Proračun čelične konstrukcije proizvodne hale

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SVEUČILIŠTE U SPLITU

FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

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Split, Matice hrvatske 15

STUDIJ:	**PREDDIPLOMSKI SVEUČILIŠNI STUDIJ GRAĐEVINARSTVA**
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PREDMET:	**Osnove metalnih konstrukcija**

ZADATAK ZA ZAVRŠNI RAD

Tema: Proračun čelične konstrukcije proizvodne hale

Opis zadatka: Na temelju zadanih podataka čelične hale potrebno je dimenzionirati glavnu nosivu konstrukciju, sekundarne nosače te spregove konstrukcije.
Način izvedbe: montažno
Materijal konstrukcije: S 355
Objekt se nalazi na području Osijeka.
Razmak okvira: 5,4 (m)

U Splitu, 28.03.2022.

Voditelj Završnog rada:

Prof. dr. sc. Ivica Boko

Proračun čelične konstrukcije proizvodne hale

Sažetak:

Na temelju zadanih podataka čelične hale potrebno je dimenzionirati glavnu nosivu konstrukciju, sekundarne nosače te spregove konstrukcije. Objekt se nalazi na području Osijeka. Proračun se provodi na temelju graničnog stanja nosivosti (GSN) i graničnog stanja uporabljivosti (GSU). Opterećenja koja se javljaju na konstrukciji su stalno: vlastita težina i promjenjivo: snijeg i vjetar. Rezultati unutarnjih sila dobiveni su u računalnom programu „Scia Engineer 2021“.

Ključne riječi:

Čelik, hala, nosiva konstrukcija, stup, rešetka, podrožnica, spregovi, dimenzioniranje, spojevi

Design of a steel manufacturing hall

Abstract:

Based on the information about a steel manufacturing hall, we are required to design it's main supporting structure, secondary structure and bracings. The object is located in Osijek.
The estimate is based on the ultimate limit state (ULS) and servicability limit states (SLS).
The loads which appear on this object are permanent: self weight, and variable: snow and wind.
Internal forces are derived from ,,Scia Engineer 2021''.

Keywords:

Steel, hall, supporting structure, collumn, grating, purlin, bracing, design, joints

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1. TEHNIČKI OPIS

1.1. KONSTRUKTIVNI SUSTAV

Glavni nosivi sustav objekta sastoji se od 11 okvira raspona L = 22 m na međusobnom osnom razmaku od 5,4 m. Sustav krova je rešetkasti nosač složenog oblika, a visina nosača u tjemenu iznosi h = 2,26 m. Visina stupova okvira iznosi H = 5,5 m, pa je ukupna visina okvira H_{uk} = 7,76 m. Krovna ploha je u odnosu na horizontalnu ravninu pod nagibom od 9% .

1.2. STATIČKA ANALIZA SUSTAVA

Proračun je napravljen prema EURONORMAMA - HRN EN 1991 (EC3). Konstrukcija je izložena djelovanju opterećenja od vlastite težine, snijega i vjetra. Proračun progiba i reznih sila izvršen je u računalnom programu Scia Engineer.

Konstrukcija se nalazi na području grada Osijek (I. vjetrovna zona). Lokalna kategorija terena je II. Odgovarajući koeficijenti za vjetar i za snijeg uzeti su prema tome iz propisanih tablica.

Spojevi su proračunati i dimenzionirani u programu IDEA StatiCa.

1.3. KONSTRUKTIVNI ELEMENTI

Stupovi su predviđeni kao europski širokopojasni vrućevaljani H profili HEA 280. Stupovi su oslonjeni na betonske temelje, tako da je na njihovom spoju upotrjebljena čelična ploča dimenzija 500 x 370 x 25 mm. Stupovi su vezani za temelj vijcima M24. Dimenzije i armatura temelja su analizirani u proračunu temelja.

Rešetkasti nosač je predviđen kao nosač izrađen od kvadratnih cjevastih (šupljih) profila. Sastoji se od gornjeg i donjeg pojasa, 11 vertikala međusobnog osnog razmaka 2,2 m i 10 dijagonala. Gornji pojas napravljen je od profila 140x140x7.1 a donji pojas od profila 100x100x5. Vertikale i dijagonale rešetkastog nosača su poprečnog presjeka 80x40x4 mm.

Podrožnica prenosi opterećenja sa krovne plohe na primarne nosače (gornji pojas rešetke). Podrožnice su vijcima vezane za nosač. Krovne podrožnice su izrađene od profila IPE 160, dok su bočne podrožnice
IPE 100 .Također je predviđena i zidna sekundarna konstrukcija na koju se zatvaraju zidni paneli za zatvaranje konstrukcije.

Kao dijagonale krovnih i bočnih **spregova** odabrane su čelične sajle Φ14 mm dok se kao **vertikale spregova** koriste profili dimenzija 70x70x4.

1.4. SPOJEVI

SPOJ STUP – TEMELJ

Spoj se izvodi podložnom pločom dimenzija 500/370/25 (mm) navarenom na kraj stupa i pričvršćenom vijcima M24 k.v. 8.8 nosivim na vlak i odrez, te sidrenim u armirano–betonski temelj. Između podložne ploče i armirano–betonskog temelja podlijeva se ekspandirajući mort.

VLAČNI NASTAVAK REŠETKE

Spoj grede i grede na krovištu ostvaruje se čeonom pločom dimenzija 300/300/15 (mm) i vijcimaM24 k.v. 8.8 nosivim na vlak i odrez

SPOJ STUP – REŠETKA

Spoj grede na pojas stupa ostvaruje se čeonom pločom dimenzija 300/285/10 (mm),ukrutom i vijcima M12 k.v. 8.8 nosivim na vlak i odrez.

1.5. PRIMIJENJENI PROPISI

Proračun čelične konstrukcije hale proveden je prema sljedećim propisima:

Analiza opterećenja	
HRN EN 1991-2-1	vlastita težina građevine
HRN EN 1991-2-3	djelovanje snijega na konstrukciju
HRN EN 1991-2-4	djelovanje vjetra
na konstrukciju	
Dimenzioniranje	
HRN EN 1993	dimenzioniranje čeličnih konstrukcija
HRN EN 1992	dimenzioniranje armirano-betonskih konstrukcija

1.6. MONTAŽA I TRANSPORT

Pozicije okvira kao što je prikazano u radioničkom nacrtu glavnog okvira će se izrezati u radionici te transportirati na gradilište i zatim montirati (montažni način izgradnje). Pri tome je potrebno obratiti posebnu pažnju na montažu i transport da bi se izbjegla nepotrebna oštećenja. Izvođač je dužan izraditi plan montaže nosača kojeg treba zajedno sa transportnim planom dostaviti nadzornoj službi na suglasnost. Potrebno je poduzeti sve mjere u skladu s „Pravilnikom o zaštiti na radu“.

1.7. ZAŠTITA OD KOROZIJE

Svi dijelovi čelične konstrukcije moraju biti zaštićeni od korozije prema odredbama „Pravilnika o
tehničkim mjerama i uvjetima za zaštitu čelične konstrukcije od korozije“. Kao vrsta zaštite od korozije odabrana je zaštita premazom boja.

1.8. ZAŠTITA OD POŽARA

U svrhu produljenja zagrijavanja konstruktivnih elemenata predmetne hale, svi takvi elementi moraju se zaštiti posebnim premazima otpornim na visoke temperature. Također je potrebno opremiti objekt za slučaj nastanka požara uređajima za najavu požara kao i opremom za njegovo gašenje.

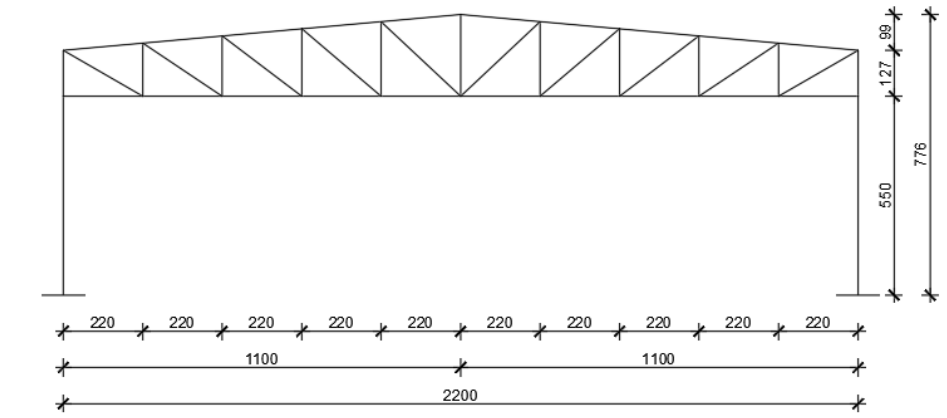
2. OPĆI PODACI, GEOMETRIJA I ANALIZA OPTEREĆENJA

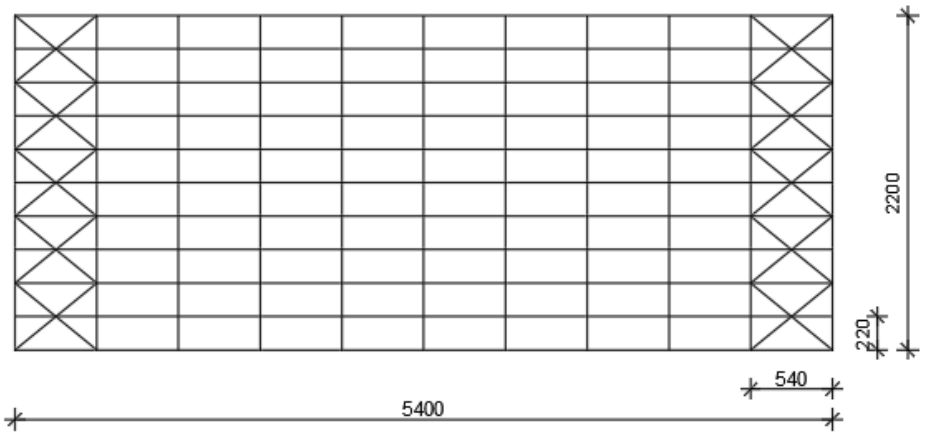
2.1. OPĆI PODACI I GEOMETRIJA NOSIVOG SUSTAVA

Krovni rešetkasti nosač + stupovi

Raspon:	L = 22,0 m
Nagib krovne plohe:	α = tgα=0,99/11→α= 5,1° (kosi krov)
Visina stupova:	H = 5,5 m
Visina rešetkastog nosača:	h = 1,27 + 0,99 = 2,26 m
Ukupna visina nosivog sustava:	H_{uk} = 5,5 + 2,26= 7,76 m
Broj polja rešetke:	10 polja
Razmak vertikalnih podrožnica:	L/10=22/10=2,2 m
Razmak bočnih podrožnica:	H/3=5,5/3=1,83 m
Razmak vertikala rešetke:	a = 2,2 m (x = 2,21 m)
Razmak nosača:	n=5,4m

Prikaz konstrukcije(tlocrt, pogled) sa svim kotama:





2.2. ANALIZA OPTEREĆENJA

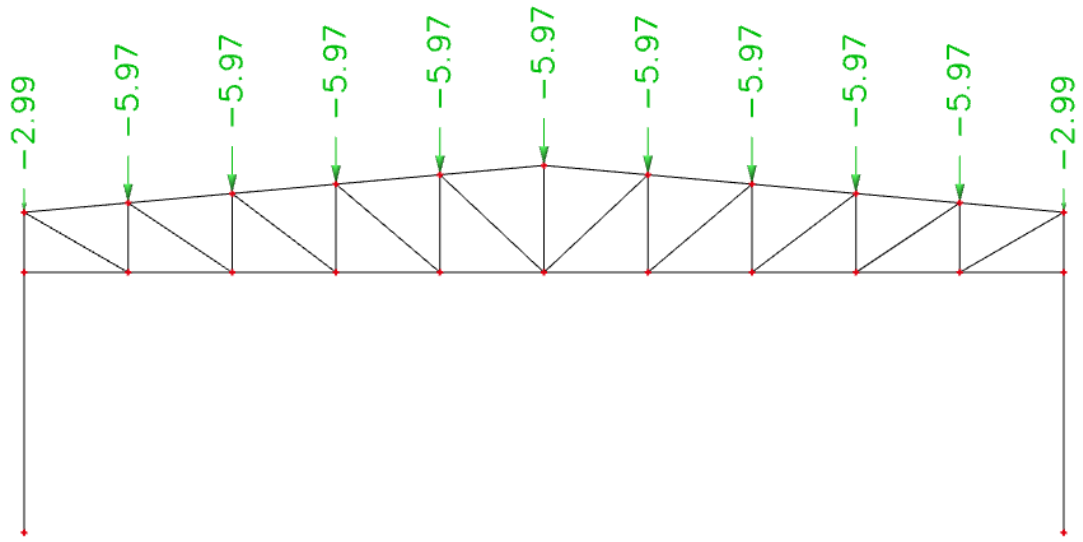
2.2.1. Stalno opterećenje

Krovna ploha:

Sendvič – paneli	0,2 kN/m^2
Sekundarna konstrukcija	0,2kN/m^2
Instalacije	0,1 kN/m^2
	ΔG= 0,5 kN/m^2

$$G = \Delta G * n * x = 0{,}50 * 5{,}4 * 2{,}21 = 5{,}97\ kN$$

Stalno opterećenje u čvorovima okvira



2.2.2. Djelovanje snijega

$$s = s_k * \mu_i * C_e * C_t \ [kN/m^2]$$

μ_i - koeficijent oblika opterećenja snijegom

s_k - karakteristična vrijednost opterećenja snijegom na tlu u kN/m^2

C_e - koeficijent izloženosti (obično se usvaja vrijednost 1,0)

C_t - toplinski koeficijent (obično se usvaja vrijednost 1,0)

$$s_k = 1{,}0\ kN/m^2 \quad za\ Osijek$$

Nagib krova:

μ_i - koeficijent oblika za opterećenje snijegom, očitamo ga ovisno o α (nagib krova)

