; 0{,}7) = 46{,}5\ \%$ **passed**

2. Axial Force-Bending-Flexural Buckling

EN 1993-1-1: 6.3.3
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 427 = 427$ cm
$N_{Ed_{13}} = 0{,}63$ kN (Beam in tension)

$\eta_{NMBuckl} = \eta_{NMV} = 46{,}5\ \%$ **passed**

3. Axial force-Bending-Lateral torsional buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2
Disabled

4. Cross-section resistance to shear (y):

EN 1993-1-1: 6.2.6, 6.2.7
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 427 = 0$ cm
$A_{V,y} = 2 \cdot b \cdot t_f = 34$ cm²

$$V_{pl,Rd,y} = \frac{A_{V,y} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{34 \cdot 36}{\sqrt{3} \cdot 1} = 701 \text{ kN} \quad (6.18)$$

$M_{x,Ed_1} = -1{,}3$ kNcm

$$V_{pl,T,Rd,y} = \left(\sqrt{1 - \frac{\tau_{T,xy_{Ed}}}{1.25 \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}}\right) \cdot V_{pl,Rd,y} = \left(\sqrt{1 - \frac{0{,}084}{1.25 \cdot \frac{36}{\sqrt{3} \cdot 1}}}\right) \cdot 701 = 700 \text{ kN} \quad (6.26)$$

$$\eta_{V_y} = \frac{\left|V_{y,Ed_1}\right|}{V_{pl,T,Rd,y}} = \frac{|4{,}9|}{700} = 0{,}7\ \%\quad (6.17) \qquad \textbf{passed}$$

5. Shear web buckling resistance:

EN 1993-1-5: 5.1, 5.2, 5.3, 5.5, Annex A: A.3

Critical combination: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 427 = 0$ cm

User setting: No need to check shear web buckling. →

$A_{V,z} = A - 2 \cdot b \cdot t_f + (t_w + 2 \cdot r) \cdot t_f = 14$ cm²

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{14 \cdot 36}{\sqrt{3} \cdot 1} = 297\ \text{kN}\quad (6.18)$$

$M_{x,Ed_1} = -1{,}3$ kNcm

$$V_{pl,T,Rd,z} = \left(\sqrt{1 - \frac{\tau_{T,xz_{Ed}}}{1.25 \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}}\right) \cdot V_{pl,Rd,z} = \left(\sqrt{1 - \frac{0{,}053}{1.25 \cdot \frac{36}{\sqrt{3} \cdot 1}}}\right) \cdot 297 = 296\ \text{kN}\quad (6.26)$$

$$\eta_{V_z} = \frac{\left|V_{z,Ed_1}\right|}{V_{pl,T,Rd,z}} = \frac{|(-19)|}{296} = 6{,}6\ \%\quad (6.17) \qquad \textbf{passed}$$

6. Web shear-Bending-Axial force

EN 1993-1-1: 6.2.9; EN 1993-1-5: 7.1

Disabled

7. SLS (Serviceability Limit State)

EN 1993-1-1: 7., EN 1990: 3.4, A1.4.

Critical combination: **Co #9**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}679 \cdot L = 0{,}679 \cdot 427 = 290$ cm

$$e_z = \left|e_{z,i} - e_{i,z} \cdot \left(1 - \frac{x}{L}\right) - e_{j,z} \cdot \frac{x}{L} + u_z\right| = \left|(-4{,}2) - (-0{,}036) \cdot \left(1 - \frac{290}{427}\right) - (-4{,}7) \cdot \frac{290}{427} + 0\right| = 1{,}3\ \text{cm}$$

$$e_{z,Limit} = \frac{L}{300{,}0} = \frac{427}{300{,}0} = 1{,}4\ \text{cm}$$

$$\eta_{e_z} = \frac{e_z}{e_{z,Limit}} = \frac{1{,}3}{1{,}4} = 91{,}4\ \%$$

$$\eta_{SLS} = \max\left(\eta_{e_z}\right) = \max(91{,}4) = 91{,}4\ \% \qquad \textbf{passed}$$

Partial results

8. Cross-section resistance to axial force:

EN 1993-1-1: 6.2.4

Critical combination: **Co #16**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}197 \cdot L = 0{,}197 \cdot 427 = 84$ cm

$$N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{45 \cdot 36}{1} = 1607 \text{ kN} \quad (6.10)$$

$$\eta_N = \frac{|N_{Ed_{17}}|}{N_{pl,Rd}} = \frac{|(-5{,}4)|}{1607} = 0{,}3\ \% \quad (6.9) \qquad \textbf{passed}$$

9. Cross-section resistance to bending (yy):

EN 1993-1-1: 6.2.5

Critical combination: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 427 = 427$ cm

$$M_{pl,Rd,y} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{325 \cdot 36}{1} = 1{,}1532 \cdot 10^4 \text{ kNcm} = 115{,}323 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{y,pl}} = \frac{|M_{y,Ed_{13}}|}{M_{pl,Rd,y}} = \frac{|(-5368)|}{1{,}1532 \cdot 10^4} = 46{,}5\ \% \quad (6.12) \qquad \textbf{passed}$$

10. Cross-section resistance to bending (zz):

EN 1993-1-1: 6.2.5

Critical combination: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 427 = 0$ cm

$$M_{pl,Rd,z} = \frac{W_{pl,z} \cdot f_y}{\gamma_{M0}} = \frac{156 \cdot 36}{1} = 5556 \text{ kNcm} = 55{,}556 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{z,pl}} = \frac{|M_{z,Ed_1}|}{M_{pl,Rd,z}} = \frac{|1009|}{5556} = 18{,}2\ \% \quad (6.12) \qquad \textbf{passed}$$

11. Cross-section resistance to shear (z):

EN 1993-1-1: 6.2.6, 6.2.7

Critical combination: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 427 = 0$ cm

$A_{V,z} = A - 2 \cdot b \cdot t_f + (t_w + 2 \cdot r) \cdot t_f = 14$ cm²

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{14 \cdot 36}{\sqrt{3} \cdot 1} = 297 \text{ kN} \quad (6.18)$$

$M_{x,Ed_1} = -1{,}3$ kNcm

$$V_{pl,T,Rd,z} = \left(\sqrt{1 - \frac{\tau_{T,xz_{Ed}}}{1.25 \cdot \frac{f_y}{\sqrt{3} \cdot \gamma_{M0}}}} \right) \cdot V_{pl,Rd,z} = \left(\sqrt{1 - \frac{0{,}053}{1.25 \cdot \frac{36}{\sqrt{3} \cdot 1}}} \right) \cdot 297 = 296 \text{ kN} \quad (6.26)$$

$$\eta_{V_z} = \frac{|V_{z,Ed_1}|}{V_{pl,T,Rd,z}} = \frac{|(-19)|}{296} = 6{,}6\ \% \quad (6.17) \qquad \textbf{passed}$$

12. Bending-shear interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 427 = 427$ cm

$V_{z,Ed_{13}} = -6 \text{ kN} \le V_{pl,Rd,z}/2 = 148 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

$V_{y,Ed_{13}} = 4{,}6 \text{ kN} \le V_{pl,Rd,y}/2 = 350 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

13. Bending-axial force interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 427 = 427$ cm

$$n = \frac{\left|N_{Ed_{13}}\right|}{N_{pl,Rd}} = \frac{0{,}63}{1607} = 0 = 0{,}04\% \le 25\%$$

$$\left|N_{Ed_{13}}\right| = 0{,}63 \text{ kN} \le N_{lim,y} = \frac{h_w \cdot t_w \cdot f_y}{2 \cdot \gamma_{M0}} = \frac{17_w \cdot 0{,}6 \cdot 36}{2 \cdot 1} = 162 \text{ kN}$$

$$\left|N_{Ed_{13}}\right| = 0{,}63 \text{ kN} \le N_{lim,z} = \frac{h_w \cdot t_w \cdot f_y}{\gamma_{M0}} = \frac{17_w \cdot 0{,}6 \cdot 36}{1} = 324 \text{ kN}$$

$M_{N,y,Rd} = M_{y,V,Rd} = 1{,}1532 \cdot 10^4$ kNcm $= 115{,}323$ kNm

$M_{N,z,Rd} = M_{z,V,Rd} = 5556$ kNcm $= 55{,}556$ kNm

$$\eta_{MN,1} = \frac{M_{y,Ed_{13}}}{M_{N,y,Rd}} = \frac{(-5368)}{1{,}1532 \cdot 10^4} = 46{,}5\ \%$$

$$\eta_{MN,2} = \frac{M_{z,Ed_{13}}}{M_{N,z,Rd}} = \frac{722}{5556} = 13{,}0\ \%$$

$\alpha_{MN} = 2$

$\beta_{MN} = \max(5 \cdot n\,;\,1) = \max(5 \cdot 0\,;\,1) = 1$

$$\eta_{MN,3} = \left(\frac{M_{y,Ed_{13}}}{M_{N,y,Rd}}\right)^{\alpha_{MN}} + \left(\frac{M_{z,Ed_{13}}}{M_{N,z,Rd}}\right)^{\beta_{MN}} = \left(\frac{(-5368)}{1{,}1532 \cdot 10^4}\right)^2 + \left(\frac{722}{5556}\right)^1 = 34{,}7\ \% \quad (6.41)$$

$\eta_{MN} = \max(\eta_{MN,1}\,;\,\eta_{MN,2}\,;\,\eta_{MN,3}\,;\,\eta_N) = \max(46{,}5\,;\,13{,}0\,;\,34{,}7\,;\,0) = 46{,}5\ \%$ **passed**

14. Buckling resistance:

EN 1993-1-1: 6.3.1

Critical combination for N-M-Buckling interaction: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 427 = 427$ cm

$N_{Ed_{13}} = 0{,}63$ kN (Beam in tension)

$\eta_{N_b} = \eta_N = 0\ \%$

15. Lateral-torsional buckling resistance:

EN 1993-1-1: 6.3.2

Disabled

STEEL MEMBER DESIGN

Design member **96**
Nodes: **32-70**
Code: **Eurocode**
EN 1993-1-1:2005 + AC:2009, EN 1993-1-5:2006
Material: **S 355**
Cross-section: **HE 180 B**
Load case: **Linear, Envelope (Default)**
Coefficient for seismic forces: **1,0**

1. Axial force-Bending-Shear

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9
Critical combination: **Co #1**
Section class: **1** (Plastic design)
Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 93 = 93$ cm
$N_{Ed_{11}} = 13$ kN $V_{y,Ed_{11}} = 0{,}36$ kN $V_{z,Ed_{11}} = -42$ kN $M_{y,Ed_{11}} = -4353$ kNcm $= -43{,}535$ kNm $M_{z,Ed_{11}} = -88$ kNcm $=$
$= -0{,}875$ kNm
$\eta_{NMV_{pl}} = \max\left(\eta_N ; \eta_{M_{y,pl}} ; \eta_{M_{z,pl}} ; \eta_{V_z} ; \eta_{V_y}\right) = \max(0{,}6 ; 25{,}5 ; 1{,}1 ; 10{,}2 ; 0) = 25{,}5\ \%$ **passed**

2. Axial Force-Bending-Flexural Buckling

EN 1993-1-1: 6.3.3, Annex B: Method 2
Critical combination: **Co #16**
Section class: **1** (Plastic design)
Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 93 = 93$ cm
$C_{my} = \max(0{,}2 + 0{,}8 \cdot \alpha_{my}, 0{,}4) = \max(0{,}2 + 0{,}8 \cdot 0{,}53, 0{,}4) = 0{,}624 \geq 0{,}4$ Table B.3
$C_{mz} = \max(0{,}2 + 0{,}8 \cdot \alpha_{mz}, 0{,}4) = \max(0{,}2 + 0{,}8 \cdot 0{,}508, 0{,}4) = 0{,}606 \geq 0{,}4$ Table B.3
$f_{yy} = \min(\lambda_y{}^* - 0{,}2 ; 0{,}8) = \min(0{,}16 - 0{,}2 ; 0{,}8) = 0$
$f_{zz} = \min(2 \cdot \lambda_z{}^* - 0{,}6 ; 1{,}4) = \min(2 \cdot 0{,}27 - 0{,}6 ; 1{,}4) = 0$

$$k_{yy} = C_{my} \cdot \left(1 + f_{yy} \cdot \frac{|N_{Ed_{11}}|}{\frac{\chi_y \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}624 \cdot \left(1 + 0 \cdot \frac{|(-75)|}{\frac{1{,}00 \cdot 2317}{1}}\right) = 0{,}624$$

$$k_{zy} = \min\left(1 - f_{zy} \cdot \frac{|N_{Ed_{11}}|}{\frac{\chi_z \cdot N_{pl,Rd}}{\gamma_{M1}}} ; 0{,}6 + \lambda_z{}^*\right) = \min\left(1 - 0{,}072 \cdot \frac{|(-75)|}{\frac{0{,}97 \cdot 2317}{1}} ; 0{,}6 + 0{,}27\right) = 0{,}868$$ Table Annex B.1