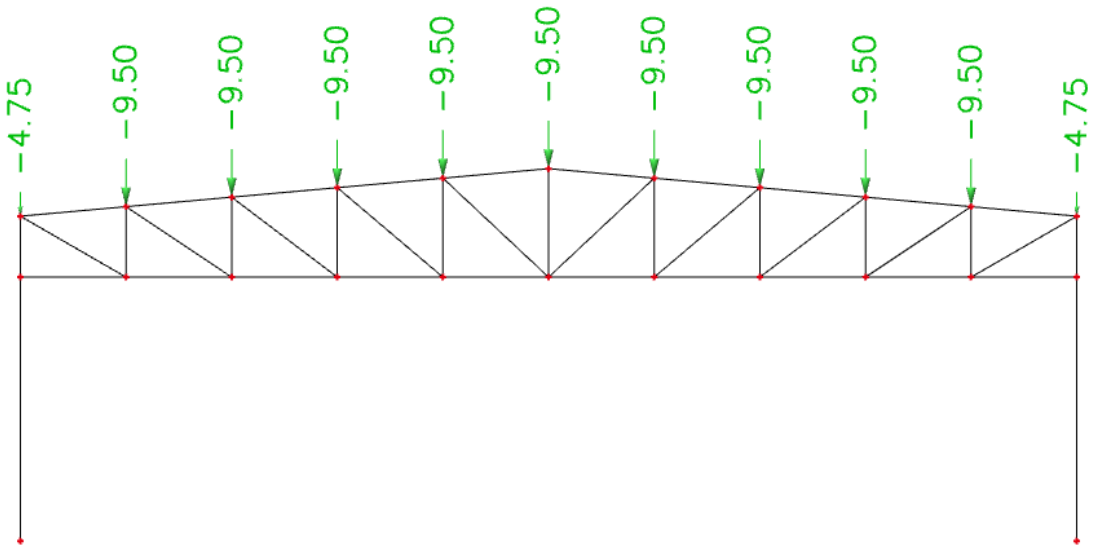
$\mu_i = 0{,}8 \ \rightarrow \ za\ nagib\ krova\ 0° < \alpha < 30°$

Opterećenje snijegom preko cijele krovne površine:

$s = 1{,}0 * 0{,}8 * 1{,}0 * 1{,}0 = 0{,}8\ kN/m^2$

$S = s * n * e = 0{,}8 * 5{,}4 * 2{,}21 = 9{,}5\ kN$

Opterećenje snijegom u čvorovima okvira



2.2.3. Proračun djelovanja vjetra

- pritisak vjetra na vanjske površine: $w_e = q_p|z_e| * c_{pe}\ [kN/m^2]$

- pritisak vjetra na unutarnje površine: $w_i = q_p|z_i| * c_{pi}\ [kN/m^2]$

gdje je:

$q_p(z_e)$ → pritisak vjetra pri udaru

$z_{e(i)}$ → referentna visina za vanjski (unutarnji) pritisak

c_{pe} → vanjski koeficijent pritiska

c_{pi} → unutarnji koeficijent pritiska

Pozitivni i negativni koeficijenti pritiska vjetra

Određivanje pritiska brzine vjetra pri udaru

Osnovni pritisak vjetra **q_b** određuje se prema formuli:

$$q_b = \frac{1}{2} * \rho * {v_b}^2\ \ [kN/m^2]$$

gdje je:

ρ - gustoća zraka (usvaja se vrijednost iz propisa 1,25 kg/m^3)

$v_{b,0}$ - fundamentalna vrijednost osnovne brzine vjetra (očitava se iz karte)

(Osijek $v_{b,0}$ = 20 m/s)

$$q_b = \frac{1}{2} * 1{,}25 * 20^2 = 250\ N/m^2$$

Osnovna brzina vjetra računa se prema izrazu:

$$v_b = c_{dir} * c_{season} * v_{b,0}\ [m/s]$$

gdje je:

v_b – osnovna brzina bjetra
c_{dir} – faktor smjera vjetra (obično se uzima **1,0**)
c_{season} – faktor doba godine (obično se uzima **1,0**)

$$v_b = 1{,}0 * 1{,}0 * 20 = 20\ m/s$$

z = 7,76 m – visina objekta

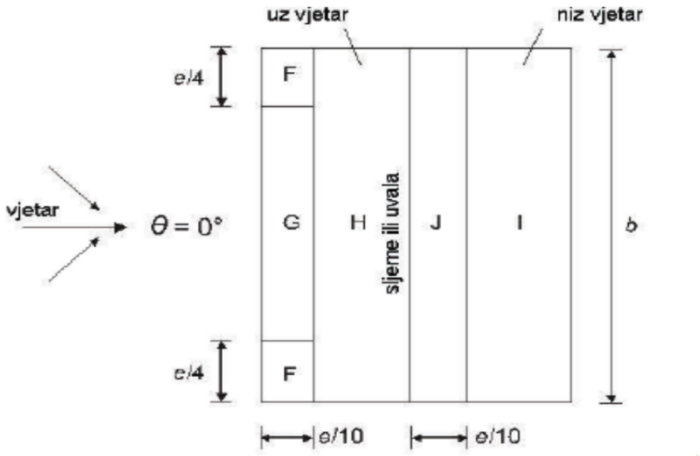
II. kategorija terena → Ce(z) = 2,15 - faktor izloženosti, odnosi se na pritisak te ovisi o visini iznad terena (z) i kategoriji terena

Pritisak brzine vjetra pri udaru $q_p(z)$ se računa kao:

$$\boldsymbol{q_p}|\boldsymbol{z}| = \boldsymbol{c_e}|\boldsymbol{z}| * \boldsymbol{q_b} = 2{,}15 * 250 = 537{,}5\ N/m^2 = 0{,}54\ kN/m^2$$

Pritisak vjetra na vanjske površine:

Vertikalne površine konstrukcije



-parametar e: e= min{b;2h}= min{54;15,52}= 15,52m

h/d = 7,76/22 = 0,35

Očitavamo koeficijente vanjskog pritiska za zone:

α=5,1°	F	G	H	I	J
c_{pe10}	-1,7	-1,2	-0,6	-0,6	+0,2

α=5,1°	F	G	H	I	J
c_{pe10}	+0,0	+0,0	+0,0	-0,6	-0,6

Unutarnji vjetar:

Cp_{i1} = + 0,2
Cp_{i2} = - 0,3

PODRUČJE	F	G	H	I	J
$c_{pe,10}$	-1,7	-1,2	-0,6	-0,6	+0,2
W_{e1} (kN/m^2)	-0,92	-0,65	-0,32	-0,32	+0,11

PODRUČJE	F	G	H	I	J
$c_{pe,10}$	+0,0	+0,0	+0,0	-0,6	-0,6
W_{e1} (kN/m^2)	+0,0	+0,0	+0,0	-0,32	-0,32

1. KOMBINACIJA (maksimalno odizanje) : $q_p(z) \cdot (C_{pe10} + C_{pi1})$

   F: w=0,54 * (1,7+0,2)= -1,03 kN/ m^2
   G: w=0,54 * (1,2+0,2)= -0,76 kN/ m^2
   H: w=0,54 *(0,6+0,2)= -0,43 kN/ m^2
   I: w=0,54 *(0,6+0,2)= -0,43 kN/ m^2
   J:w=0,54 * (0,2-0,2)= 0,0 kN/ m^2

   F: W=5,4 * (-1,03) = -5,56 kN/ m'
   G: W=5,4 * (-0,76) = -4,1 kN/ m'
   H: W=5,4 * (-0,43) = -2,32 kN/ m'
   I: W=5,4 * (-0,43) = -2,32 kN/ m'
   J: W=5,4 * 0,0 = 0,0 kN/ m'

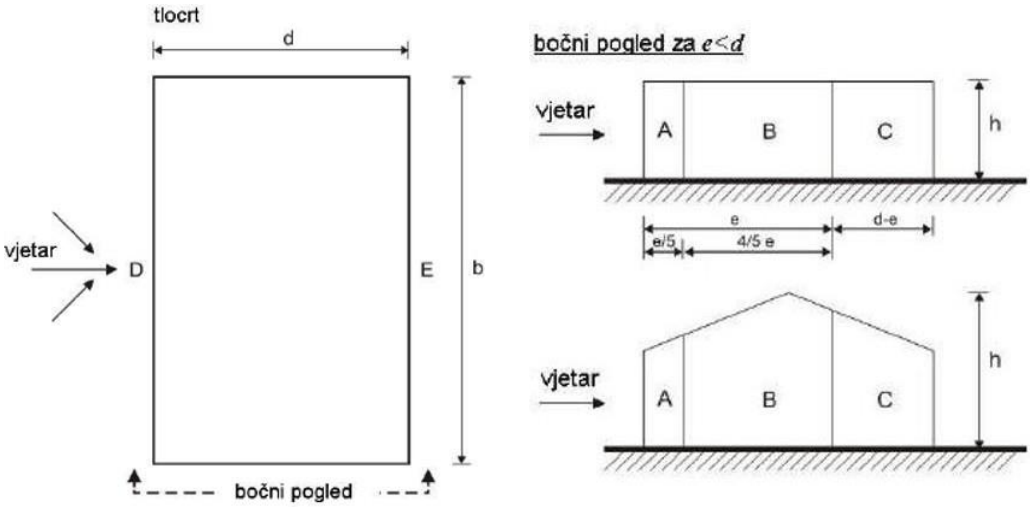
2. KOMBINACIJA (maksimalni pritisak) : $q_p(z) \cdot (C_{pe1} + C_{pi2})$

F1: w=0,54 * (0,0+0,3)=0,16 kN/ m^2
G1: w=0,54 *(0,0+0,3)=0,16 kN/ m^2
H1: w=0,54 * (0,0+0,3)=0,16 kN/ m^2
I1: w=0,54 * (0,2+0,3)= 0,27 kN/ m^2
J1:w=0,54 * (0,2+0,3)= 0,27 kN/ m^2

F1: W=5,4 * 0,16 = 0,86 kN/ m'
G1: W=5,4 * 0,16 = 0,86 kN/ m'
H1: W=5,4 * 0,16 = 0,86 kN/ m'
I1: W=5,4 * 0,27 = 1,46 kN/ m'
J1: W=5,4 * 0,27 = 1,46 kN/ m'

-MJERODAVNE KOMBINACIJE: 1. (maksimalno odizanje) i 2. (maksimalni pritisak)

H/d=0,35



Slika 6 Prikaz područja vjetra za vertikalne zidove

- Koeficijenti vanjskog pritiska na halu za vertikalne zidove h/d=0,35

PODRUČJE	A	B	C	D	E
$c_{pe,10}$	–1,2	–0,8	–0,5	+0,8	–0,5

Tablica 6 Vanjski koeficijenti pritiska prema područjima konstrukcije

Određivanje koeficijenata unutarnjeg pritiska

Koeficijenti c_{pi} ovise o veličini i raspodjeli otvora na oblozi hale (fasada i krov). U ovom primjerunije definiran raspored i veličina otvora, zato se za vrijednost c_{pi} usvajaju vrijednosti:

Unutrašnji koeficijent pritiska → c_{pi} = -0,3 i +0,2

Pritisak vjetra na vanjske površine

$w_e = q_p \cdot c_{pe}$ [kN/m^2]

q_p = 0,54 kN/m^2 -preuzeto iz analize opterećenja glavne nosive konstrukcije

PODRUČJE	**A**	**B**	**C**	**D**	**E**
$\mathbf{c_{pe,10}}$	–1,2	–0,8	–0,5	+0,8	–0,5
$\mathbf{w_e}$ **(kN/m^2)**	-0,65	-0,43	-0,27	+0,43	-0,27

Tablica 7 Vanjski koeficijenti pritiska prema područjima konstrukcije

Pritisak vjetra na unutarnje površine

$w_i = q_p \cdot c_{pi}$ [kN/m^2]

q_p = 0,54 kN/m^2, $c_i(z_i)$ = 2,0

w_i = 0,54 · 0,2 = +0,11 kN/m^2

w_i = 0,54 · (-0,3) = -0,16 kN/m^2

Rezultirajuće djelovanje vjetra

$w_k = w_e - w_i$ [kN/m^2]

1.KOMBINACIJA (pozitivni unutarnji pritisak) : $q_p(z) \cdot (C_{pe10} + C_{pi1})$

A: w=0,54 * (1,2+0,2)= -0,76 kN/ m^2
B: w=0,54 * (0,8+0,2)= -0,54 kN/ m^2
C: w=0,54 *(0,5+0,2)= -0,38 kN/ m^2
D: w=0,54 *(0,8-0,2)= +0,32 kN/ m^2
E:w=0,54 * (0,5+0,2)= -0,38 kN/ m^2

A: W=5,4 * (-0,76) = -4,1 kN/ m'
B: W=5,4 * (-0,54) = -2,92 kN/ m'
C: W=5,4 * (-0,38) = -2,05 kN/ m'
D: W=5,4 * 0,32 = +1,73 kN/ m'
E: W=5,4 * (-0,38) = -2,05 kN/ m'

2.KOMBINACIJA (negativni unutarnji pritisak) : $q_p(z) \cdot (C_{pe10} + C_{pi2})$

A: w=0,54 * (1,2-0,3)= -0,49 kN/ m^2
B: w=0,54 * (0,8-0,3)= -0,27 kN/ m^2
C: w=0,54 *(0,5-0,3)= -0,11 kN/ m^2
D: w=0,54 *(0,8+0,3)= +0,59 kN/ m^2
E:w=0,54 * (0,5-0,3)= -0,11 kN/ m^2

A: W=5,4 * (-0,49) = -2,65 kN/ m'
B: W=5,4 * (-0,27) = -1,46 kN/ m'
C: W=5,4 * (-0,11) = -0,59 kN/ m'
D: W=5,4 * 0,59 = +3,20 kN/ m'
E: W=5,4 * (-0,11) = -0,59 kN/ m

Sile u čvorovima od vjetra W1 (1. kombinacija):

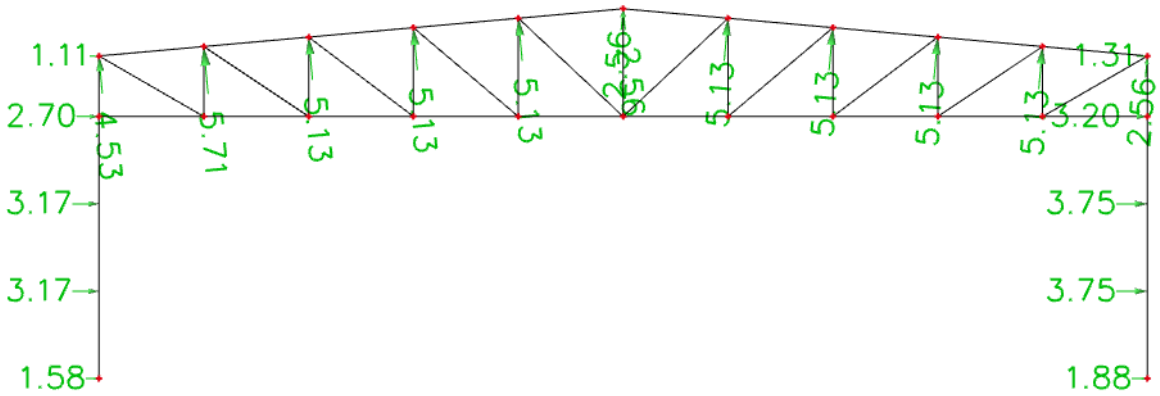
-Krov:

W1 = 1,105 * 4,1 = 4,53 kN
W2 = 0,33 * 4,1 + 1,88 * 2,32 = 5,71 kN
W3 = 2,21 * 2,32 = 5,13 kN
W4 = 2,21 * 2,32 = 5,13 kN
W5 = 2,21 * 2,32 = 5,13 kN
W6 = 1,105 * 2,32 = 2,56 kN
W7 = 1,105 * 2,32 = 2,56 kN
W8 = 2,21 * 2,32 = 5,13 kN
W9 = 2,21 * 2,32 = 5,13 kN
W10 = 2,21 * 2,32 = 5,13 kN
W11 = 2,21 * 2,32 = 5,13 kN
W12 = 1,105 * 2,32 = 2,56 kN

-Stupovi:

W (D1) = 0,64 * (-1,73) = -1,11 kN
W (D2) = 0.64 * (-1,73) + 0,92 * (-1,73) = -2,7 kN
W (D3) = 1,83 * (-1,73) = -3,17 kN
W (D4) = 1,83 * (-1,73) = -3,17 kN
W (D5) = 0,92 * (-1,73) = -1,58 kN

W (E1) = 0,64 * 2,05 = 1,31 kN
W (E2) = 0,64 * 2,05 + 0,92 * 2,05 = 3,2 kN
W (E3) = 1,83 * 2,05 = 3,75 kN
W (E4) = 1,83 * 2,05 = 3,75 kN
W (E5) = 0,92 * 2,05 = 1,88 kN



Sile u čvorovima od vjetra W2 (2. kombinacija):

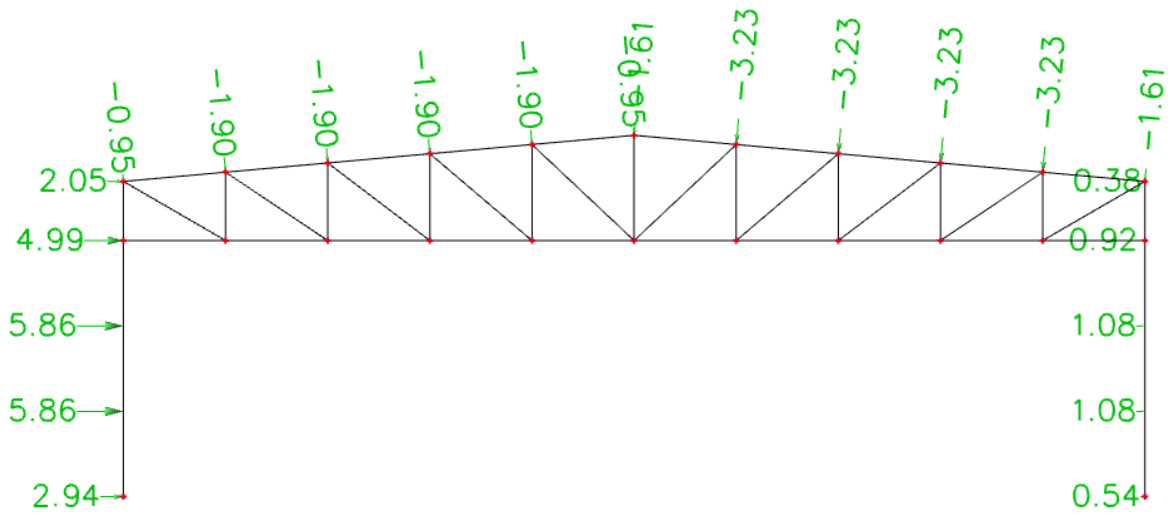
-Krov:

W1 = 1,105 * 0,86 = 0,95 kN
W2 = 2,21 * 0,86 = 1,9 kN
W3 = 2,21 * 0,86 = 1,9 kN
W4 = 2,21 * 0,86 = 1,9 kN
W5 = 2,21 * 0,86 = 1,9 kN
W6 = 1,105 * 0,86 = 0,95 kN
W7 = 1,105 * 1,46 = 1,61 kN
W8 = 2,21 * 1,46 = 3,23 kN
W9 = 2,21 * 1,46 = 3,23 kN
W10 = 2,21 * 1,46 = 3,23 kN
W11 = 2,21 * 1,46 = 3,23 kN
W12 = 1,105 * 1,46 = 1,61 kN

-Stupovi:

W (D1) = 0,64 * (-3,20) = -2,05 kN
W (D2) = 0.64 * (-3,20) + 0,92 * (-3,20) = -4,99 kN
W (D3) = 1,83 * (-3,20) = -5,86 kN
W (D4) = 1,83 * (-3,20) = -5,86 kN
W (D5) = 0,92 * (-3,20) = -2,94 kN

W (E1) = 0,64 * 0,59 = 0,38 kN
W (E2) = 0,64 * 0,59 + 0,92 * 0,59 = 0,92 kN
W (E3) = 1,83 * 0,59 = 1,08 kN
W (E4) = 1,83 * 0,59 = 1,08 kN
W (E5) = 0,92 * 0,59 = 0,54 kN



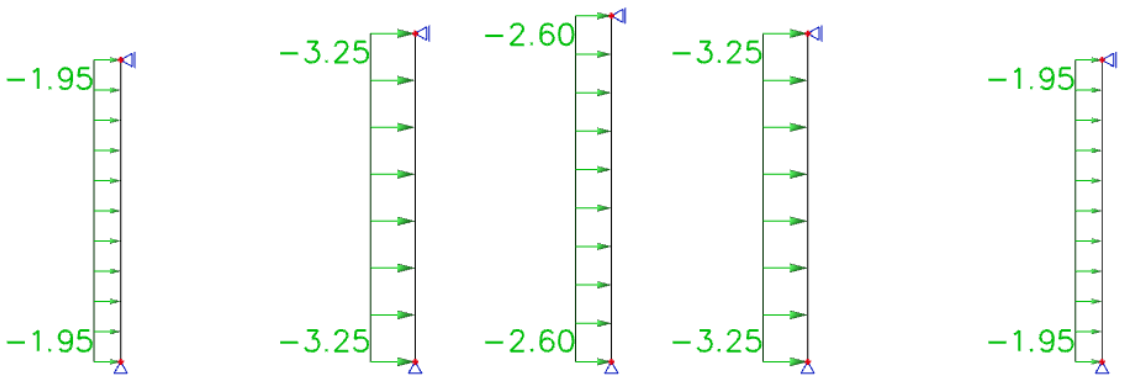
Vjetar na zabatnim stupovima

PODRUČJE	D
$c_{pe,10}$	+0,8

Koeficijent unutrašnjeg pritiska: $C_{pi} = 0,3$

$Wz = 0,54 * (0,8 + 0,3) = 0,59$ kn/m^2

$Wz_1 = 0,59 * 3,3 = 1,95$ kn/m'
$Wz_2 = 0,59 * (3,3 + 2,2) = 3,25$ kn/m'
$Wz_3 = 0,59 * 4,4 = 2,6$ kn/m'
$Wz_4 = 0,59 * (2,2 + 3,3) = 3,25$ kn/m'
$Wz_5 = 0,59 * 3,3 = 1,95$ kn/m'



3. KONTROLA PROGIBA (GSU)

Kombinacije:

Kombinacija: $\mathrm{GSU}_1 = 1{,}00 * \mathrm{G}$ "+" $1{,}00 * \mathrm{S}$ "+" $1{,}00 * \mathrm{W}_{\mathrm{pritisak}}$

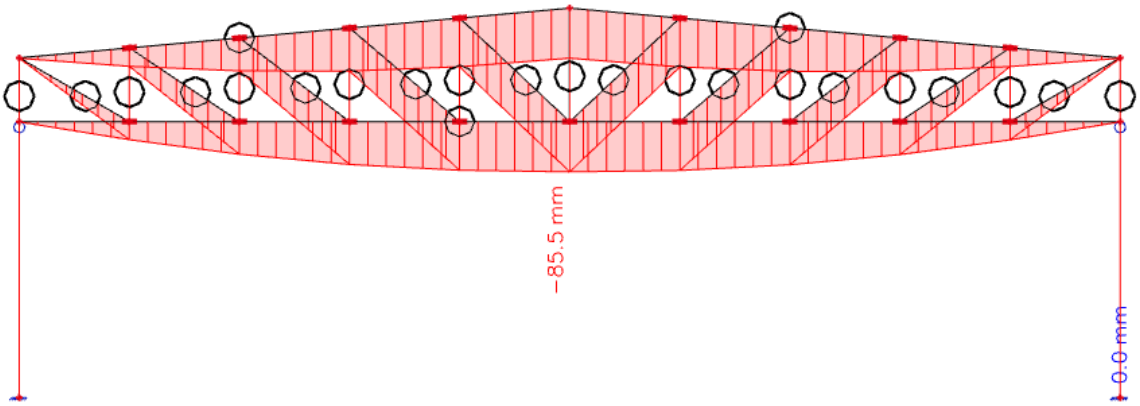
Kombinacija: $\mathrm{GSU}_2 = 1{,}00 * \mathrm{G}$ "+" $1{,}00 * \mathrm{W}_{\mathrm{odizanje}}$

Odabrani profili za koje dobivamo vrijednosti progiba u iznosu od minimalno 80% dopuštenih progiba su:

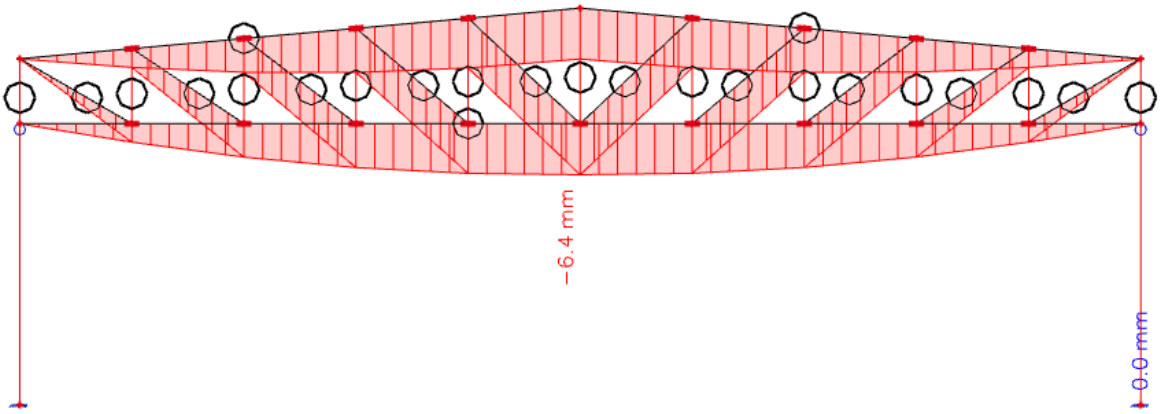
a)stup- HEA 280
b)Gornji i donji pojas – CFRHS 50x50x5

4.1. VERTIKALNI PROGIB U SREDINI DONJEG POJASA REŠETKE

GSU 1



GSU 2



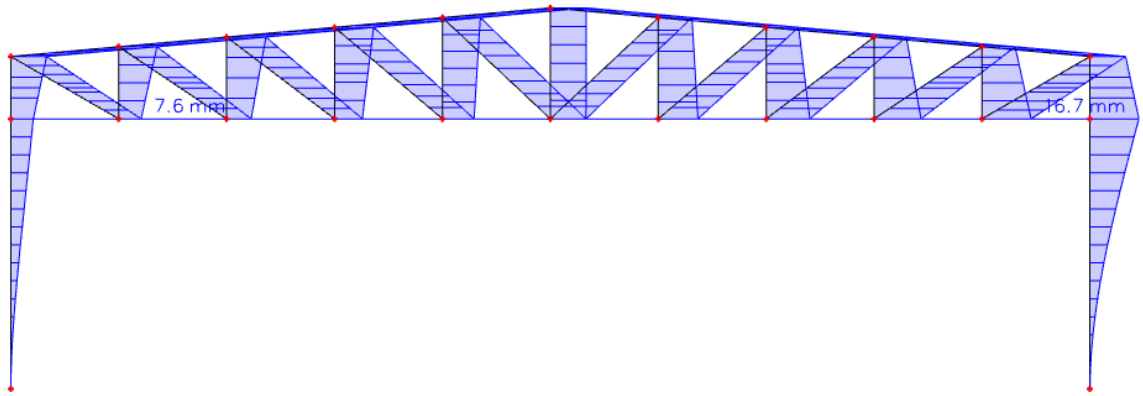
Preporuka: $\mathrm{W}_{\mathrm{FIN.V}} \leq \frac{\mathrm{L}}{250} = \frac{22*1000\ \mathrm{mm}}{250} = 88\ \mathrm{mm}$

$$\mathrm{W}_{\mathrm{GSU1}} = 85{,}50\ \mathrm{mm}$$
$$\mathrm{W}_{\mathrm{GSU2}} = 6{,}40\ \mathrm{mm}$$