$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 0{,}606 = 0{,}364$

$$k_{zz} = C_{mz} \cdot \left(1 + f_{zz} \cdot \frac{|N_{Ed_{11}}|}{\frac{\chi_z \cdot N_{pl,Rd}}{\gamma_{M1}}}\right) = 0{,}606 \cdot \left(1 + 0 \cdot \frac{|(-75)|}{\frac{0{,}97 \cdot 2317}{1}}\right) = 0{,}606$$ Table Annex B.1

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{}^{*2}}} ; 1\right) = 1{,}00$$ (6.49)

$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{}^{*2}}}; 1\right) = 0{,}97 \quad (6.49)$$

$$\eta_{NMBuckl_1} = \frac{\left|N_{Ed_{11}}\right|}{\frac{\chi_y \cdot A \cdot f_y}{\gamma_{M1}}} + k_{yy} \cdot \frac{\left|M_{y,Ed_{11}}\right|}{\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}}} + k_{yz} \cdot \frac{\left|M_{z,Ed_{11}}\right|}{\frac{W_{pl,z} \cdot f_y}{\gamma_{M1}}} = \frac{|(-75)|}{\frac{1{,}00 \cdot 65 \cdot 36}{1}} + 0{,}624 \cdot \frac{|(-3591)|}{\frac{481 \cdot 36}{1}} + 0{,}364 \cdot \frac{|1349|}{\frac{231 \cdot 36}{1}} = 22{,}3\ \% \quad (6.61)$$

$$\eta_{NMBuckl_2} = \frac{\left|N_{Ed_{11}}\right|}{\frac{\chi_z \cdot A \cdot f_y}{\gamma_{M1}}} + k_{zy} \cdot \frac{\left|M_{y,Ed_{11}}\right|}{\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}}} + k_{zz} \cdot \frac{\left|M_{z,Ed_{11}}\right|}{\frac{W_{pl,z} \cdot f_y}{\gamma_{M1}}} = \frac{|(-75)|}{\frac{0{,}97 \cdot 65 \cdot 36}{1}} + 0{,}868 \cdot \frac{|(-3591)|}{\frac{481 \cdot 36}{1}} + 0{,}606 \cdot \frac{|1349|}{\frac{231 \cdot 36}{1}} = 34{,}3\ \% \quad (6.62)$$

$\eta_{NMBuckl} = 34{,}3\ \%$ **passed**

3. Axial force-Bending-Lateral torsional buckling

ENV 1993-1-1 5.5.3

Disabled

4. Cross-section resistance to shear (y):

EN 1993-1-1: 6.2.6

Critical combination: **Co #15**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 93 = 0$ cm

$A_{V,y} = 2 \cdot b \cdot t_f = 50$ cm²

$$V_{pl,Rd,y} = \frac{A_{V,y} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{50 \cdot 36}{\sqrt{3} \cdot 1} = 1033\ \text{kN} \quad (6.18)$$

$$\eta_{V_y} = \frac{\left|V_{y,Ed_1}\right|}{V_{pl,Rd,y}} = \frac{|15|}{1033} = 1{,}5\ \% \quad (6.17) \qquad \textbf{passed}$$

5. Shear web buckling resistance:

EN 1993-1-5: 5.1, 5.2, 5.3, 5.5, Annex A: A.3

Critical combination: **Co #1**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 93 = 0$ cm

User setting: No need to check shear web buckling. →

$A_{V,z} = A - 2 \cdot b \cdot t_f + (t_w + 2 \cdot r) \cdot t_f = 20$ cm²

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{20 \cdot 36}{\sqrt{3} \cdot 1} = 415\ \text{kN} \quad (6.18)$$

$$\eta_{V_z} = \frac{\left|V_{z,Ed_1}\right|}{V_{pl,Rd,z}} = \frac{|(-52)|}{415} = 12{,}6\ \% \quad (6.17) \qquad \textbf{passed}$$

6. Web shear-Bending-Axial force

EN 1993-1-1: 6.2.9; EN 1993-1-5: 7.1

Disabled

7. SLS (Serviceability Limit State)

EN 1993-1-1: 7., EN 1990: 3.4, A1.4.
Critical combination: **Co #9**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}304 \cdot L = 0{,}304 \cdot 93 = 28$ cm

$$e_z = \left| e_{z,i} - e_{j,z} \cdot \frac{x}{L} + u_z \right| = \left| (-0{,}78) - (-2{,}5) \cdot \frac{28}{93} + 0 \right| = 0{,}25 \text{ cm}$$

$$e_{z,Limit} = \frac{L}{300{,}0} = \frac{93}{300{,}0} = 0{,}31 \text{ cm}$$

$$\eta_{e_z} = \frac{e_z}{e_{z,Limit}} = \frac{0{,}25}{0{,}31} = 81{,}8\ \%$$

$$\eta_{SLS} = \max\left(\eta_{e_z}\right) = \max(81{,}8) = 81{,}8\ \% \quad \textbf{passed}$$

Partial results

8. Cross-section resistance to axial force:

EN 1993-1-1: 6.2.4
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 0{,}990 \cdot L = 0{,}990 \cdot 93 = 93$ cm

$$N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{65 \cdot 36}{1} = 2317 \text{ kN} \quad (6.6)$$

$$N_{u,Rd} = \frac{0{,}9 \cdot A \cdot f_u}{\gamma_{M2}} = \frac{0{,}9 \cdot 65 \cdot 51}{1{,}25} = 2396 \text{ kN} \quad (6.7)$$

$$N_{t,Rd} = \min(N_{pl,Rd}; N_{u,Rd}) = \min(2317; 2396) = 2317 \text{ kN}$$

$$\eta_N = \frac{\left|N_{Ed_1}\right|}{N_{t,Rd}} = \frac{|85|}{2317} = 3{,}7\ \% \quad (6.5) \qquad \textbf{passed}$$

9. Cross-section resistance to bending (yy):

EN 1993-1-1: 6.2.5
Critical combination: **Co #1**
Section class: **1** (Plastic design)
Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 93 = 93$ cm

$$M_{pl,Rd,y} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{481 \cdot 36}{1} = 1{,}7091 \cdot 10^4 \text{ kNcm} = 170{,}914 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{y,pl}} = \frac{\left|M_{y,Ed_{11}}\right|}{M_{pl,Rd,y}} = \frac{|(-4353)|}{1{,}7091 \cdot 10^4} = 25{,}5\ \% \quad (6.12) \qquad \textbf{passed}$$

10. Cross-section resistance to bending (zz):

EN 1993-1-1: 6.2.5
Critical combination: **Co #15**
Section class: **1** (Plastic design)
Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 93 = 93$ cm

$$M_{pl,Rd,z} = \frac{W_{pl,z} \cdot f_y}{\gamma_{M0}} = \frac{231 \cdot 36}{1} = 8201 \text{ kNcm} = 82{,}010 \text{ kNm} \quad (6.13)$$

$$\eta_{M_{z,pl}} = \frac{\left|M_{z,Ed_{11}}\right|}{M_{pl,Rd,z}} = \frac{|(-1371)|}{8201} = 16{,}7\ \% \quad (6.12) \qquad \textbf{passed}$$

11. Cross-section resistance to shear (z):

EN 1993-1-1: 6.2.6

Critical combination: **Co #1**

Section class: **1** (Plastic design)

Critical section: $x = 0{,}000 \cdot L = 0{,}000 \cdot 93 = 0$ cm

$A_{V,z} = A - 2 \cdot b \cdot t_f + (t_w + 2 \cdot r) \cdot t_f = 20$ cm²

$$V_{pl,Rd,z} = \frac{A_{V,z} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{20 \cdot 36}{\sqrt{3} \cdot 1} = 415 \text{ kN} \quad (6.18)$$

$$\eta_{V_z} = \frac{\left|V_{z,Ed_1}\right|}{V_{pl,Rd,z}} = \frac{|(-52)|}{415} = 12{,}6\ \% \quad (6.17) \qquad \textbf{passed}$$

12. Bending-shear interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #1**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 93 = 93$ cm

$V_{z,Ed_{11}} = -42 \text{ kN} \le V_{pl,Rd,z}/2 = 208 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

$V_{y,Ed_{11}} = 0{,}36 \text{ kN} \le V_{pl,Rd,y}/2 = 516 \text{ kN} \rightarrow$ The effect of shear force on moment resistance is negligible. 6.2.8 (2)

13. Bending-axial force interaction check

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9

Critical combination for N-M-V strength interaction: **Co #1**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 93 = 93$ cm

$$n = \frac{\left|N_{Ed_{11}}\right|}{N_{pl,Rd}} = \frac{13}{2317} = 0{,}01 = 0{,}57\% \le 25\%$$

$$\left|N_{Ed_{11}}\right| = 13 \text{ kN} \le N_{lim,y} = \frac{h_w \cdot t_w \cdot f_y}{2 \cdot \gamma_{M0}} = \frac{18_w \cdot 0{,}85 \cdot 36}{2 \cdot 1} = 229 \text{ kN}$$

$$\left|N_{Ed_{11}}\right| = 13 \text{ kN} \le N_{lim,z} = \frac{h_w \cdot t_w \cdot f_y}{\gamma_{M0}} = \frac{18_w \cdot 0{,}85 \cdot 36}{1} = 459 \text{ kN}$$

$M_{N,y,Rd} = M_{y,V,Rd} = 1{,}7091 \cdot 10^4$ kNcm = 170,914 kNm

$M_{N,z,Rd} = M_{z,V,Rd} = 8201$ kNcm = 82,010 kNm

$$\eta_{MN,1} = \frac{M_{y,Ed_{11}}}{M_{N,y,Rd}} = \frac{(-4353)}{1{,}7091 \cdot 10^4} = 25{,}5\ \%$$

$$\eta_{MN,2} = \frac{M_{z,Ed_{11}}}{M_{N,z,Rd}} = \frac{(-88)}{8201} = 1{,}1\ \%$$

$\alpha_{MN} = 2$

$\beta_{MN} = \max(5 \cdot n ; 1) = \max(5 \cdot 0{,}01 ; 1) = 1$

$$\eta_{MN,3} = \left(\frac{M_{y,Ed_{11}}}{M_{N,y,Rd}}\right)^{\alpha_{MN}} + \left(\frac{M_{z,Ed_{11}}}{M_{N,z,Rd}}\right)^{\beta_{MN}} = \left(\frac{(-4353)}{1{,}7091 \cdot 10^4}\right)^2 + \left(\frac{(-88)}{8201}\right)^1 = 7{,}6\ \%$$ (6.41)

$\eta_{MN} = \max(\eta_{MN,1} ; \eta_{MN,2} ; \eta_{MN,3} ; \eta_N) = \max(25{,}5 ; 1{,}1 ; 7{,}6 ; 0{,}6) = 25{,}5\ \%$ **passed**

14. Buckling resistance:

EN 1993-1-1: 6.3.1

Critical combination for N-M-Buckling interaction: **Co #16**

Section class: **1** (Plastic design)

Critical section: $x = 1{,}000 \cdot L = 1{,}000 \cdot 93 = 93$ cm

$K_y = 1$

$K_z = 1$

$L_{cr_y} = K_y \cdot L = 1 \cdot 93 = 93$ cm

$L_{cr_z} = K_z \cdot L = 1 \cdot 93 = 93$ cm

Buckling curve about the y axis: b Table 6.2

$\rightarrow \alpha_y = 0{,}34$ Table 6.1

Buckling curve about the z axis: c Table 6.2

$\rightarrow \alpha_z = 0{,}49$ Table 6.1

$$\lambda_y{}^* = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{65 \cdot 36}{9{,}0933 \cdot 10^4}} = 0{,}16$$ (6.50)

$$\lambda_z{}^* = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{65 \cdot 36}{3{,}2344 \cdot 10^4}} = 0{,}27$$ (6.50)

$$\phi_y = \frac{1 + \alpha_y \cdot (\lambda_y{}^* - 0{,}2) + \lambda_y{}^{*2}}{2} = \frac{1 + 0{,}34 \cdot (0{,}16 - 0{,}2) + 0{,}16^2}{2} = 0{,}5059$$

$$\phi_z = \frac{1 + \alpha_z \cdot (\lambda_z{}^* - 0{,}2) + \lambda_z{}^{*2}}{2} = \frac{1 + 0{,}49 \cdot (0{,}27 - 0{,}2) + 0{,}27^2}{2} = 0{,}5524$$

$$\chi_y = \min\left(\frac{1}{\phi_y + \sqrt{\phi_y^2 - \lambda_y{}^{*2}}} ; 1\right) = \min\left(\frac{1}{0{,}5059 + \sqrt{0{,}5059^2 - 0{,}16^2}} ; 1\right) = 1{,}00$$ (6.49)

$$\chi_z = \min\left(\frac{1}{\phi_z + \sqrt{\phi_z^2 - \lambda_z{}^{*2}}} ; 1\right) = \min\left(\frac{1}{0{,}5524 + \sqrt{0{,}5524^2 - 0{,}27^2}} ; 1\right) = 0{,}97$$ (6.49)

$\chi_{TF} = 0{,}9642$ (6.52, 6.49)

$\chi = \min(\chi_y ; \chi_z ; \chi_{TF}) = \min(1{,}00 ; 0{,}97 ; 0{,}9642) = 0{,}96 \leq 1{,}0$

$$N_{b,Rd} = \frac{\chi \cdot A \cdot f_y}{\gamma_{M1}} = \frac{0{,}96 \cdot 65 \cdot 36}{1} = 2234\ \text{kN}$$ (6.47)

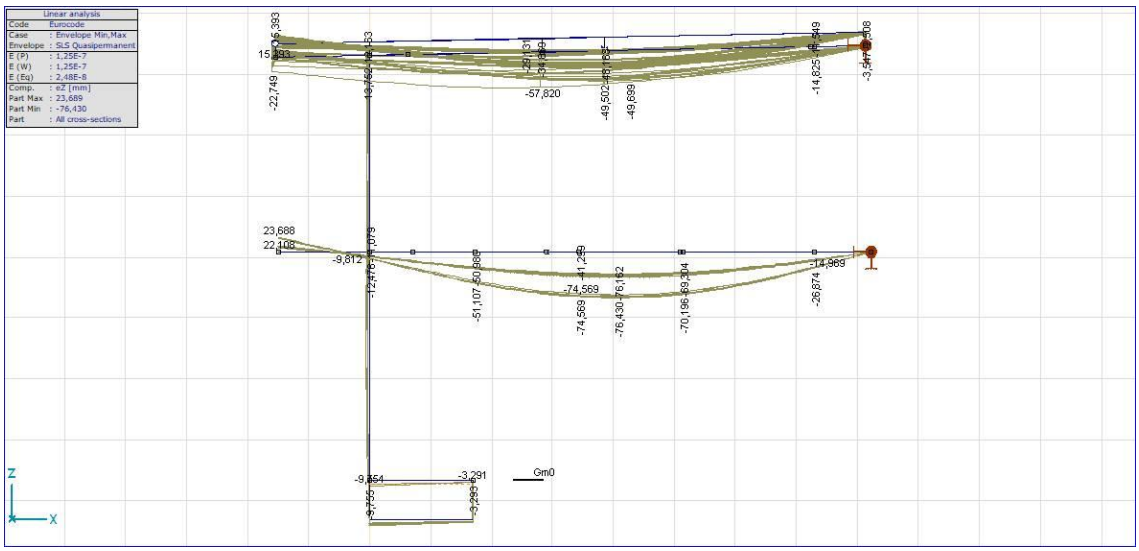
$$\eta_{N_b} = \frac{|N_{Ed_{11}}|}{N_{b,Rd}} = \frac{|(-75)|}{2234} = 3{,}3\ \%$$ (6.46) **passed**

15. Lateral-torsional buckling resistance:

EN 1993-1-1: 6.3.2

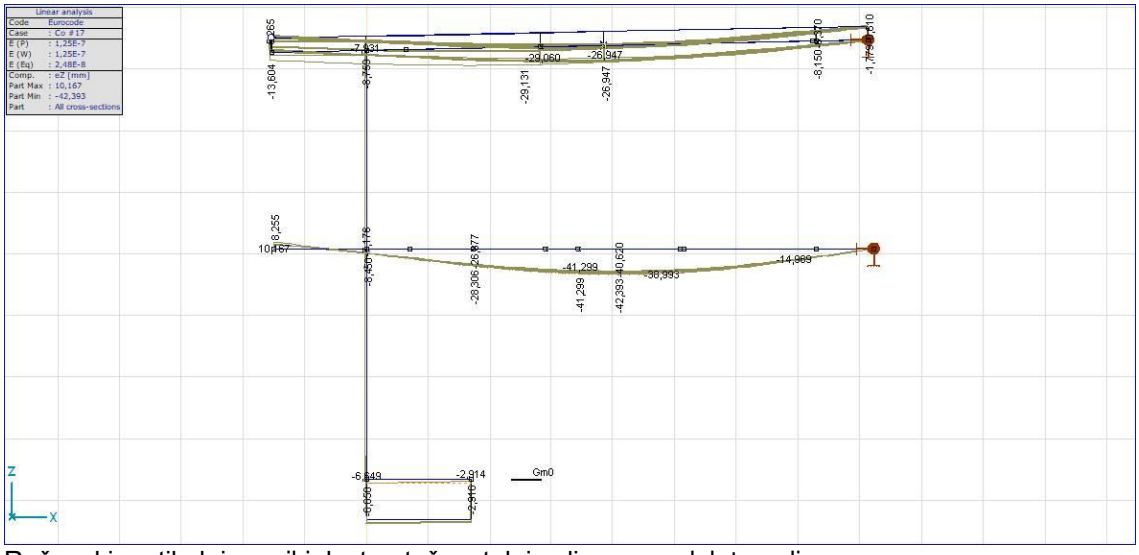
Disabled

- *Pomiki*



Skupni računski vertikalni pomiki; max pomiki:

- Temelj : e_Z = 9.7mm; HEB180: e_Z = 76,43mm; HEA180: e_Z = 49,70mm



Računski vertikalni pomiki; lastna teža, stalni vpliv – posedek temelja

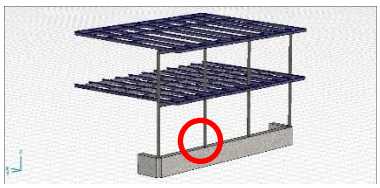
- Temelj : e_Z = 6.65mm
- HEB180: e_Z = 42,39mm e_Z = 42,39- 6,65mm= 35,74mm
- HEA180: e_Z = 26,95mm e_Z = 26,95- 6,65mm= 20.30mm

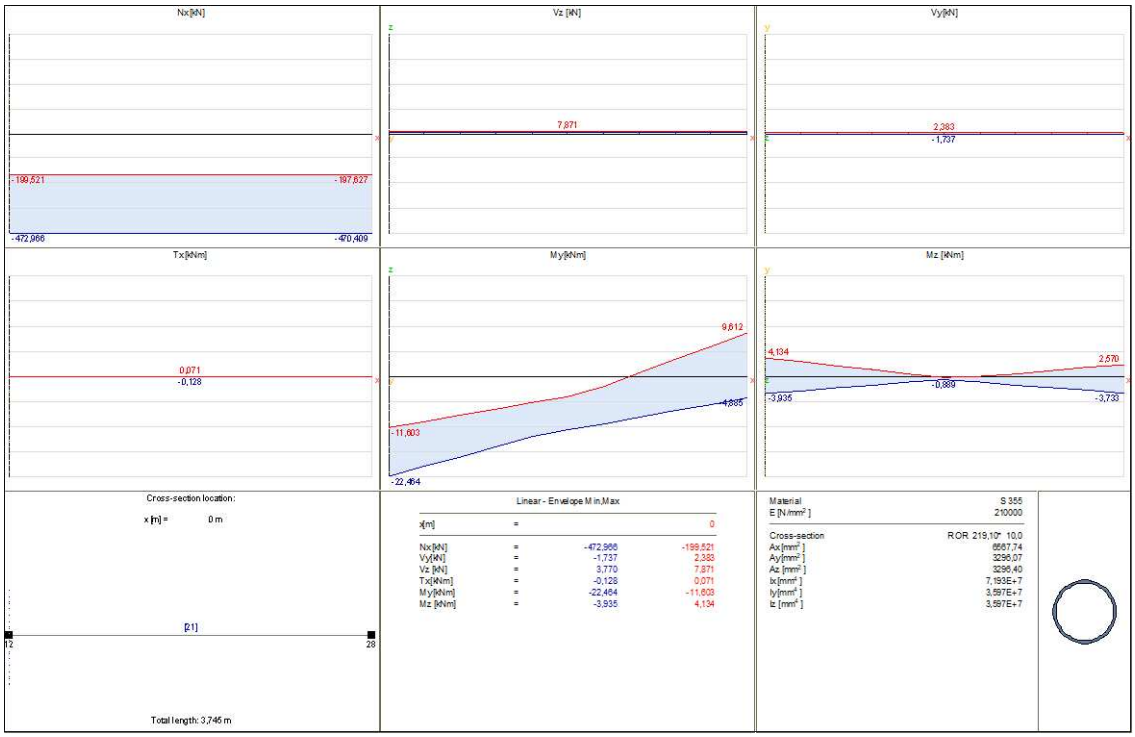
Za zmanjšanje vertikalne deformacije v fazi uporabe se nosilci :

- HEA 180 nadvišajo v sredini prostega polja za 20mm
- HEB 180 nadvišajo v sredini prostega polja za 40mm
- HEA 300 nadviša v sredini vsakega polja za 10mm

2.3.4 Kontrola vozlišč

2.3.4.1 SIDRANJE STEBRA V TEMELJ:





IZBEREMO SIDRNI VIJAK M20, KVALITETE 8.8. Projektirano je s sidri Hilti.