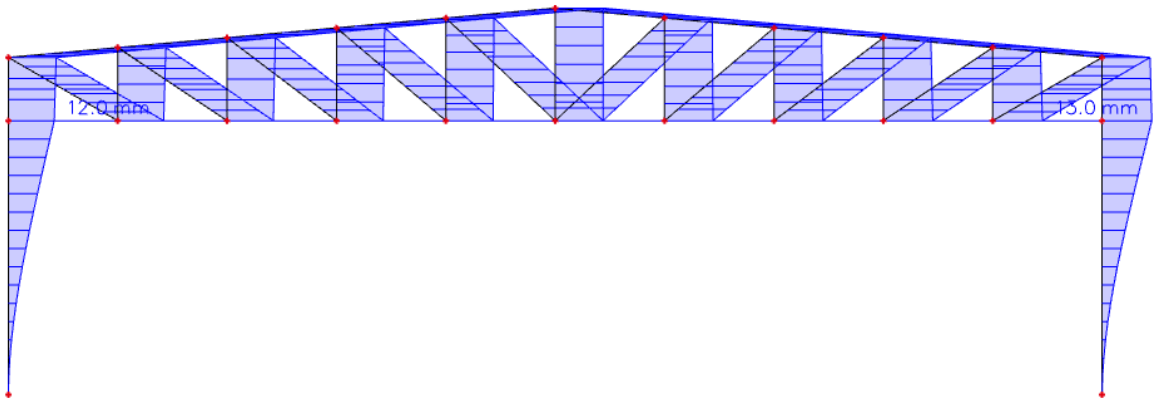
Konačni progib zadovoljava uvjet uz iskoristivost od: : $\boldsymbol{\eta = \frac{85{,}50}{88} = 0{,}9716 = 97{,}16\ \%}$

4.2. HORIZONTALNI PROGIB VRHA STUPA

GSU 1



GSU 2



Preporuka: $W_{FIN.H} \leq \frac{L}{300} = \frac{5{,}5*1000\ mm}{300} = 18{,}33\ mm$

$$W_{GSU1} = 16{,}7\ mm$$
$$W_{GSU2} = 13{,}0\ mm$$

Konačni progib zadovoljava uvjet uz iskoristivost od: : $\boldsymbol{\eta = \frac{16{,}70}{18{,}33} = 0{,}9111 = 91{,}11\ \%}$

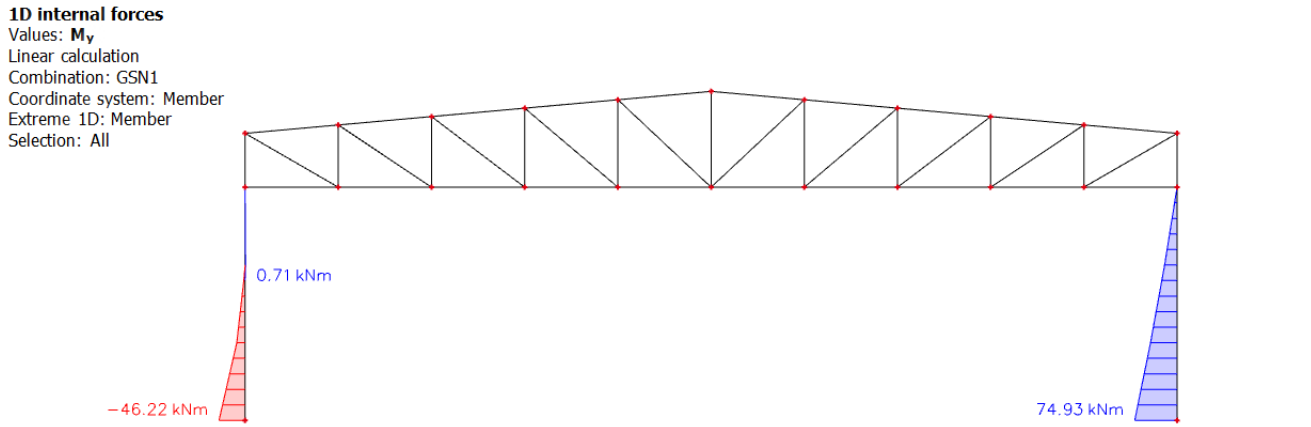
4. DIJAGRAM REZNIH SILA ZA KOMBINACIJE DJELOVANJA (GSN)

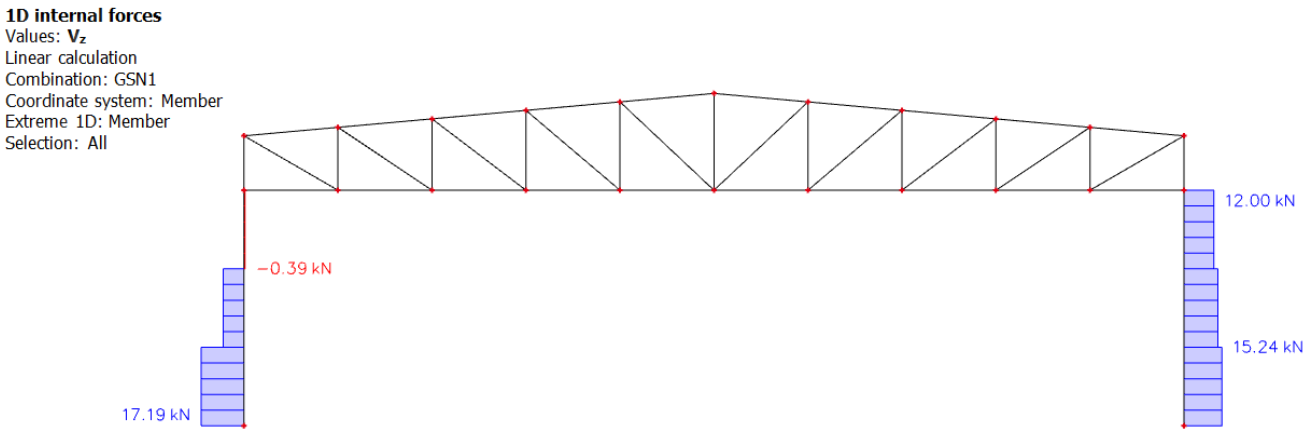
Kombinacije:

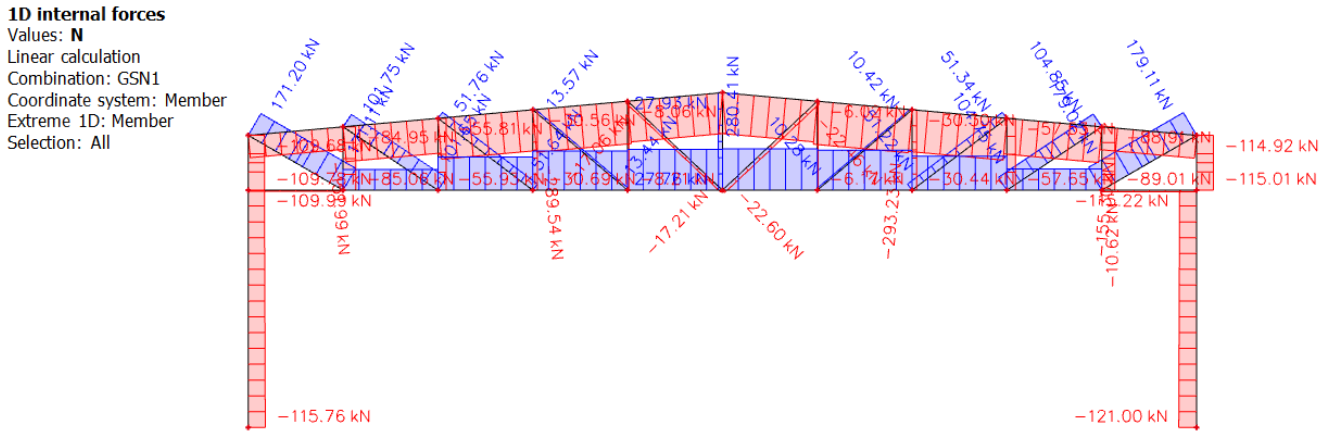
Kombinacija: $\mathrm{GSN}_1 = 1{,}35 * \mathrm{G}$ "+" $0{,}9 * \mathrm{S} + 1{,}5 * \mathrm{W}_{\mathrm{pritisak}}$
Kombinacija: $\mathrm{GSN}_1 = 1{,}35 * \mathrm{G}$ "+" $0{,}9 * \mathrm{W}_{\mathrm{pritisak}} + 1{,}5 * \mathrm{S}$
Kombinacija: $\mathrm{GSN}_2 = 1{,}00 * \mathrm{G}$ "+" $1{,}50 * \mathrm{W}_{\mathrm{odizanje}}$

4.1. Dijagrami reznih sila po modelima:

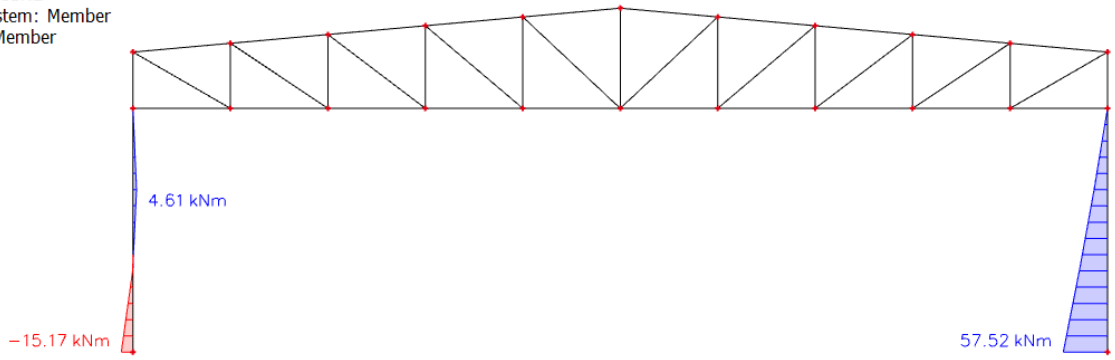
4.1.1. Glavna nosiva konstrukcija



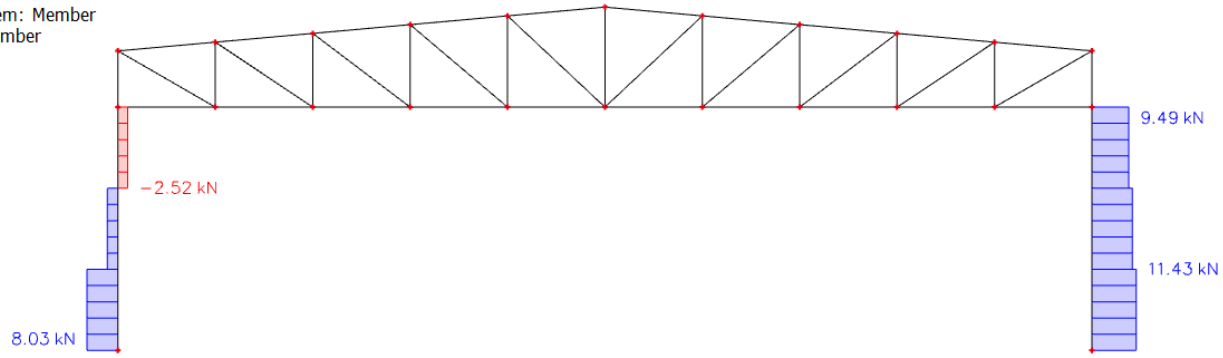




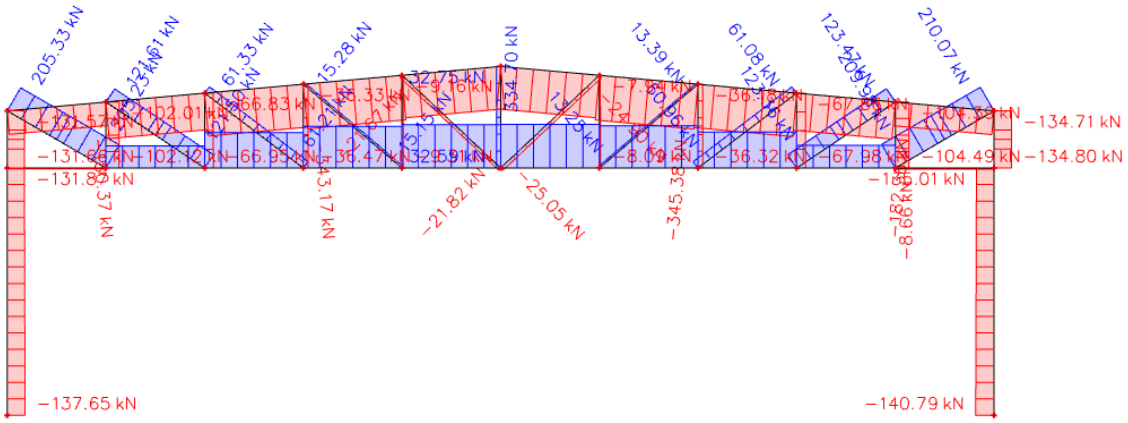
1D internal forces
Values: $\mathbf{M_y}$
Linear calculation
Combination: GSN2
Coordinate system: Member
Extreme 1D: Member
Selection: All



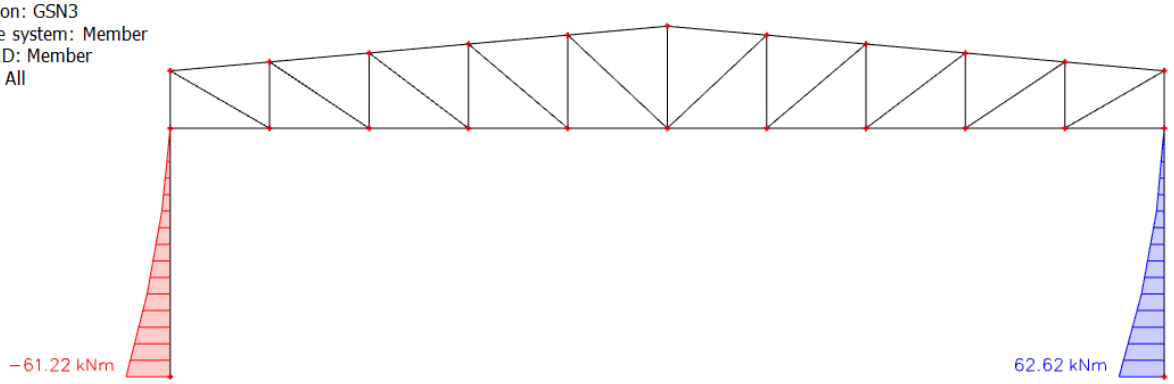
1D internal forces
Values: $\mathbf{V_z}$
Linear calculation
Combination: GSN2
Coordinate system: Member
Extreme 1D: Member
Selection: All