STEBER Φ 219/10 je privarjen na podložno ploščo debeline 15mm z zvarom a=7mm.

$$a_{min} = 3mm$$
$$a_{max} = 0{,}7 * 10mm = 7mm$$

Na sidra deluje tlačna sila N in prečna sila V ter moment M:

N=-473kN

V=$\sqrt{7{,}87^2 + 2{,}38^2}$=8.22 kN

$M_{max} = M_y$ = 22,46 kNm

Izberem M20, kvalitete 8.8:

f_{yb}=64 kN/cm^2
f_{ub}=80 kN/cm^2
d_0=2 cm
A_s=3,14 cm^2
4 kosi
pločevina S355, t=1.5 cm
f_u=49 kN/cm^2

STRIŽNA NOSILNOST VIJAKOV:

$$F_{v,Ed} = \frac{V}{4} = 2{,}06kN \leq F_{v,Rd} = \frac{0{,}5 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}5 * 80 * 3{,}14}{1{,}25} = 100{,}48kN$$

NOSILNOST PLOČEVINE NA BOČNI PRITISK:

$$F_{b,Ed} = \frac{V}{4} = 2{,}06kN \leq F_{b,Rd} = \frac{k_1 * \alpha_b * f_u * d * t}{\gamma_{M2}} = \frac{2{,}5 * 0{,}76 * 49 * 2{,}2 * 15}{1{,}25} = 246kN$$

$$k_1 = min \begin{cases} 2{,}8 * \frac{e_2}{d_0} - 1{,}7 = 2{,}8 * \frac{5}{2{,}2} - 1{,}7 = 4{,}66 \leq 2{,}5 \\ 1{,}4 * \frac{p_2}{d_0} - 1{,}7 = 1{,}4 * \frac{27}{2{,}2} - 1{,}7 = 15{,}48 \leq 2{,}5 \end{cases}$$

$$\alpha_b = min \begin{cases} \frac{e_1}{3 * d_0} = \frac{5}{3 * 2{,}2} = 0{,}76 \\ \frac{f_{ub}}{f_u} = \frac{80}{49} = 1{,}63 \\ 1{,}0 \end{cases}$$

NOSILNOST VIJAKA NA IZVLEK:

N= 22,46 / 0,31 = 72,45 kN; izberem 2 vijaka M20 N_i=36.23kN

Izberem ekspanzijsko sidro HIT HY 200-A s sidrnimi palicami HIT-V **globina sidranja** min 160mm; izberem 200mm

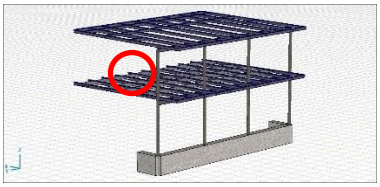
N_{prip} =40,60 kN; $N_{prip} > N_i$

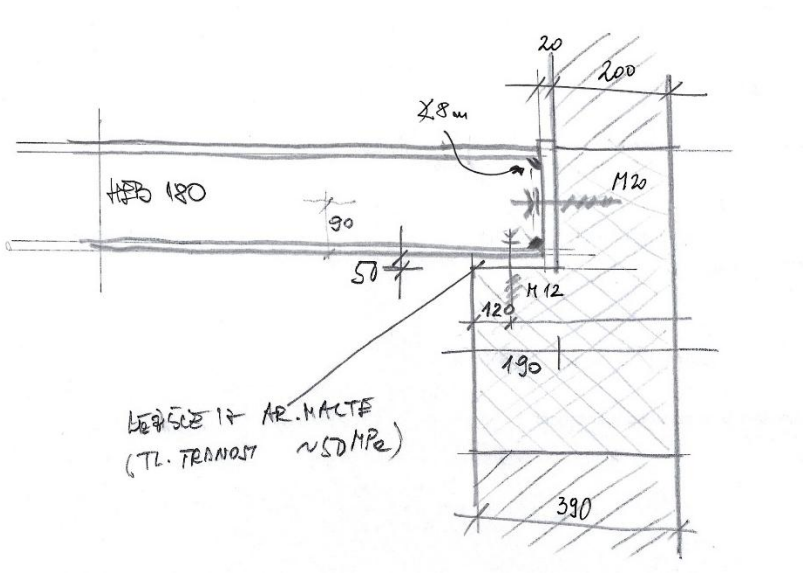
KONTROLA ZVARA a_{zv} = 7mm; $L_{zv,\,min}$ = 120mm

$$F_{wRd} = \left(\frac{430}{(\sqrt{3} * 0{,}85 * 1{,}35)}\right) * 6 = 1{,}516\ kN/mm$$

$$l_{pot} = \frac{72{,}45}{1{,}516} = 48mm;\ l_{zv\,dej} = 2x60 = 120mm$$

2.3.4.2 SIDRANJE NOSILCA HEB180 v AB gredo





IZBEREMO SIDRNI VIJAK M20, KVALITETE 8.8. Projektirano je s sidri Hilti.

NOSILEC HEB180 je privarjen na podložno ploščo debeline 15mm z zvarom a=8mm.

$$a_{min} = 3mm$$

$$a_{max} = 0{,}7 * 14mm = 9.8mm$$

Na sidra deluje :

natezna sila N R_x=-15,76kN = N

prečna sila V R_y= 2.03 KN in R_z=59,92kN

$V_{max}=\sqrt{2{,}03^2 + 59{,}92^2}$=59,95 kN

NOSILNOST VIJAKA NA STRIG: V_{max}=59,95 kN; izberem 2 vijaka M20 V_i=29,98kN

NOSILNOST VIJAKA NA IZVLEK: N= 15,76 kN; izberem 2 vijaka M20 N_i=7,88kN

Izberem ekspanzijsko sidro HIT HY 200-A s sidrnimi palicami HIT-V **globina sidranja** min 120mm;

N_{prip} =20,00 kN; $N_{prip} > N_i$

V_{prip} =34,90 kN; $V_{prip} > V_i$

KONTROLA ZVARA a_{zv} = 8mm; L_{zv} = 2x (180-2x14)=304mm

$F_{wRd} = (\,^{430}/_{(\sqrt{3}} * 0{,}85 * 1{,}35)) * 8 = 1{,}73\ kN/mm$

$$l_{pot} = {}^{60}/_{1{,}73} = 35mm;\ l_{zv\ dej} = 2x60 = 120mm$$

2.3.4.3 SIDRANJE NOSILCA HEA180 v AB gredo



IZBEREM SIDRNI VIJAK M20, KVALITETE 8.8. Projektirano je s sidri Hilti.

NA NOSILEC HEA180 so privarjene plošče debeline 12mm z zvarom a=6mm.

$$a_{min} = 3mm$$
$$a_{max} = 0{,}7 * 9{,}5mm = 6{,}6mm$$

Na sidra deluje :

natezna sila N R_x=-10,14kN = N

prečna sila V R_y= 86,43 KN in $R_{z;pripad}$=44,63kN

prečna sila V $R_{y,pripad}$= 44,96 KN in R_z=88,19kN

$V_{max}=\sqrt{44{,}96^2 + 88{,}19^2}$=98,98 kN

NOSILNOST VIJAKA NA STRIG: V_{max}=98,98 kN; izberem 4 vijake M20 V_i=24,75kN

NOSILNOST VIJAKA NA IZVLEK: N= 10,14 kN; izberem 4 vijake M20 N_i=2,54kN

Izberem ekspanzijsko sidro HIT HY 200-A s sidrnimi palicami HIT-V **globina sidranja** min 120mm;

N_{prip} =20,00= kN; $N_{prip} > N_i$

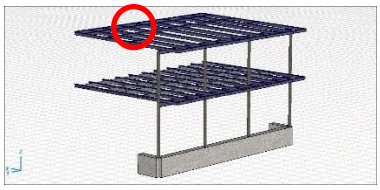
V_{prip} =34,90 kN; $V_{prip} > V_i$

KONTROLA ZVARA a_{zv} = 6mm; L_{zv} = 2x (171-2x9,5)=304mm

$F_{wRd} = (\,^{430}/_{(\sqrt{3}} * 0{,}85 * 1{,}35)) * 6 = 1{,}30\ kN/mm$

$$l_{pot} = {}^{98.98}/_{1{,}30} = 76{,}14mm;\ l_{zv\ dej} = 2x60 = 120mm$$

2.3.4.4 STIK HEA 180 – HEA 180 (ob osi C)



Vozliščna pločevina je na HEA140 privarjena z zvarom a=6mm.

$$a_{min} = 3mm$$
$$a_{max} = 0{,}7 * 9{,}5mm = 6{,}6mm$$
$$a_{dej} = 6mm$$

Zvar: $F_{wRd} = {}^{430}/_{(\sqrt{3}} * 0{,}85 * 1{,}35) * 6 = 1{,}30\ kN/mm$

Na stik deluje :

natezna sila N R_x=-6,55kN = N

moment M_y = 2,21 kNm

N = 6,55 + 2,21/ 0,09= 31,11 kN

prečna sila V R_y= 2,50 KN in $R_{z;pripad}$=5,50kN
prečna sila V $R_{y,pripad}$= 1,37 KN in R_z=24,58kN
$V_{max}=\sqrt{1{,}37^2+24{,}58^2}$=24,62 kN

Izberem M16, kvalitete 10.9 (strig):
f_{yb}=90 kN/cm2
f_{ub}=100 kN/cm2
d_0=1,6 cm
A_s=1,57 cm2
2 kosa
pločevina S355, t=1,5 cm
fu=49 kN/cm2

STRIŽNA NOSILNOST VIJAKOV M16:

$$F_{v,Ed}=\frac{\mathrm{Qz}}{2}=\frac{24{,}62}{2}=12{,}31kN\le F_{v,Rd}=\frac{0{,}5*f_{ub}*A_s}{\gamma_{M2}}=\frac{0{,}5*90*1{,}57}{1{,}25}=56{,}52kN$$

NATEZNA NOSILNOST VIJAKOV M16:

$$F_{t,Ed}=\frac{Z}{2}=\frac{31{,}11}{2}=15{,}56\ kN\le F_{t,Rd}=\frac{0{,}9*f_{ub}*A_s}{\gamma_{M2}}=\frac{0{,}9*90*1{,}57}{1{,}25}=101{,}74kN$$

Vozliščna pločevina je na stojino HEA140 privarjena z zvarom a=6mm.

Kontrola zvara:
Za strig : $\rightarrow l_{pot}={}^{24{,}62}/_{1{,}3}=18{,}94mm;\ l_{zv\,dej}=2x(171-2x9{,}50)=304mm$
Za nateg : $\rightarrow l_{pot}={}^{31{,}11}/_{1{,}3}=23{,}93mm;\ l_{zv\,dej}=2x180=360mm$

2.3.4.5 STIK HEA 180 – HEA 180 (med osmi B in C)



Vozliščna pločevina debeline 12mm je na HEA140 privarjena z zvarom a=6mm.

$$a_{min}=3mm$$
$$a_{max}=0{,}7*9{,}5mm=6{,}6mm$$
$$a_{dej}=6mm$$

Zvar: $F_{wRd}={}^{430}/_{(\sqrt{3}}*0{,}85*1{,}35)*6=1{,}30\ kN/mm$

Na stik deluje :
natezna sila N R_x=-7,38kN = N
moment M_y = 15,06 kNm
N = 7,38 + 15,06 / 0,09= 174,71 kN

prečna sila V R_y= 4,09KN in $R_{z;pripad}$=12,57kN
prečna sila V $V_{max}=\sqrt{4{,}09^2+12{,}57^2}$= 13,22 kN

Izberem M16, kvalitete 10.9 (strig):
f_{yb}=90 kN/cm2
f_{ub}=100 kN/cm2

d_0=1,6 cm
A_s=1,57 cm2
2 kosa
pločevina S355, t=1,5 cm
fu=49 kN/cm2

STRIŽNA NOSILNOST VIJAKOV M16:

$$F_{v,Ed} = \frac{\mathrm{Qz}}{2} = \frac{13{,}22}{2} = 6{,}61kN \leq F_{v,Rd} = \frac{0{,}5 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}5 * 90 * 1{,}57}{1{,}25} = 56{,}52kN$$

NATEZNA NOSILNOST VIJAKOV M16:

$$F_{t,Ed} = \frac{Z}{2} = \frac{174{,}71}{2} = 87{,}36kN \leq F_{t,Rd} = \frac{0{,}9 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}9 * 90 * 1{,}57}{1{,}25} = 101{,}74kN$$

Vozliščna pločevina je na stojino HEA140 privarjena z zvarom a=6mm.

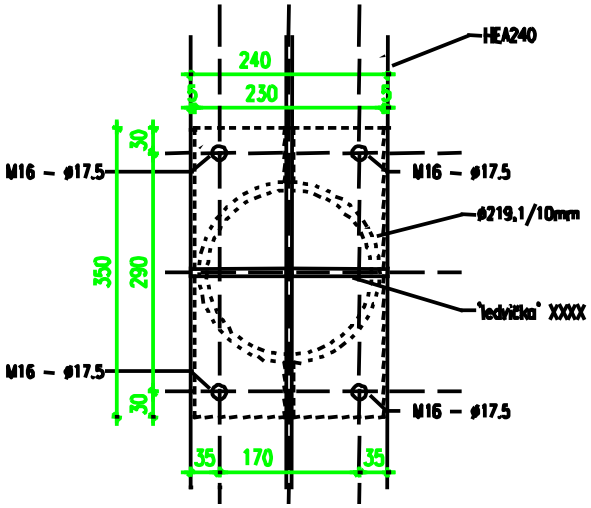
Kontrola zvara:

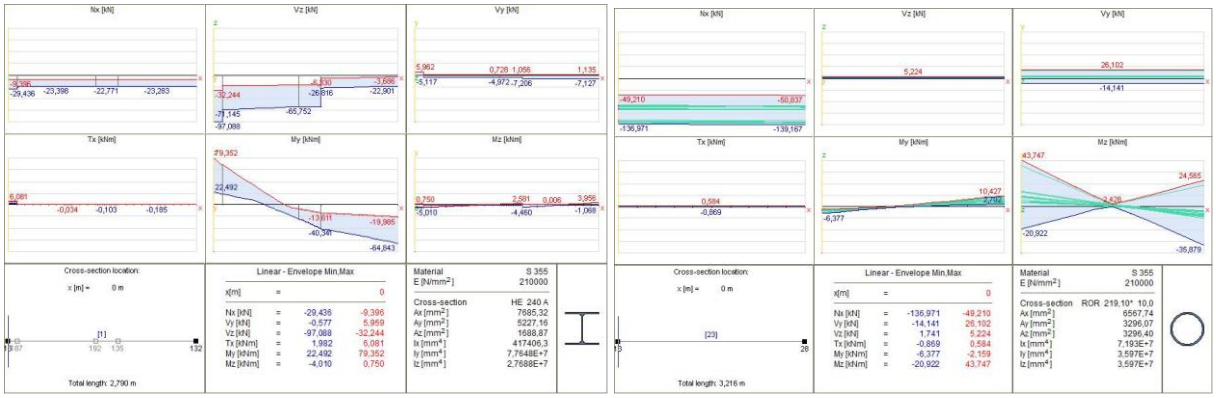
Za strig : $\rightarrow l_{pot} = {}^{13{,}22}/_{1{,}3} = 10{,}17mm;\ l_{zv\,dej} = 2x(171 - 2x9{,}50) = 304mm$

Za nateg : $\rightarrow l_{pot} = {}^{174{,}71}/_{1{,}3} = 134{,}39mm;\ l_{zv\,dej} = 2x180 = 360mm$

2.3.4.6 STIK STEBER – NOSILEC HEA 240 os 2,3







Stik je preko vozliščne pločevine debeline 15mm in vijakov kvalitete 10.9 M16

M_z= -20,92 kNm	M_z=43,75kNm	→ Z = 43,75/0,29-49,21 = 101,65 kN
M_y= -6,38 kNm	M_y=-2,16kNm	
N_{pripad} =-136,97kN	N_{pripad}= -49,21 kN	
$V_{y,\ pripad}$=-14,14 kN	$V_{y,\ pripad}$= 26,10 kN	→ $Q_z = \sqrt{26{,}10^2 + 5{,}22^2}$= 26,62 kN
$V_{z,\ pripad}$ = 1,74 kN	$V_{z,\ pripad}$= 5,22 kN	

NATEZNA NOSILNOST VIJAKOV M16:

$$F_{t,Ed} = \frac{Z}{2} = \frac{101{,}65}{2} = 50{,}83kN \leq F_{t,Rd} = \frac{0{,}9 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}9 * 90 * 1{,}57}{1{,}25} = 101{,}74kN$$

STRIŽNA NOSILNOST VIJAKOV M16:

$$F_{v,Ed} = \frac{\mathrm{Qz}}{4} = \frac{26{,}62}{4} = 6{,}65kN \leq F_{v,Rd} = \frac{0{,}5 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}5 * 90 * 1{,}57}{1{,}25} = 56{,}52kN$$

Vozliščna pločevina debeline 15mm je na steber Φ 219 privarjena z zvarom a=7mm.

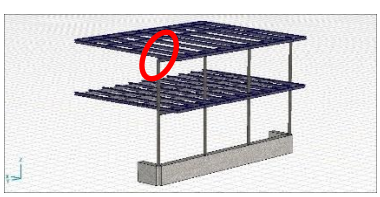
$$a_{min} = 3mm$$
$$a_{max} = 0{,}7 * 10mm = 7mm$$
$$a_{dej} = 7mm$$

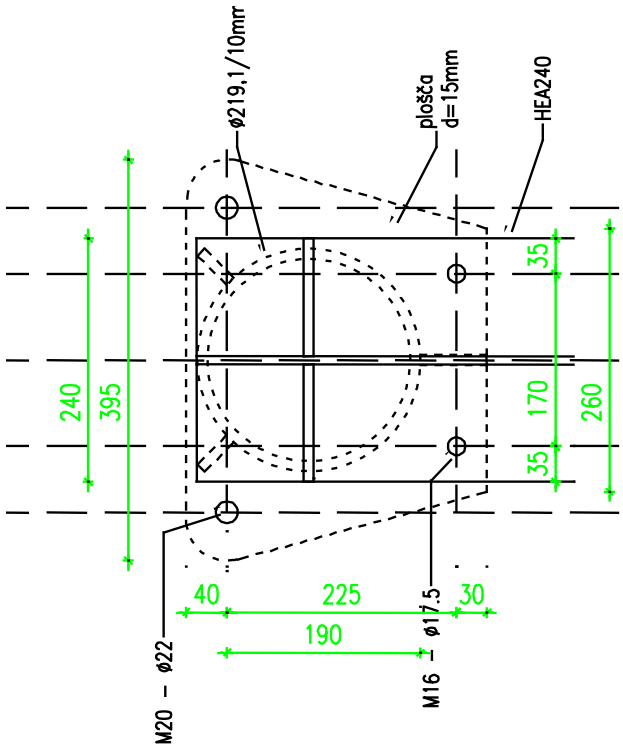
Zvar: $F_{wRd} = {}^{430}/_{(\sqrt{3}} * 0{,}85 * 1{,}35) * 7 = 1{,}52\ kN/mm$

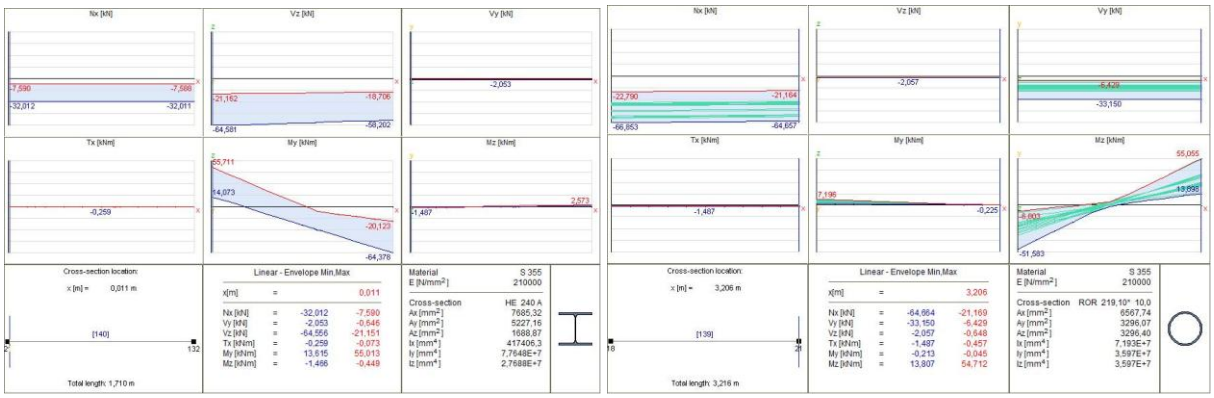
Kontrola zvara:

Za nateg : $\rightarrow l_{pot} = {}^{101{,}65}/_{1{,}52} = 67mm;\ l_{zv\ dej} = 2x65 = 130mm$

2.3.4.7 STIK STEBER – NOSILEC HEA 240 os 1,4







Stik je preko vozliščnih pločevin debeline 15mm in vijakov kvalitete 10.9 M16 (M20).
Kontrola vijakov :

M_z= 13,81 kNm	M_z=54,71 kNm	→ Z = 54,71/0,190-21,17 = 266,78 kN
M_y= -0,21 kNm	M_y=- 0,04 kNm	
N_{pripad} =-64,66kN	N_{pripad}= -21,17 kN	
$V_{y,\ pripad}$=-33,15 kN	$V_{y,\ pripad}$= -5,43 kN	→ $Q_z = \sqrt{33{,}15^2 + 2{,}07^2}$= 33,21 kN
$V_{z,\ pripad}$ = -2,07 kN	$V_{z,\ pripad}$= -0,65 kN	

NATEZNA NOSILNOST VIJAKOV M16:

$$F_{t,Ed} = \frac{Z}{2} = \frac{266{,}78}{2} = 133{,}39kN \leq F_{t,Rd} = \frac{0{,}9*f_{ub}*A_s}{\gamma_{M2}} = \frac{0{,}9*90*1{,}57}{1{,}25} = 101{,}74kN$$; ne ustreza!

NATEZNA NOSILNOST VIJAKOV M20 :

$$F_{t,Ed} = \frac{Z}{2} = \frac{266{,}78}{2} = 133{,}39kN \leq F_{t,Rd} = \frac{0{,}9*f_{ub}*A_s}{\gamma_{M2}} = \frac{0{,}9*90*2{,}45}{1{,}25} = 158{,}77kN$$; ustreza!

STRIŽNA NOSILNOST VIJAKOV M16:

$$F_{v,Ed} = \frac{\mathrm{Qz}}{2} = \frac{33{,}21}{2} = 16{,}61kN \leq F_{v,Rd} = \frac{0{,}5*f_{ub}*A_s}{\gamma_{M2}} = \frac{0{,}5*90*1{,}57}{1{,}25} = 56{,}52kN$$ ustreza!

Kontrola zvarov:
Vozliščna pločevina debeline 15mm je na steber Φ 219 privarjena z zvarom a=7mm.

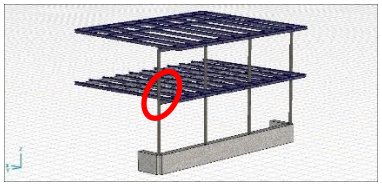
$$a_{min} = 3mm$$
$$a_{max} = 0{,}7 * 10mm = 7mm$$
$$a_{dej} = 7mm$$

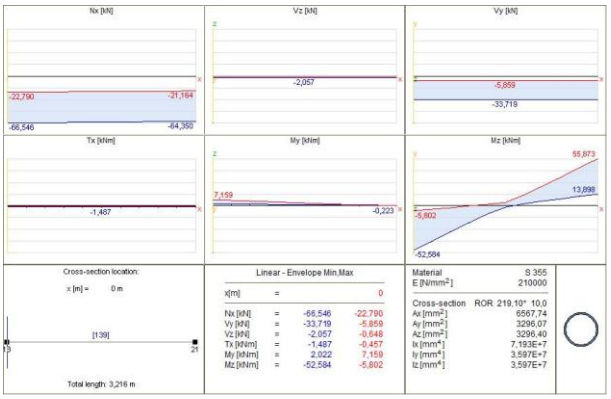
Zvar: $F_{wRd} = {}^{430}\big/_{(\sqrt{3}} * 0{,}85 * 1{,}35) * 7 = 1{,}52\ kN/mm$

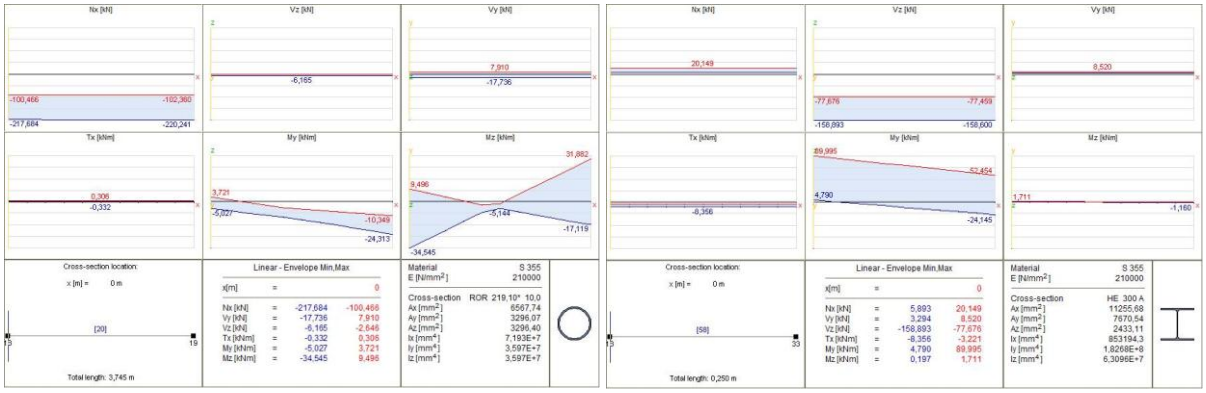
Za nateg (plošča na steber):→ $l_{pot} = {}^{266{,}78}\big/_{1{,}52} = 175{,}51mm;\ l_{zv\ dej} = 164 + 2x40 = 244mm$