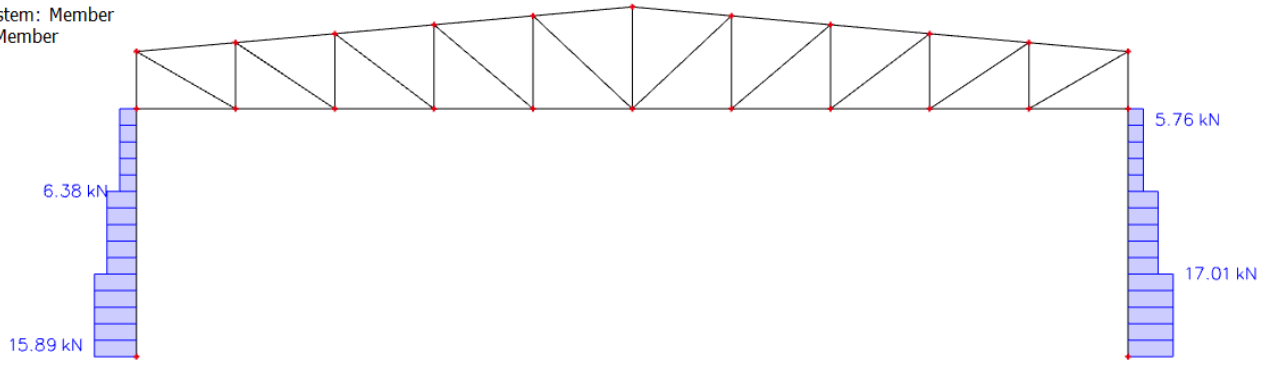
1D internal forces
Values: **N**
Linear calculation
Combination: GSN2
Coordinate system: Member
Extreme 1D: Member
Selection: All



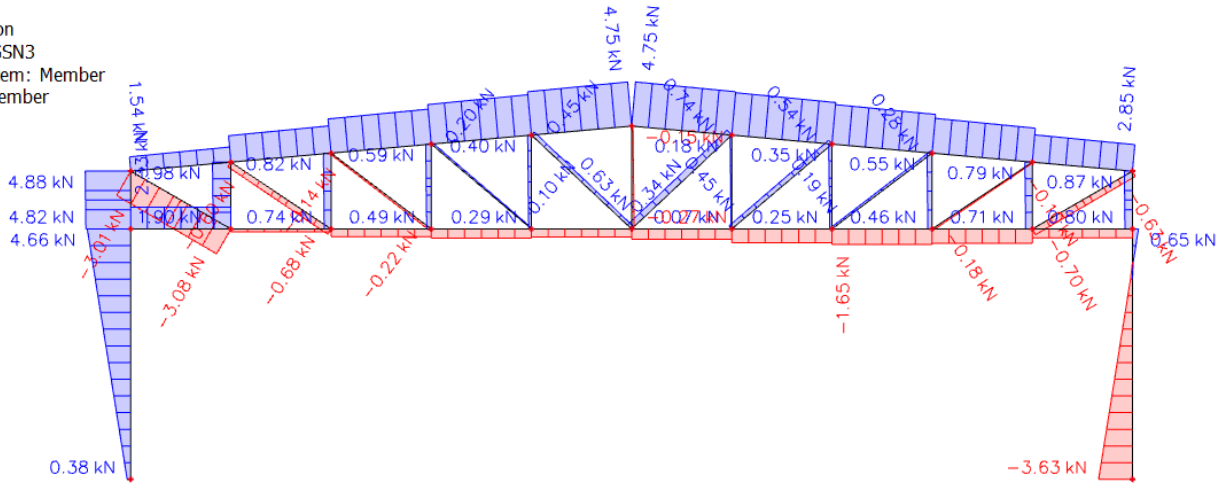
1D internal forces
Values: $\mathbf{M_y}$
Linear calculation
Combination: GSN3
Coordinate system: Member
Extreme 1D: Member
Selection: All



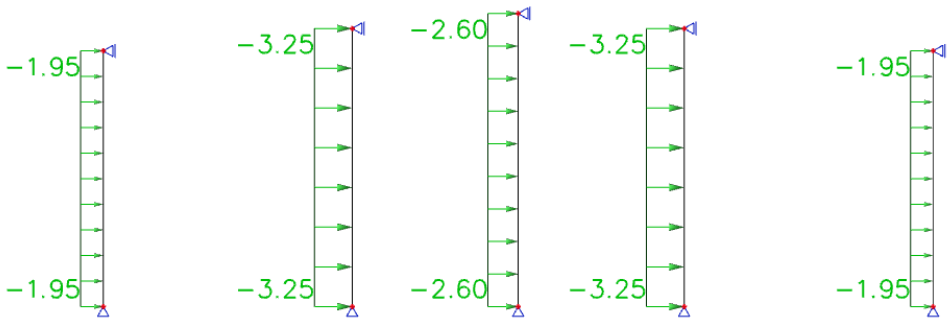
1D internal forces
Values: $\mathbf{V_z}$
Linear calculation
Combination: GSN3
Coordinate system: Member
Extreme 1D: Member
Selection: All



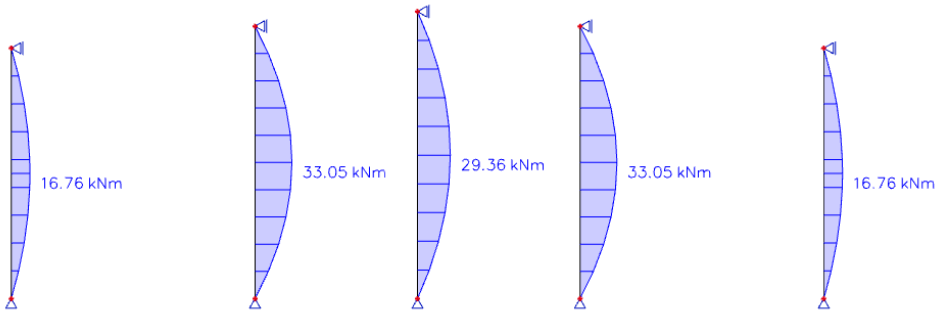
1D internal forces
Values: **N**
Linear calculation
Combination: GSN3
Coordinate system: Member
Extreme 1D: Member
Selection: All



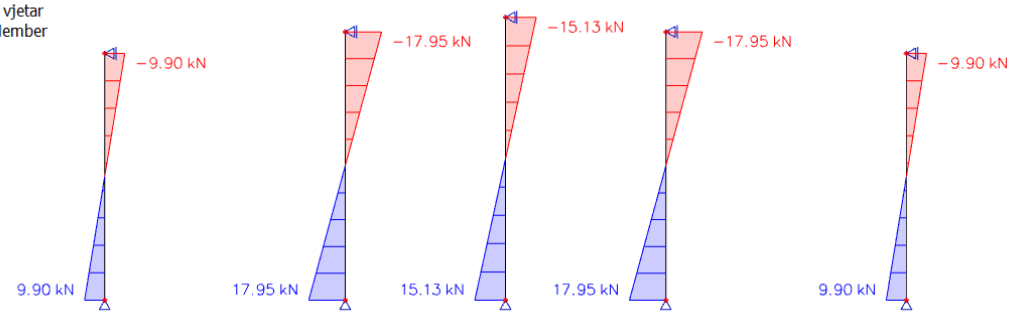
4.1.2. Zabatni stupovi



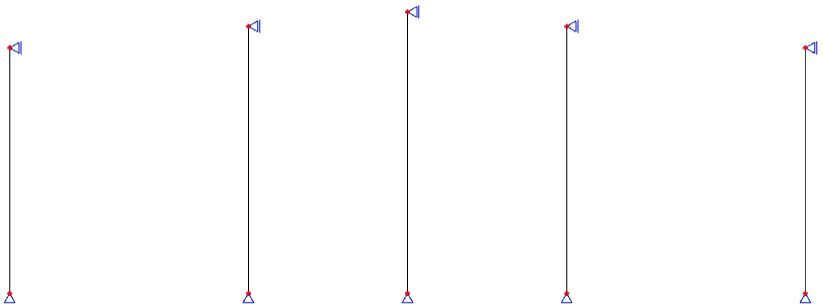
1D internal forces
Values: $\mathbf{M_y}$
Linear calculation
Combination: zabatni vjetar
Coordinate system: Member
Extreme 1D: Member
Selection: All



1D internal forces
Values: $\mathbf{V_z}$
Linear calculation
Combination: zabatni vjetar
Coordinate system: Member
Extreme 1D: Member
Selection: All



1D internal forces
Values: $\mathbf{N}$
Linear calculation
Combination: zabatni vjetar
Coordinate system: Member
Extreme 1D: Member
Selection: All

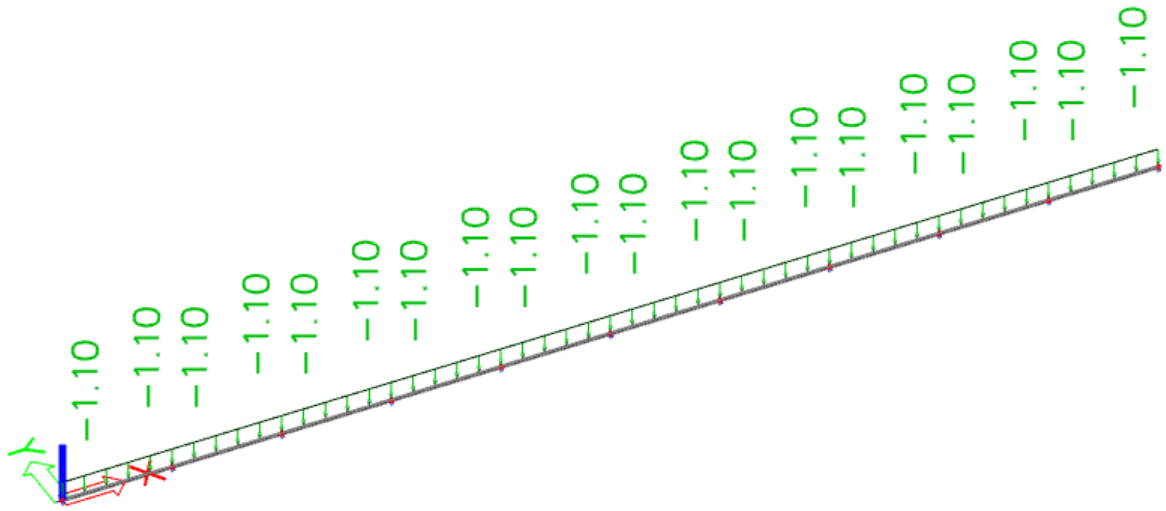


4.1.3. Krovne podrožnice

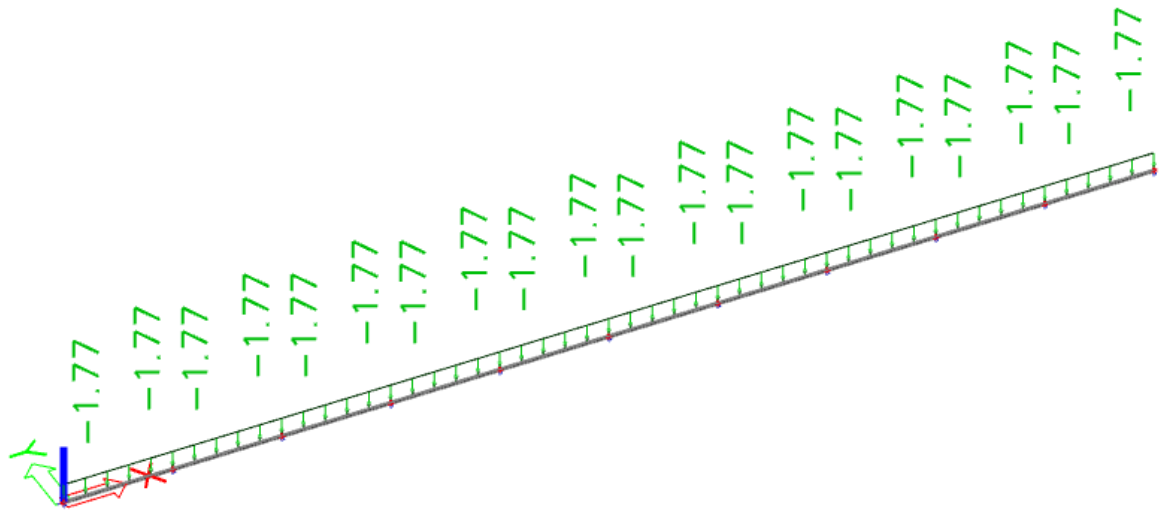
Kombinacije:

Kombinacija: $\mathrm{GSN}_1 = 1{,}35 * \mathrm{G}$ "+" $0{,}9 * \mathrm{S} + 1{,}5 * \mathrm{W}_{\mathrm{pritisak}}$
Kombinacija: $\mathrm{GSN}_1 = 1{,}35 * \mathrm{G}$ "+" $0{,}9 * \mathrm{W}_{\mathrm{pritisak}} + 1{,}5 * \mathrm{S}$
Kombinacija: $\mathrm{GSN}_2 = 1{,}00 * \mathrm{G}$ "+" $1{,}50 * \mathrm{W}_{\mathrm{odizanje}}$