Za nateg (plošča na HEA240):→ $l_{pot} = {}^{266{,}78}\big/_{1{,}52} = 175{,}51mm;\ l_{zv\ dej} = 240mm$

2.3.4.8 STIK STEBER – NOSILEC HEA 300 os 1,4







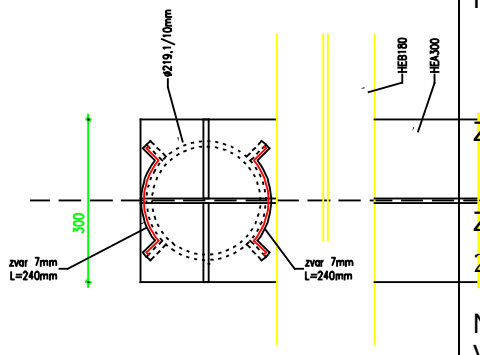
Varjeni stik med HEA 300 in cevjo 219,1/10

$M_{max} = M_z$ = 52,58 kNm → Z = 52,58/0,22-66,55 = 172,45 kN

N_{pripad} = -66,55 kN

$V_{y,pripad}$ = -33,72 kN → $Q_z = \sqrt{33{,}72^2 + 2{,}06^2}$ = 33,78 kN

$V_{z,pripad}$ = -2,06 kN



Kontrola zvarov:

HEA300 je na steber Φ 219 privarjen z zvarom a=7mm.

$$a_{min} = 3mm$$
$$a_{max} = 0{,}7 * 10mm = 7mm$$
$$a_{dej} = 7mm$$

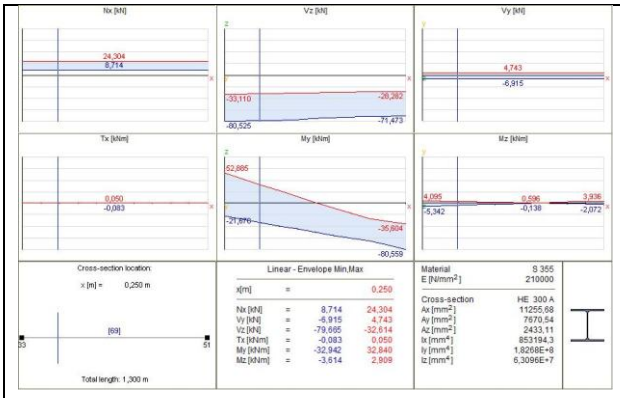
Zvar: $F_{wRd} = {}^{430}/_{(\sqrt{3} * 0{,}85 * 1{,}35)} * 7 = 1{,}52\ kN/mm$

Za nateg:→ $l_{pot} = {}^{172{,}45}/_{1{,}52} = 113{,}45mm;\ l_{zv\,dej} = 164 + 2x40 = 244mm$

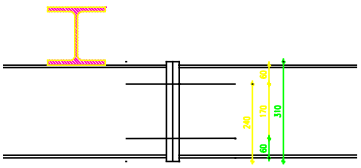
Na stiku min »krilca 40/40/10mm!

Vgraditi simetrično 4 kose.

Vijačni spoj na nosilcu HEA 300 (550mm iz osi stebra)



$M_y = \pm$ 32,90 kNm →Z=32,90/0,24+24,30=
=161,38 kN
N_{pripad} = 24,30 kN
$V_{y,}$ = -6,92 kN→ $Q_z = \sqrt{6{,}92^2 + 79{,}67^2}$=79,97 kN
V_z = -79,67 kN



Kontrola zvarov:
HEA300 je na vezno pločevino debeline 20mm privarjen z zvarom a=7mm.

$$a_{min} = 3mm$$
$$a_{max} = 0{,}7 * 8{,}5mm = 6mm$$
$$a_{dej} = 6mm$$

Zvar: $F_{wRd} = {}^{430}/_{(\sqrt{3}} * 0{,}85 * 1{,}35) * 6 = 1{,}30\ kN/mm$

Za nateg:→ $l_{pot} = {}^{161{,}38}/_{1{,}30} = 123{,}87mm;\ l_{zv\,dej} = 300mm$

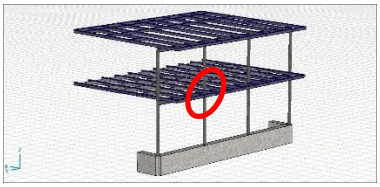
Kontrola vijaka:
NATEZNA NOSILNOST VIJAKOV M20 :

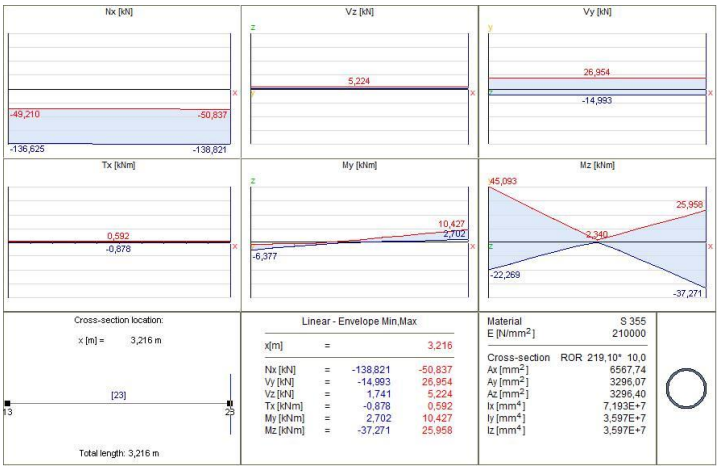
$F_{t,Ed} = \frac{Z}{2} = \frac{161{,}38}{2} = 80{,}69kN \leq F_{t,Rd} = \frac{0{,}9 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}9 * 90 * 2{,}45}{1{,}25} = 158{,}77kN$; ustreza!

STRIŽNA NOSILNOST VIJAKOV M20 :

$F_{v,Ed} = \frac{Qz}{2} = 40{,}00kN \leq F_{v,Rd} = \frac{0{,}5 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}5 * 90 * 2{,}45}{1{,}25} = 88{,}2kN$; ustreza!

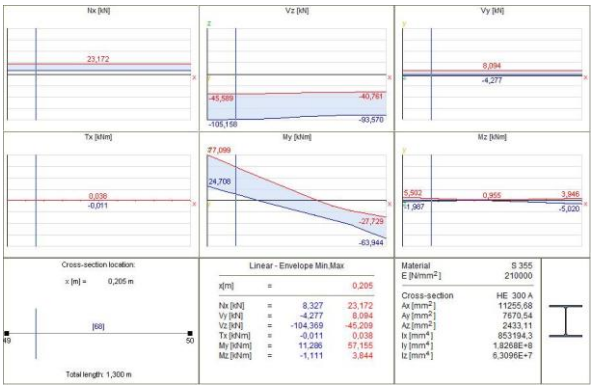
2.3.4.9 STIK STEBER – NOSILEC HEA 300 os 2,3

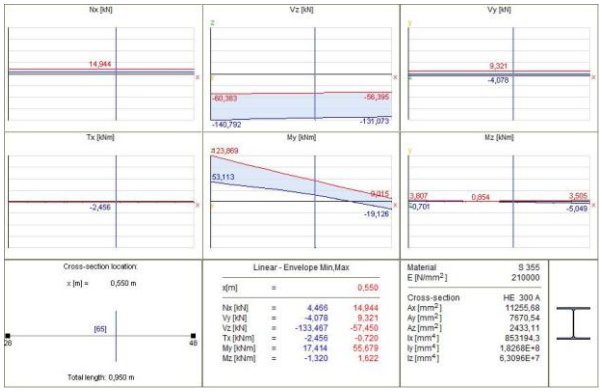




Stik steber - HEA : glej tč. 2.3.4.8

Vijačni spoj na nosilcu HEA 300 (550mm iz osi stebra):



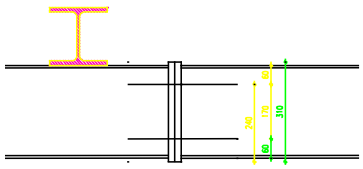


M_y= 57,16 kNm →Z=57,16/0,24+23,17 =261,33 kN
N_{pripad} = 23,17 kN

$V_{y,}$ = -104,37 kN→ Q_z =$\sqrt{104{,}37^2 + 4{,}28^2}$=104,46 kN
V_z = -4,28 kN

M_y= 55,68 kNm →Z=55,68/0,24+14,94 =246,94 kN
N_{pripad} = 14,94 kN

$V_{y,}$ = -133,47 kN→ Q_z =$\sqrt{133{,}47^2 + 4{,}08^2}$=133,53 kN
V_z = -4,08 kN



Kontrola zvarov:
HEA300 je na vezno pločevino d=20mm privarjen z zvarom a=7mm.

$$a_{min} = 3mm$$
$$a_{max} = 0{,}7 * 8{,}5mm = 6mm$$
$$a_{dej} = 6mm$$

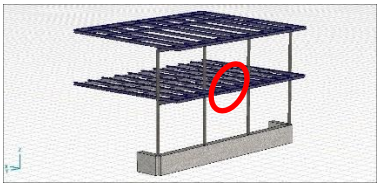
Zvar: $F_{wRd} = {}^{430}\big/_{(\sqrt{3} * 0{,}85 * 1{,}35) * 6} = 1{,}30\ kN/mm$

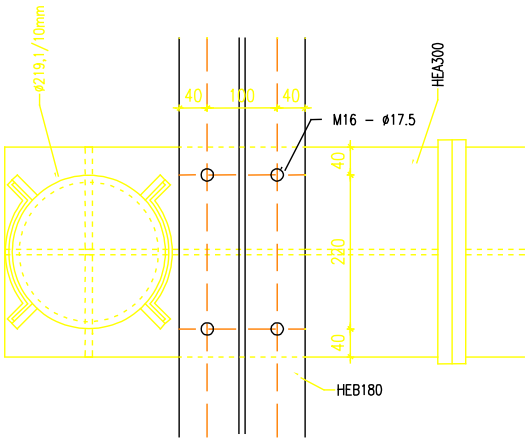
Za nateg:→ $l_{pot} = {}^{261{,}33}\big/_{1{,}30} = 201{,}0mm;\ l_{zv\,dej} = 300mm$

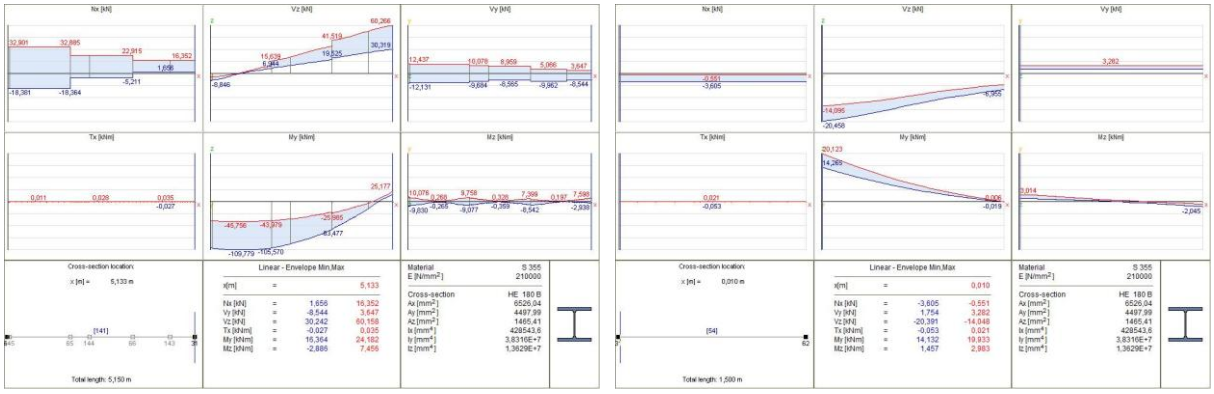
Kontrola vijaka:
NATEZNA NOSILNOST VIJAKOV M20 :
$F_{t,Ed} = \frac{Z}{2} = \frac{261{,}33}{2} = 130{,}66kN \leq F_{t,Rd} = \frac{0{,}9 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}9 * 90 * 2{,}45}{1{,}25} = 158{,}77kN$; ustreza!