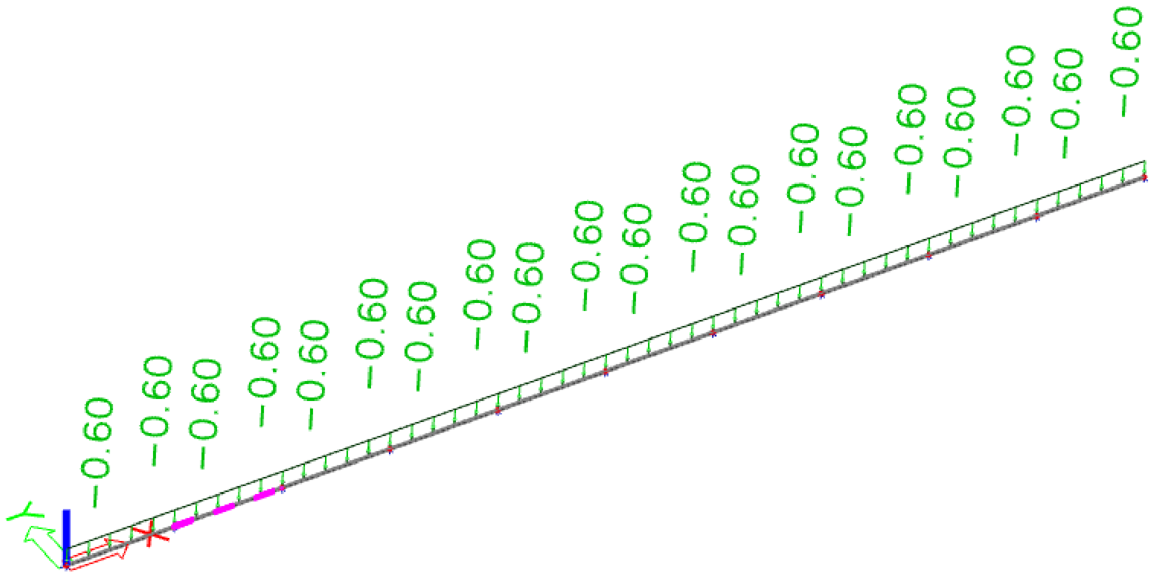
-Stalno opterećenje



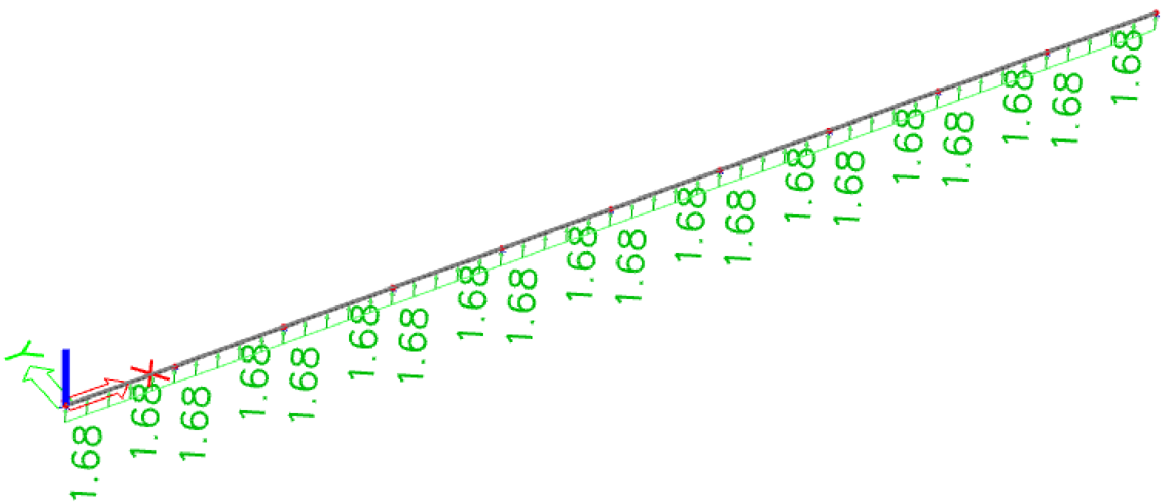
-Snijeg



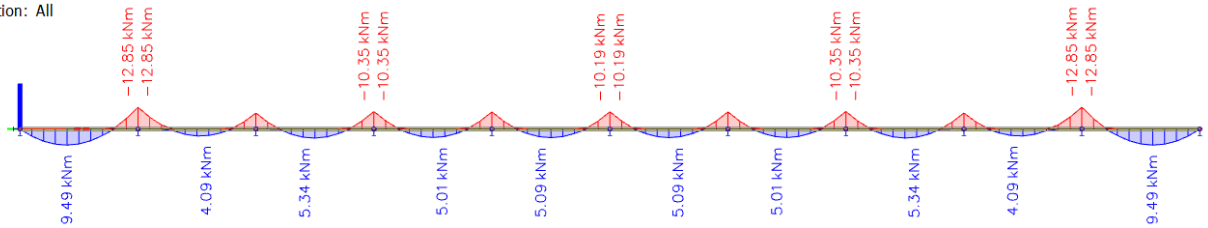
-Pritiskajući vjetar



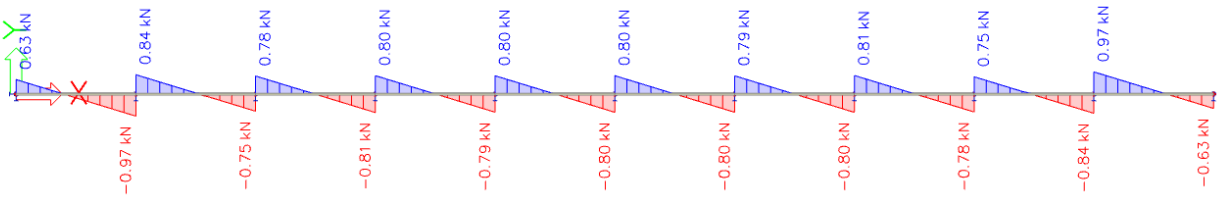
-Odižući vjetar



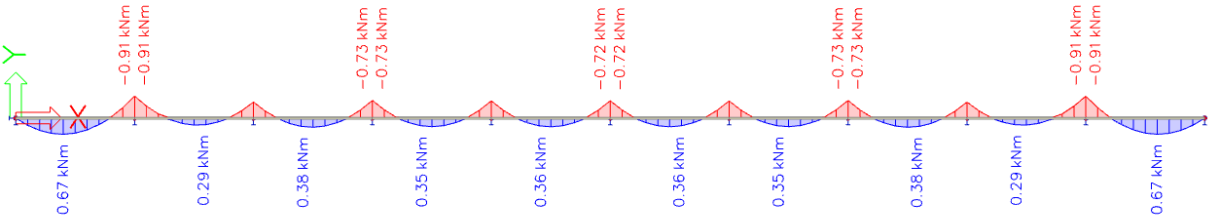
1D internal forces
Values: $\mathbf{M_y}$
Linear calculation
Combination: GSN1
Coordinate system: Principal
Extreme 1D: Member
Selection: All



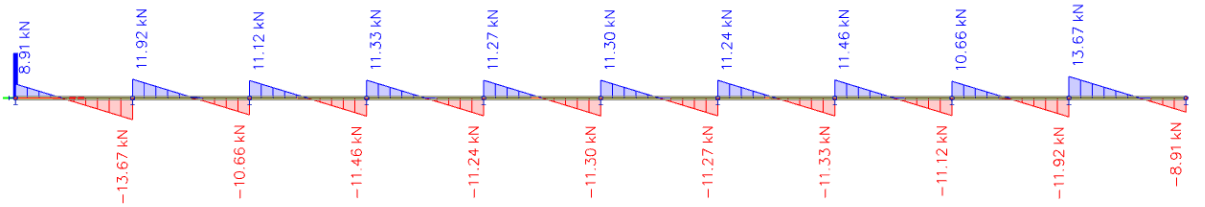
1D internal forces
Values: $\mathbf{V_y}$
Linear calculation
Combination: GSN1
Coordinate system: Principal
Extreme 1D: Member
Selection: All



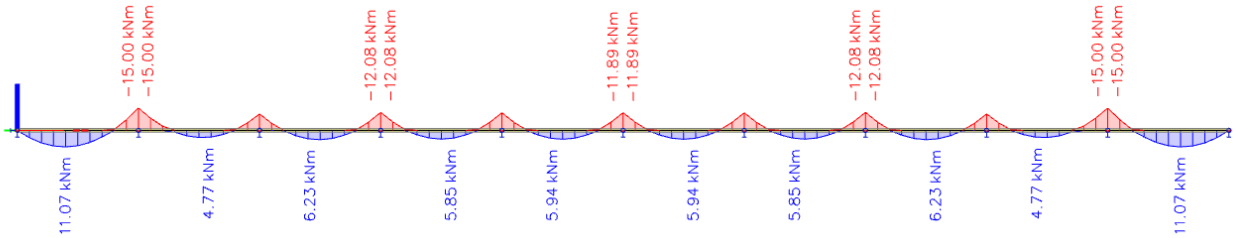
1D internal forces
Values: $\mathbf{M_z}$
Linear calculation
Combination: GSN1
Coordinate system: Principal
Extreme 1D: Member
Selection: All



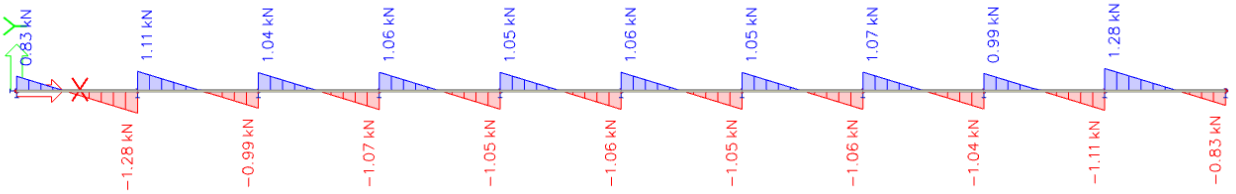
1D internal forces
Values: $\mathbf{V_z}$
Linear calculation
Combination: GSN1
Coordinate system: Principal
Extreme 1D: Member
Selection: All



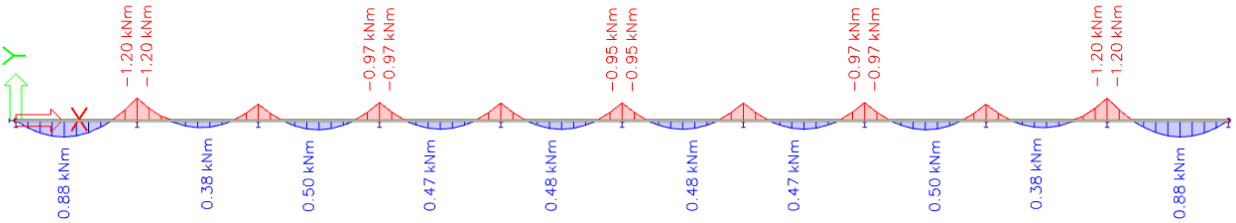
1D internal forces
Values: $\mathbf{M_y}$
Linear calculation
Combination: GSN2
Coordinate system: Principal
Extreme 1D: Member
Selection: All



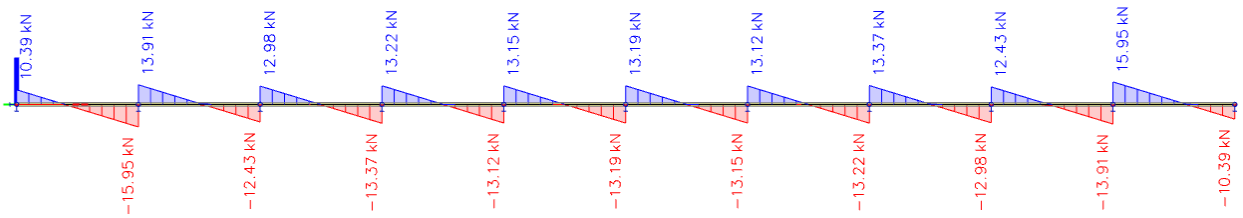
1D internal forces
Values: $\mathbf{V_y}$
Linear calculation
Combination: GSN2
Coordinate system: Principal
Extreme 1D: Member
Selection: All



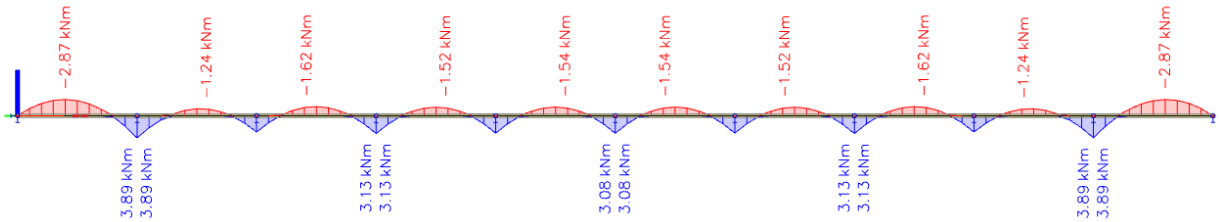
1D internal forces
Values: $\mathbf{M_z}$
Linear calculation
Combination: GSN2
Coordinate system: Principal
Extreme 1D: Member
Selection: All



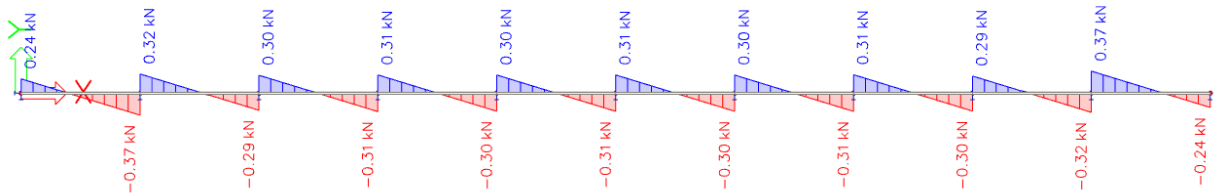
1D internal forces
Values: $\mathbf{V_z}$
Linear calculation
Combination: GSN2
Coordinate system: Principal
Extreme 1D: Member
Selection: All



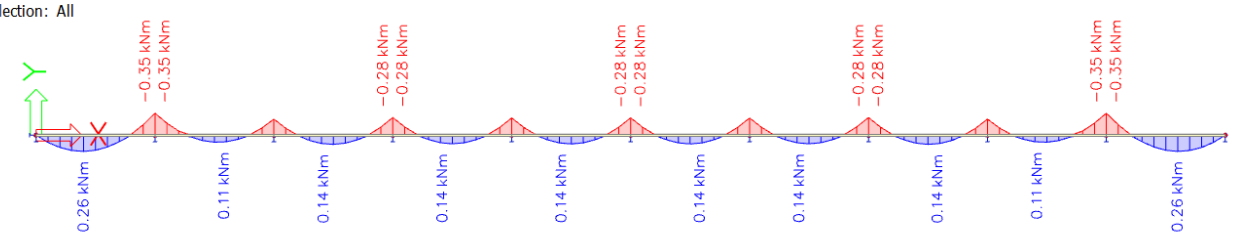
1D internal forces
Values: $\mathbf{M_y}$
Linear calculation
Combination: GSN3
Coordinate system: Principal
Extreme 1D: Member
Selection: All



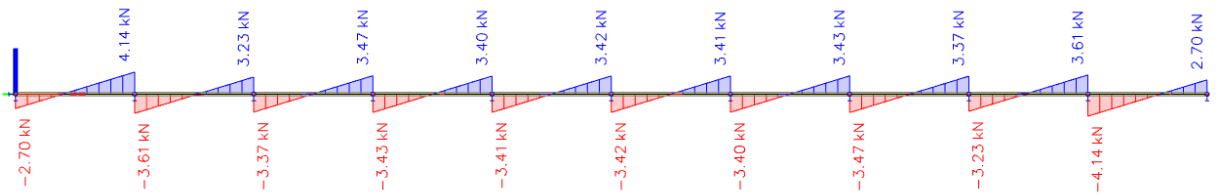
1D internal forces
Values: $\mathbf{V_y}$
Linear calculation
Combination: GSN3
Coordinate system: Principal
Extreme 1D: Member
Selection: All



1D internal forces
Values: $\mathbf{M_z}$
Linear calculation
Combination: GSN3
Coordinate system: Principal
Extreme 1D: Member
Selection: All

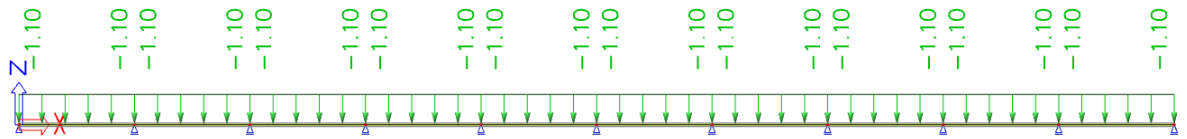


1D internal forces
Values: $\mathbf{V_z}$
Linear calculation
Combination: GSN3
Coordinate system: Principal
Extreme 1D: Member
Selection: All

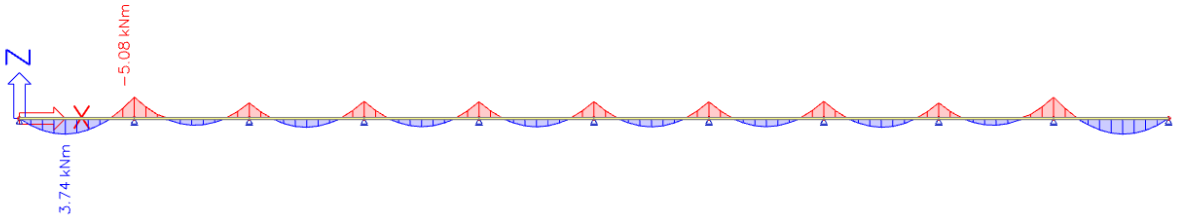


4.1.4. Bočne podrožnice

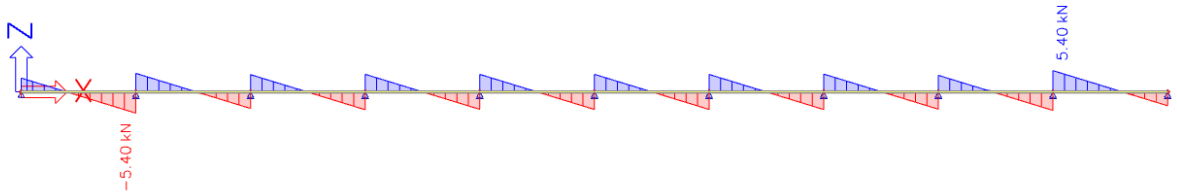
-Pritiskajući vjetar



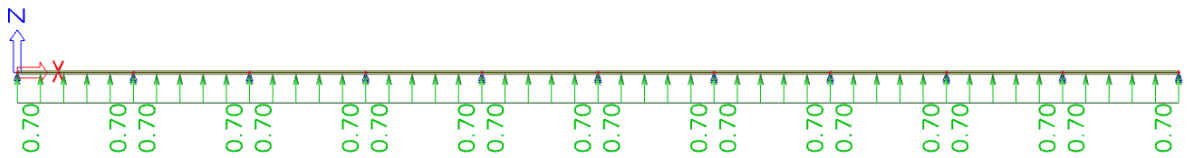
1D internal forces
Values: M_y
Linear calculation
Combination: pritiskajuci vjetar
Coordinate system: Member
Extreme 1D: Global
Selection: All



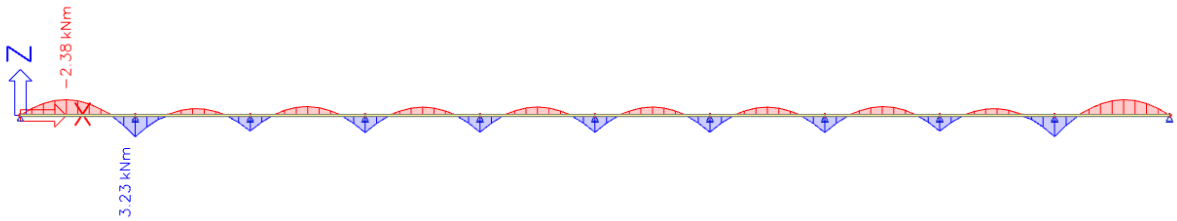
1D internal forces
Values: V_z
Linear calculation
Combination: pritiskajuci vjetar
Coordinate system: Member
Extreme 1D: Global
Selection: All



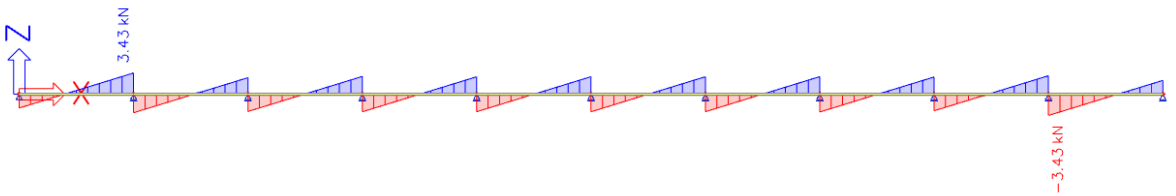
-Odižući vjetar



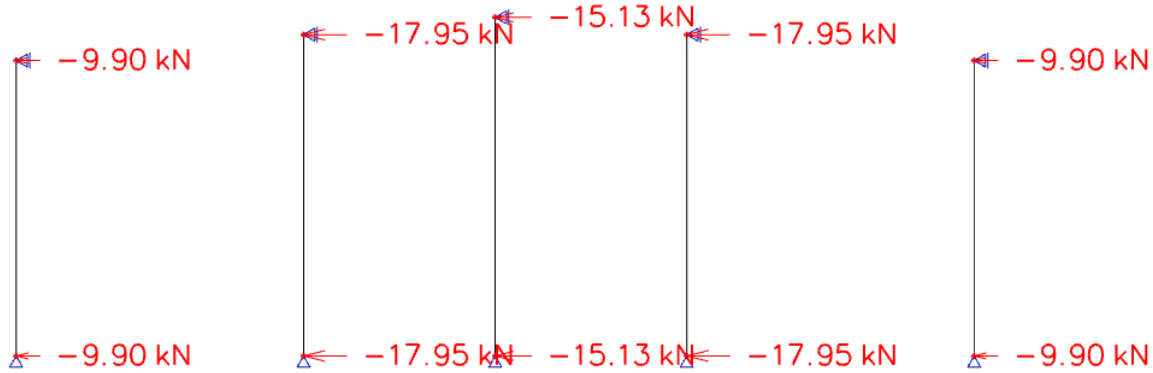
1D internal forces
Values: $\mathbf{M_y}$
Linear calculation
Combination: odizuci vjetar
Coordinate system: Member
Extreme 1D: Global
Selection: All

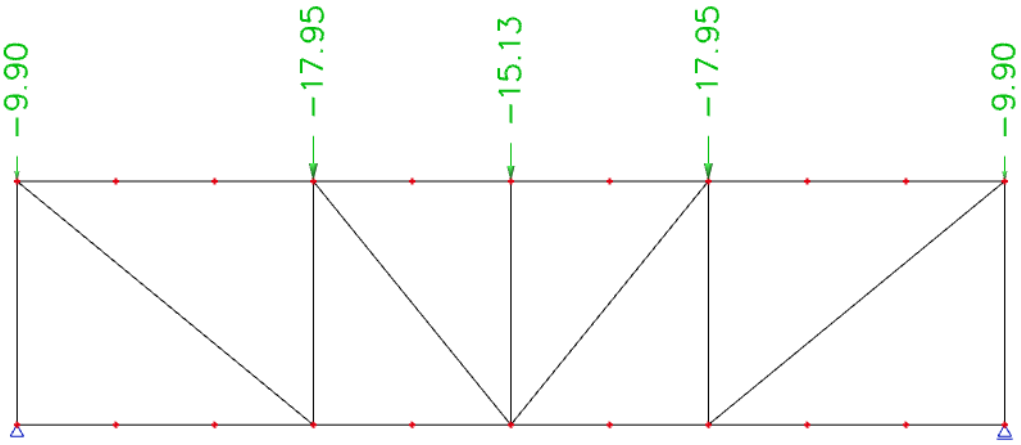


1D internal forces
Values: $\mathbf{V_z}$
Linear calculation
Combination: odizuci vjetar
Coordinate system: Member
Extreme 1D: Global
Selection: All

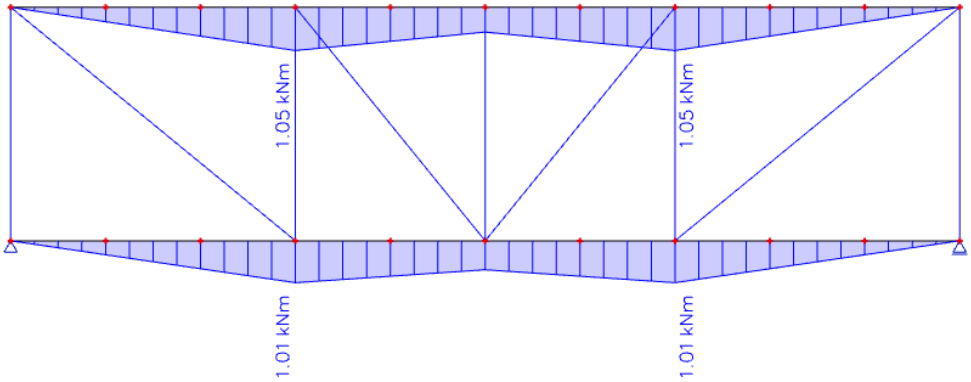


4.1.5. Krovni spreg

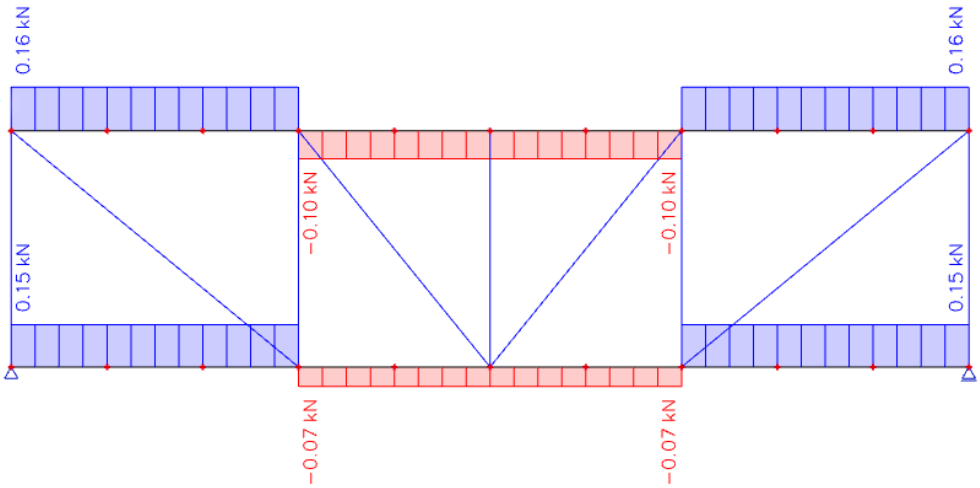




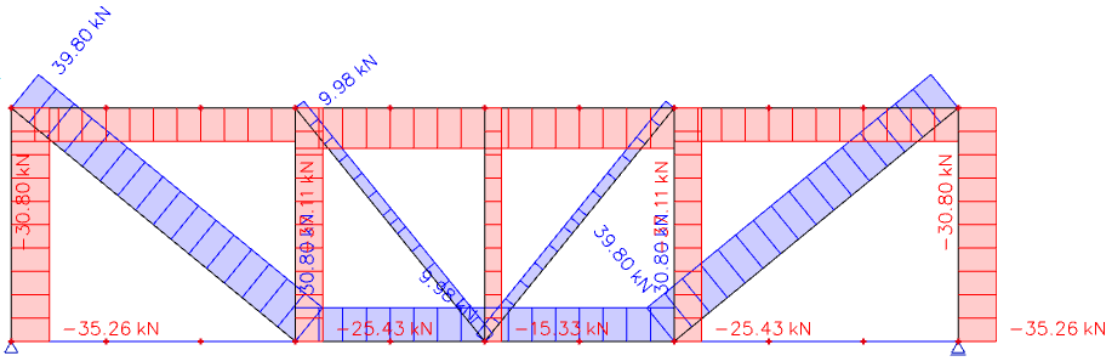
1D internal forces
Values: $\mathbf{M_y}$
Linear calculation
Load case: LC2
Coordinate system: Member
Extreme 1D: Member
Selection: All



1D internal forces
Values: $\mathbf{V_z}$
Linear calculation
Load case: LC2
Coordinate system: Member
Extreme 1D: Member
Selection: All