STRIŽNA NOSILNOST VIJAKOV M20 :
$F_{v,Ed} = \frac{Qz}{2} = \frac{133{,}53}{2} = 66{,}77kN \leq F_{v,Rd} = \frac{0{,}5 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}5 * 90 * 2{,}45}{1{,}25} = 88{,}2kN$; ustreza!

2.3.4.10 STIK NOSILEC HEA 300 – HEB180







Strižne sile na vijačni spoj
N_x = 16,35 kN
$V_{(141)y}$ = 8.54 kN ; $V_{(54)y}$ = 3,28 kN → V_y = 8,54 + 3,38 = 11,82 kN
$Q_z = \sqrt{16{,}35^2 + 11{,}82^2} = 20{,}18$ kN
M_z = 7,59 kNm →Q_{Mz} =7,59/0,10 =75,90 kN
Q = 20,18 + 75,90 = 96,08 kN

Kontrola vijaka:
STRIŽNA NOSILNOST VIJAKOV M16 :

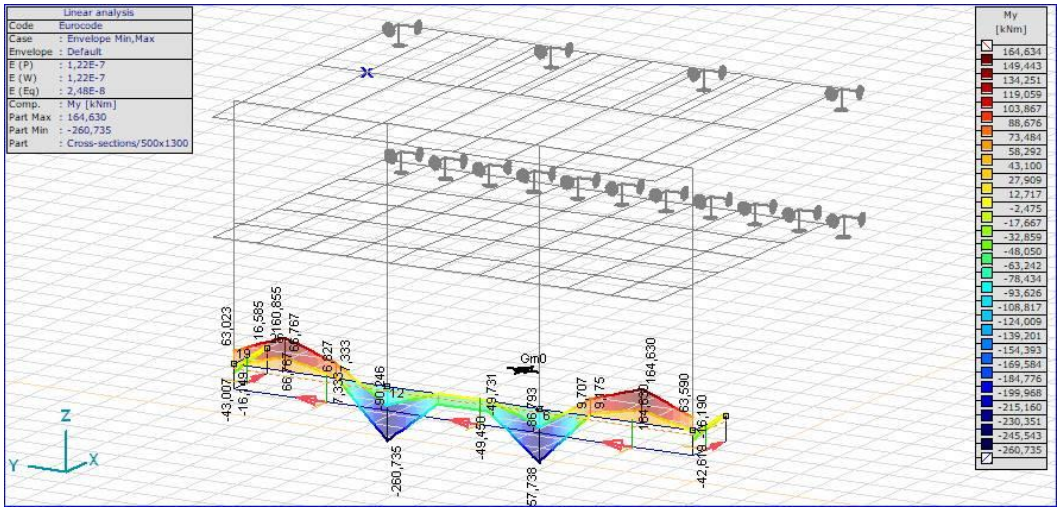
$$F_{v,Ed} = \frac{Qz}{2} = \frac{96{,}08}{2} = 48.03kN \leq F_{v,Rd} = \frac{0{,}5 * f_{ub} * A_s}{\gamma_{M2}} = \frac{0{,}5 * 90 * 1{,}57}{1{,}25} = 56{,}52kN$$; ustreza!

2.3.5 Temeljna greda

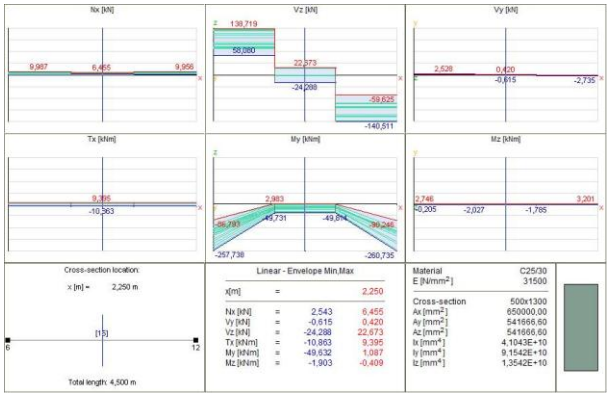
- *Opis elementov dela konstrukcije*

Temeljne grede so dim b/h = 70/130cm in so iz betona C25/30 ter armirane z rebrasto armaturo S500B. Zaščitni sloj betona je 5cm.
Greda je računana kot elastično podprti nosilec in je obremenjena z akcijo jeklene nadgradnje (objekta). Stebri so v gredo vpeti preko sidrnih plošč in vijakov.

- *Kontrola grede (v osi A)*

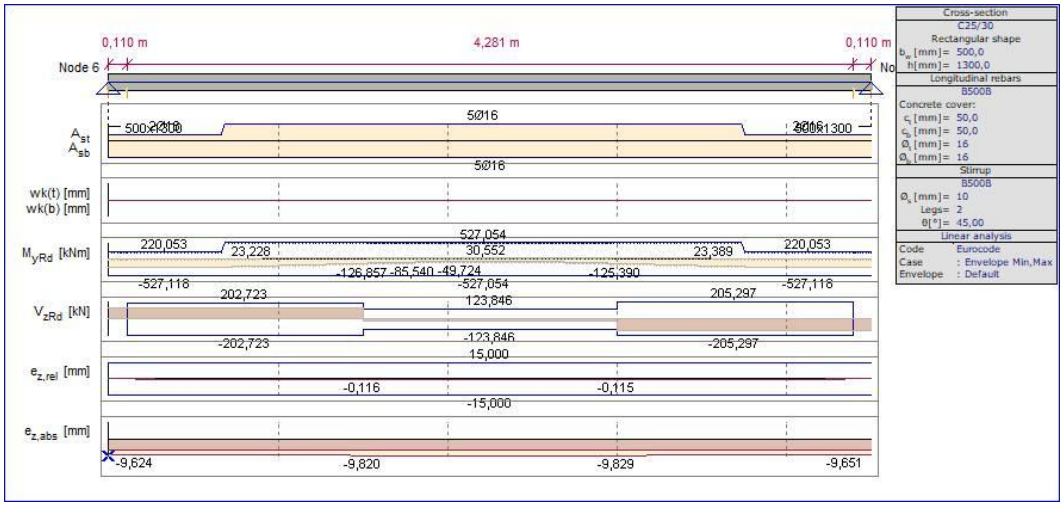


M_y greda v osi A



Notranje sile v gredi 15

Co

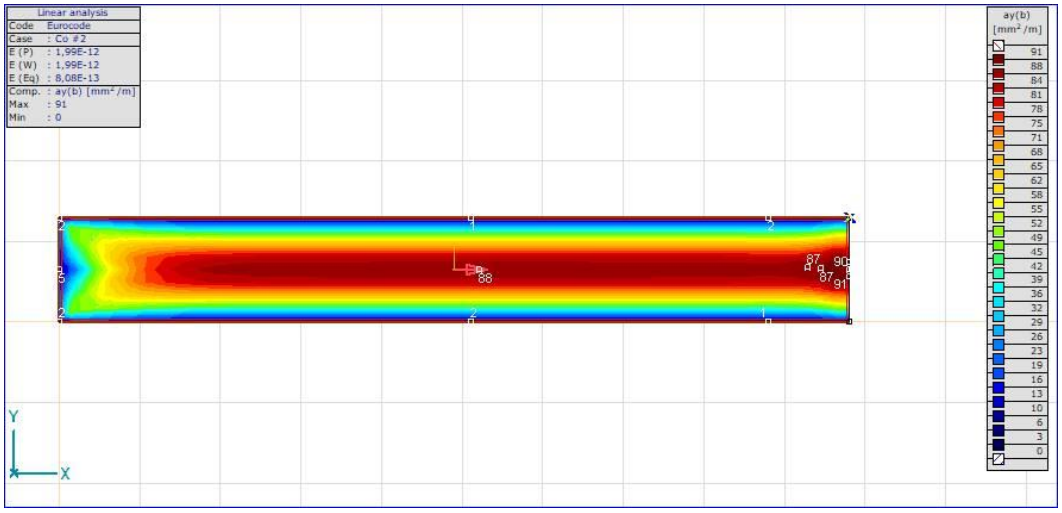


Potrebna armatura 5 Φ 16, stremena (izberem) Φ 10/25 cm

2.3.6 Etažna plošča med HEB nosilci

- *Opis elementov dela konstrukcije*

Plošča je debeline 10cm iz betona C25/30 ter armirana z mrežno armaturo MAG 500.
Zaščitni sloj betona je 1,5cm.
Plošča prenaša obtežbo etaže med nosilci HEB, ki so v osnem razmiku 130cm.



Potrebna armatura v y smeri 0,91cm^2/m^1

Izberem konstruktivno : ±Q mreža 283; sidra na HEB fi 10/30cm!

3.0 PROJEKTNE ZAHTEVE

1.1 ZA BETON

1.1.1 Sestava betonskih mešanic

Beton je potrebno proizvajati v betonarni, ki je pod stalnim nadzorstvom pooblaščene institucije in ima vsa potrebna potrdila o usposobljenosti proizvodnje betona. Beton je potrebno proizvajati po recepturah, ki so tekoče potrjene s strani pooblaščene institucije, v sklopu poročil o rednem nadzoru kontrole kakovosti pri proizvodnji betona. Tekočo kontrolo proizvodnje sveže betonske mešanice mora kontrolirati laboratorij betonarne, ki pa mora biti za to usposobljen in imeti ustrezna potrdila za :

- Kameni agregat mora ustrezati kriterijem podanim v SIST EN 12620:2002; agregat mora imeti sejalno analizo frakcij izvedeno po standardu SIST EN 933-1 in preskus ugotavljanja finih delcev – ekvivalent peska po standardu SIST EN 933-8.
- Cement mora ustrezati standardu SIST EN 197-1
- Voda; uporabiti pitno vodo ali pa dokazati skladnost s standardom SIST EN 1008
- Kemijski dodatki betonu; potrebno je uporabiti dodatke za preprečevanje oz. omejevanje tehnološkega krčenja svežega betona. Vsi dodatki morajo ustrezati zahtevam določenim s SIST EN 934-2; T 3.1/3.2.
- mineralni dodatki – ekspanditor mora ustrezati kriterijem po SIST EN 206-1 oziroma v primeru uporabe mikrosilike pa SIST EN 13263-1:2005.

1.1.2 Način transportiranja in vgrajevanja betonske mešanice

Betonsko mešanico je potrebno iz betonarne do gradbišča transportirati z avtomešalci. Vsak avtomešalec mora imeti spremni list v skladu z veljavnimi standardi, na katerem je zapisana ura zamešanja ter ura prihoda na gradbišče.
Med transportom betona in vgrajevanjem se ne sme dodajati voda, temveč se mora zaradi morebitne spremembe konsistence dodajati le superplastifikator direktno v avtomešalec, na kar je potrebno hruško avtomešalca vrteti še 5,5 minute preden se začne vgrajevanje. Transport betona sme trajati max 45 minut.
Pri vseh betonažah, ne glede na količino betona, mora biti prisoten laborant tehnolog, ki spremlja in kontrolira kvaliteto svežega betona, o čemer se vodi pisna evidenca.
Z avtomešalci pripeljan beton se vgrajuje s pomočjo črpalke za beton, ob obvezni uporabi previbratorjev.
Beton je potrebno vgrajevati v slojih, naslednji sloj se mora vgraditi v času, ko še zagotavlja spojitev s predhodnim slojem. Pri vibriranju vsakega sloja je potrebno vibrirati tudi predhodno vgrajenega. Max višina stenastih elementov, v katere se vgrajuje beton s prostim padom, je 1,5m. Pri višjih elementih je potrebno beton vgrajevati s pomočjo lijaka.
Zgoščevanje betona se vrši z vibracijskimi iglami primerne velikosti glede na razmak med palicami armature in debelino elementov.
Zunanja temperatura v času vgrajevanja betona ne sme biti višja od +25°C in ne nižja od +5°C.

1.1.3 Načrt betoniranja

Vodstvo gradbišča mora pred betoniranjem posameznih elementov konstrukcije izdelati načrt betoniranja in ga predati nadzornemu organu v vednost, z naslednjo vsebino :

- element, ki se betonira;
- količina betona;
- betonarna in vrsta betona;
- transportna sredstva in način vgrajevanja;
- vibracijska sredstva;
- število ljudi ob betoniranju;
- višina sloja betoniranja.

1.1.4 Vgrajevanje betona pod posebnimi okoliščinami

V primeru vgrajevanja betona pri nizkih temperaturah je potrebno:

- uporabljati toplotno izolirane opaže;
- površine betona nad opaži pa zaščititi s toplotnoizolativnimi ploščami (npr. stiropor).

V primeru betoniranja pri visokih temperaturah in vetru je potrebno beton prekriti s filcem, ki mora biti stalno moker.

V vsakem primeru pa je potrebno vršiti betoniranje brez nepotrebnih prekinitev in pospešeno.

1.1.5 Nega betona

Sveže vgrajen beton na objektu je potrebno negovati minimalno 7 (sedem) dni, vendar ne manj kot je potrebno, da beton doseže 60% projektirani trdnostni razred.
Pred vplivom vremenskih vplivov ga je potrebno po betoniranju zaščititi pred:

- prehitrim izsuševanjem;
- prehitro izmenjavo toplote med betonom in zrakom;
- padavinami;
- visokimi in nizkimi temperaturami.

Takoj po betoniranju je potrebno izvesti naslednje ukrepe:

- pred prehitrim sušenjem ga je potrebno zaščititi s filcem in ga stalno močiti;
- pred padavinami je beton potrebno zaščititi s PVC folijo, s katero pokrijemo celotno betonsko konstrukcijo katera je izpostavljena vplivu padavin.

Pred prenizkimi temperaturami (pod +5°C) je beton potrebno zaščititi:

- s toplotnoizolacijskimi ploščami (npr. stiropor deb. min 5cm);
- betonu se poleg dodatkov doda cementol B;
- betonska konstrukcija se po potrebi ogreva.

1.1.6 Program dokazane kontrole betona

Dokazovanje kvalitete betona se vrši z odvzemanjem ustreznega števila kock, tako na mestu priprave betonske mešanice, kot na mestu vgrajevanja betonske mešanice. V betonarni se jemljejo vzorci v skladu z tekočo kontrolo proizvodnje betona. Na gradbišču (mestu vgradnje) se bodo odvzemali vzorci po programu (glej priloženo tabelo) in sicer kocke dim. 20/20/20 cm ali 15/15/15 cm.

TABELA – PROGRAM ODVZEMA BETONSKIH PREIZKUŠANCEV

Konstruktivni element	Trdnostni razred	Količina [m^3]	Število kock za dokazovanje tlačne trdnosti	Druge zahteve	Opombe
Pasovni temelji	C 25/30	14	1		
Plošča	C 25/30	14	1		

1.1.7 Negovanje odvzetih vzorcev

Odvzete vzorce je potrebno še v kalupih postaviti v vlažen prostor ter pokriti s PE folijo. Po 24 urah je potrebno vzorce razopažiti. Na vsak vzorec napišemo sledeče podatke :

- datum betoniranja;
- konstruktivni element (pozicijo);
- zahtevano kvaliteto

Tako označene kocke postavimo v posodo z vodo, ki mora imeti konstantno temperaturo +20°C (+5°C).
Po dvajsetih dneh se preizkušanci, s potrebno dokumentacijo, odpošljejo v laboratorij, kjer se bo določevala tlačna trdnost in ostale zahtevane kvalitete.

1.1.8 Končna ocena

Končno oceno kvalitete betona izdela pooblaščena organizacija v skladu z zahtevami predpisov. Pred končno oceno se zahteva tudi vizualni pregled izvedene betonske konstrukcije.

1.1.9 Druga določila

Izvajalec del mora pred pričetkom betonskih del, glede na svojo tehnologijo opaženja, proizvodnje betona itd, pripraviti projekt betona, ki pa ne sme biti v neskladju s temi projektnimi zahtevami.

1.2 ZA JEKLENO KONSTRUKCIJO

1.2.1 Splošno

Konstrukcija spada v izvedbeni razred EXC2. Vsebina tega načrta predstavlja podlogo za izdelavo :

- delavniškega načrta, ki ga izdela, pred pričetkom izdelave konstrukjcje, izbrani izvajalec izdelave jeklne konstrukcije
- programa montaže jeklene konstrukcije, ki ga izdela montažer jeklene konstrukcije glede na svojo tehnološko opremo in zahteve iz Varnostnega načrta.

Konstrukcija je vijačne izvedbe. Nosilni elementi konstrukcije so med seboj vijačeni. Vsi konstruktivni vijaki so kvalitete HV 10.9. Slednje je potrebno napeti s 50% privojnega momenta. V konstrukcijo morajo biti vgrajeni atestirani materiali. Osnovni material konstrukcije je kvalitete S355. Konstrukcijo lahko varijo samo atestirani varilci. Vsi zvari spadajo v kvalitetni razred B. Kotne zvare, za katere debelina ni predpisana se predpiše v delavniškem načrtu in morajo biti debeline $a=0.7t_{min}$. Na čelnih priključkih priključnih plošč na profile, kjer so robovi priključka poravnani je potrebno pasnico privariti s polnim sočelnim zvarom. Pri čelnih stikih pasnic je potrebno izvesti RTG kontrolo v predpisanem obsegu za B kvaliteto zvarov. Kontrolo mora izvesti inštitucija, ki bo izdelala končno poročilo. Potrebne korekture zaradi varilnih deformacij predvidi izvajalec v delavniškem načrtu. Enako velja za tolerance profilov. Na cevnih profilih mora biti zagotovljena tesnost vseh zvarov.

1.2.2 Nadvišanje konstrukcije

Konstrukcija prizidka se bo deformirala zaradi stalnih in občasnih vplivov. Za zmanjšanje deformacije je potrebno konstrukcijo nadvišati. Višina nadvošanja posameznih elementov je predvidena v statičnem izračunu (glej str. 18). Slednje je potrebno upoštevati pri izdelavi delavniškega načrta.

1.2.3 Zaščita jekla pred korozijo

Pred korozijo je konstrukcija zaščitena z antikorozijskim sitemom, ki se dogovori z investitorjem. Projektno je predvideno barvanje elementov jeklene konstrukcije.

Protikorozijska zaščita se določa v tehnologiji protikorozijske zaščite. Predpisana je priprava površine po SIST EN ISO 12944-4. Glede na agresivnost okolja se določi sistem protikorozijske zaščite.

Jeklena konstrukcija se pred korozijo materiala zaščiti pasivno s premaznimi sredstvi, ki zagotavljajo pričakovano veliko trajnost (L), več od 15 let po standardu ISO 12994 za najmočnejše obremenjeno industrijsko okolje. Pri načrtovanju in izvedbi protikorozijske zaščite je potrebno upoštevati določila skupine standardov SIST EN ISO 12944 (deli 1,2,3,4,5,6,7,8). Sistem zaščite mora izkazovati ustrezno kvaliteto in trajnost glede na agresivno okolje konstrukcije. S tem projektom je kot varianta predvidena naslednja sestava PKZ:

- priprava površine - peskanje Sa2½ (SIST EN ISO 12944-4)
- sistem premazov
    - osnovni premaz Epoksi-ZN
      dvokomponentni epoksi temeljni premaz
    - vmesni premaz Epoksi Miox (dbs)
      dvokomponentni debeloslojni epoksi medslojni premaz (MIOX):
    - pokrivni premaz 2K PUR emajl
      dvokomponentni poliuretanski pokrivni premaz

1.2.4 Sidranje konstrukcije v AB elemente objekta

Konstrukcija je sidrana v obstoječe AB grede in sicer na nivoju +3,60m in +7,00m in v nov pasovni temelj na koti -0,20m.

- Nivo -0,20 :

Nosilni stebri so preko vozliščne plošče debeline 15mm sidrani v nov pasovni AB temelj s štirimi kemičnimi sidri M20. Projektno je izbrano in računsko preverjeno sidro tipa HIT-HY 200-A s sidrnimi palicami HIT-V. Globina sidranja je min 200mm. Sidro je potrebno vgraditi skladno z navodili proizvajalca.
Za anuliranje toleranc (neravnin) na temeljni gredi je predvideno, da se stebri podlijejo s spodlivno npr. Tekamal Alteks maso v debelini do 3cm.

- Nivo +3,60 :

Nosilci HEB 180 so preko vozliščne plošče debeline 20mm sidrani v AB gredo dim 40/50cm z dvema

kemičnima sidroma M20 v horizontalni smeri. Vertikalno pa je sidranje predvideno z dvema kemičnima sidroma M12.
Projektno je izbrano in računsko preverjeno sidro tipa HIT-HY 200-A s sidrnimi palicami HIT-V. Globina sidranja je min 120mm oz. za sidri M12 80mm. Sidro je potrebno vgradi skladno z navodili proizvajalca.
Za anuliranje toleranc (neravnin) na obstoječi AB gredi je predvideno, da se izdelaležišče npr. s Tekamal Alteks maso v debelini do 5cm.

- Nivo +7,00 :

Vzdolžni nosilec HEA 180, ki poteka vzporedno s fasado obstoječega objekta je preko štirih vozliščnih plošč debeline 12mm sidran v AB gredo dim 35/60cm. Vsaka plošča je v AB gredo sidrana s po štirimi kemičnimi sidri M20. Projektno je izbrano in računsko preverjeno sidro tipa HIT-HY 200-A s sidrnimi palicami HIT-V. Globina sidranja je min 120mm. Sidro je potrebno vgraditi skladno z navodili proizvajalca.

1.2.5 Zaključne zahteve

Vsa odstopanja od predpisanih zahtev mora pisno potrditi Odgovorni projektant gradbene konstrukcije. V času izdelave in montaže mora biti zagotovljen stokovni nadzor nad izvajanjem del. Zakoličba jeklene konstrukcije mora biti izvedena na osnovi geodetskih izmer betonske konstrukcije in obstoječe konstrukcije. Po končani izdelavi konstrukcije mora izvajalec pridobiti zaključno poročilo o pregledu jeklenih konstrukcij pri ustrezni inštituciji in konstrukcijo primerno označiti s CE oznako.

III. TEHNIČNI PRIKAZI

1.0 MONOLITNI DEL

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2.0 JEKLENI DEL

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2.2	TLORIS NADSTROPJA	1:50
2.3	TLORIS OSTREŠJA	1:50
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2.8	DETAJLI VOZLIŠČ	1:10

IV. PROJEKTANTSKI POPIS DEL

Glej v ločeni mapi!

V. NAVODILA ZA GRADNJO

Montažne načrte (prikaz montaže in demontaže gradbenih elementov in sklopov, kakor tudi opažne načrte betonskih sten) izdela izvajalec del skladno z navodili dobaviteljev materiala in predvideno tehnološko opremo. Pred vgradnjo jih mora potrditi odgovorni projektant tega načrta.

Jeklena konstrukcija je zasnovana tako, da se pri montaži z dvigalom najprej medsebojno zvijačijo vogalni stebri prekladni nosilec in strešni nosilec. Celoten okvir se postavi na mesto in polno posidra v temelno gredo. Ker projektno ni predvideno polno vpetje v temelj, mora biti okvir začasno podprt z opiračami. Po postavitvi drugega okvirja se dogradijo prečke v kapu in slemenu. Vse do polnega napetja diagonal morajo biti nosilni okvirji varovani proti prevrnitvi. Nato sledi montaža leg etaže.

Potredna dodatna navodila za gradnjo se bodo podala v času izvjajanja projektantskega nadzora, z vpisom v gradbeni dnevnik ter s sklepi koordanicijskih sestankov med udeleženci pri graditvi.

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