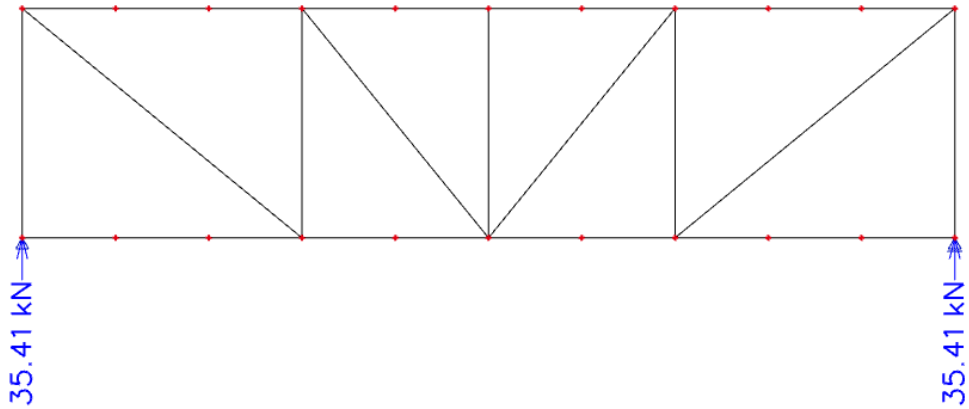


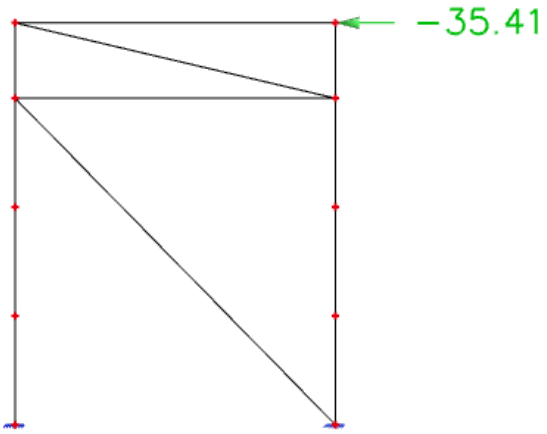
1D internal forces
Values: **N**
Linear calculation
Load case: LC2
Coordinate system: Member
Extreme 1D: Member
Selection: All



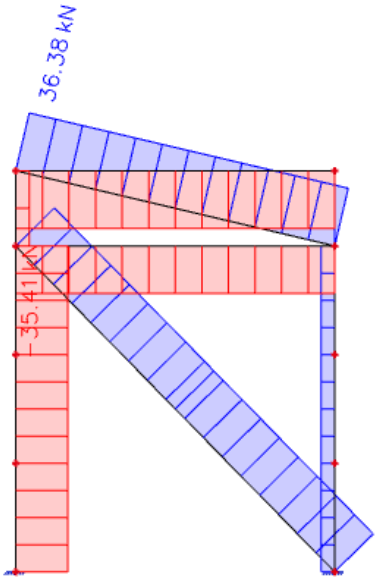
4.1.6. Bočni spreg

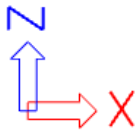
Reactions
Values: R_z
Linear calculation
Load case: LC2
System: Global
Extreme: Member
Selection: All





1D internal forces
Values: **N**
Linear calculation
Load case: krovni reakcija
Coordinate system: Member
Extreme 1D: Global
Selection: All





5. DIMENZIONIRANJE ELEMENATA KONSTRUKCIJE PREMA GRANIČNOM STANJU NOSIVOSTI

5.1. Glavna nosiva konstrukcija

5.1.1. Gornji pojas rešetke

PROFIL:		**CFRHS 140x140x7.1**		ε= 0.81	
KVALITETA ČELIKA:	S 355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	14.0	t (cm)	0.71	r_o (cm)	1.80
h (cm)	14.0	A (cm^2)	36.01	r_i (cm)	1.10
$W_{Pl,Y}$ (cm^3)	176.27	I_y (cm^4)	1031.4	I_w (cm^6)	31821
$W_{Pl,Z}$ (cm^3)	176.27	I_z (cm^4)	1031.4	I_T (cm^4)	1718.7
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritične kombinacije (GSN 2):

M_{Ed}= 0 (kNm)
V_{Ed}= 0 (kN)
N_{Ed}= -328.72 (kN)

Klasifikacija poprečnog presjeka:

- Hrbat (tlak):

$\frac{d}{t} = \frac{h-3*t}{t} = 17.00$

Uvjet za klasu 1: $\frac{d}{t} \leq 33$ ε= 26.73 Hrbat je klase 1

Poprečni presjek je klase 1.

Otpornost poprečnog presjeka:

- Uzdužna tlačna sila

$N_{c,Rd} = N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M,0}} = \frac{36.01 \cdot 35.5}{1} = 1278.36\ (kN) \geq N_{Ed}$= 328.72 (kN)

Profil zadovoljava na tlačnu silu s iskoristivosti p.p. od 27.02 %

Otpornost elementa:

- Tlačna sila:

L_i^Z= 6.63 (m)= 663 (cm)

L_i^Y = 2.21 (m)= 221 (cm)

$N_{CR}^Z=\frac{\pi^2*E*I_z}{L_i^2}$= 486.80 (kN)

$N_{CR}^Y=\frac{\pi^2*E*I_y}{L_i^2}$= 4381.24 (kN)

Izvijanje oko osi: Y-Y ili Z-Z

Faktor imperfekcije: α=0.49 ←Linija izvijanja: c ← Hladno oblikovani

$\lambda^Z=\sqrt{\frac{A*f_y}{N_{CR}^Z}}$ = 1.62 → Očitano za liniju izvijanja c: χ^Z=0.28

$\lambda^Y=\sqrt{\frac{A*f_y}{N_{CR}^Y}}$ = 0.54 → Očitano za liniju izvijanja c: χ^Y=0.82

$N_{B,Rd}=\chi^Z*\frac{A*f_y}{\gamma_{m1}}$ = 356.02 (kN) ≥ N_{Ed}= 328.72 (kN)

Profil CFRHS 140/140/7.1 zadovoljava otpor. elementa s iskoristivosti od 92 %

5.1.2. Donji pojas rešetke

PROFIL:		**CFRHS 100x100x5**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	10.0	t (cm)	0.5	r_o (cm)	1.0
h (cm)	10.0	A (cm^2)	18.36	r_i (cm)	0.5
$W_{Pl,Y}$ (cm^3)	64.59	I_y (cm^4)	271.1	I_w (cm^6)	4166.7
$W_{Pl,Z}$ (cm^3)	64.59	I_z (cm^4)	271.1	I_T (cm^4)	440.52
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritičnih kombinacija za mjerodavnu dijagonalu:

GSN 2	**GSN 2**
M_{Ed}= 0 (kNm)	M_{Ed}= 0 (kNm)
V_{Ed}= 0 (kN)	V_{Ed}= 0 (kN)
N_{Ed}= - 9.44 (kN)	N_{Ed}= + 329.76 (kN)

Klasifikacija poprečnog presjeka:

- Hrbat:

$\frac{d}{t} = \frac{h-3*t}{t} = 17.0$

Uvjet za klasu 1: $\frac{d}{t} \leq 33$ ε= 26.73 Hrbat je klase 1

Poprečni presjek je klase 1.

Otpornost poprečnog presjeka:

- Uzdužna vlačna sila

$N_{t,Rd} = N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M,0}} = \frac{18.36 \cdot 35.5}{1} = 651.78\ (kN) \geq N_{Ed}$= 329.76 (kN)

$N_{u,Rd} = \frac{0.9*A*f_u}{\gamma_{M,2}} = \frac{0.9*18.36*49.0}{1.25} = 647.74\ (kN) \geq N_{Ed}$= 329.76 (kN)

$N_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd}) = \min(651.78, 647.74) = 647.74 kN$

Profil CFRHS 100/100/5 zadovoljava otpor. elementa s iskoristivosti od 50.75 %

- Uzdužna tlačna sila

$N_{c,Rd} = N_{pl,Rd} = \frac{A*f_y}{\gamma_{M,0}} = \frac{18.36*35.5}{1} = 651.78(kN) \geq N_{Ed}$= 9.44 (kN)

Profil zadovoljava na tlačnu silu s iskoristivosti p.p. od 1.45 %

Otpornost elementa:

- Tlačna sila:

L_i^Z= 22.0 (m)= 2200 (cm)

L_i^Y = 2.20 (m)= 220 (cm)

$N_{CR}^Z = \frac{\pi^2*E*I_z}{L_i^2}$= 11.61 (kN)

$N_{CR}^Y = \frac{\pi^2*E*I_y}{L_i^2}$= 1160.92 (kN)

Izvijanje oko osi: Y-Y ili Z-Z

Faktor imperfekcije: α=0.49 ←Linija izvijanja: c ← Hladno oblikovani

$\lambda^Z = \sqrt{\frac{A*f_y}{N_{CR}^Z}}$ = 7.49 → Očitano za liniju izvijanja c: χ^Z=0.02

$\lambda^Y = \sqrt{\frac{A*f_y}{N_{CR}^Y}}$ = 0.75 → Očitano za liniju izvijanja c: χ^Y=0.69

$N_{B,Rd} = \chi^Z * \frac{A*f_y}{\gamma_{m1}}$ = 10.90 (kN) ≥ N_{Ed}= 9.44 (kN)

Profil CFRHS 100/100/5 zadovoljava otpor. elementa s iskoristivosti od 86.61 %

5.1.3 Dijagonale rešetke

PROFIL:		**CFRHS 80x40x4.0**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	4.0	t (cm)	0.4	r_o (cm)	0.80
h (cm)	8.0	A (cm^2)	8.55	r_i (cm)	0.40
$W_{Pl,Y}$ (cm^3)	20.91	I_y (cm^4)	64.79	I_w (cm^6)	204.08
$W_{Pl,Z}$ (cm^3)	12.77	I_z (cm^4)	21.49	I_T (cm^4)	55.24
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritičnih kombinacija za mjerodavnu dijagonalu:

GSN 3	**GSN 2**
M_{Ed}= 0 (kNm)	M_{Ed}= 0 (kNm)
V_{Ed}= 0 (kN)	V_{Ed}= 0 (kN)
N_{Ed}= - 3.13 (kN)	N_{Ed}= + 206.21 (kN)

Klasifikacija poprečnog presjeka:

- Hrbat:

$\frac{d}{t} = \frac{h-3*t}{t} = 9.50$

Uvjet za klasu 1: $\frac{d}{t} \leq 33\ \varepsilon$ = 26.73 Hrbat je klase 1

Poprečni presjek je klase 1.

Otpornost poprečnog presjeka:

- Uzdužna vlačna sila (GSN 2)

$N_{pl,Rd} = \frac{A*f_y}{\gamma_{M,0}} = \frac{8.55*35.5}{1} = 303.53\ (kN) \geq N_{Ed}$= 206.21 (kN)

$N_{u,Rd} = \frac{0.9*A*f_u}{\gamma_{M,2}} = \frac{0.9*8.55*49.0}{1.25} = 301.64\ (kN) \geq N_{Ed}$= 206.21 (kN)

$N_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd}) = \min(303.53, 301.64) = 301.64 kN$

Profil zadovoljava na vlačnu silu s iskoristivosti p.p. od 68.36 %

- Uzdužna tlačna sila (GSN 3)

$N_{c,Rd} = N_{pl,Rd} = \frac{A*f_y}{\gamma_{M,0}} = \frac{8.55*35.5}{1} = 303.53 (kN) \geq N_{Ed}$= 3.13 (kN)

Profil zadovoljava na tlačnu silu s iskoristivosti p.p. od 1.03 %

Otpornost elementa:

- Tlačna sila:

L_i^Z=2.54 (m)= 2.54 (cm)

$N_{CR,z}= \frac{\pi^2 * E * I_z}{L_i^2}$ = 69.03(kN)

Izvijanje oko osi: Z-Z

Faktor imperfekcije: α=0.49 ←Linija izvijanja: c ← Hladno oblikovani

$\lambda_z= \sqrt{\frac{A * f_y}{N_{CR,z}}}$ = 2.10 → Očitano za liniju izvijanja c: χ_z=0.18

$N_{B,Rd}= \chi * \frac{A * f_y}{\gamma_{m1}}$ = 54.87 (kN) ≥ N_{Ed}= 3.13 (kN)

Profil CFRHS 80/40/4 zadovoljava otpor. elementa s iskoristivosti od 5.70 %

5.1.4. Vertikale rešetke

PROFIL:		**CFRHS 80x40x4.0**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	4.0	t (cm)	0.4	r_o (cm)	0.80
h (cm)	8.0	A (cm^2)	8.55	r_i (cm)	0.40
$W_{Pl,Y}$ (cm^3)	20.91	I_y (cm^4)	64.79	I_w (cm^6)	204.08
$W_{Pl,Z}$ (cm^3)	12.77	I_z (cm^4)	21.49	I_T (cm^4)	55.24
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritične kombinacije (GSN 2) za mjerodavnu vertikalu:

M_{Ed}= 0 (kNm)
V_{Ed}= 0 (kN)
N_{Ed}= -102.84 (kN)

Klasifikacija poprečnog presjeka:

- Hrbat:

$\frac{d}{t} = \frac{h-3*t}{t} = 9.5$

Uvjet za klasu 1: $\frac{d}{t} \leq 33\ \varepsilon$=26.73 Hrbat je klase 1

Poprečni presjek je klase 1.

Otpornost poprečnog presjeka:

- Uzdužna tlačna sila

$N_{c,Rd} = N_{pl,Rd} = \frac{A*f_y}{\gamma_{M,0}} = \frac{8.55*35.5}{1} = 303.53\ (kN) \geq N_{Ed}$= 102.84 (kN)

Profil zadovoljava na tlačnu silu s iskoristivosti p.p. od 33.88%

Otpornost elementa:

- Tlačna sila:

L_i=1.47 (m)= 147 (cm)

$N_{CR}{}^{Z}=\frac{\pi^2 * E * I_z}{L_i{}^2}$= 206.68 (kN)

Izvijanje oko osi: Y-Y ili Z-Z

Faktor imperfekcije: α=0.49 ←Linija izvijanja: a ← Vruće dogotovljeni

$\lambda_z=\sqrt{\frac{A * f_y}{N_{CR}}}$ = 1.21 → Očitano za liniju izvijanja a: χ_z=0.43

$N_{B,Rd}=\chi * \frac{A * f_y}{\gamma_{m1}}$ = 129.96(kN) ≥ N_{Ed}= 102.84(kN)

Profil CFRHS 80/40/4 zadovoljava otpor. elementa s iskoristivosti od 79.13%

5.1.5. Stupovi okvira

PROFIL:		**HEA 280**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	28.0	r (cm)	2.4	t_f (cm)	1.3
h (cm)	27.0	A (cm^2)	97.30	t_w (cm)	0.8
$W_{Pl,Y}$ (cm^3)	1112.5	I_y (cm^4)	13700	I_w (cm^6)	785370
$W_{Pl,Z}$ (cm^3)	516.67	I_z (cm^4)	4760	I_T (cm^4)	62.1
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritične kombinacije (GSN 2):

M_{Ed}= 68.49 (kNm)
V_{Ed}= 14.07 (kN)
N_{Ed}= -119.06 (kN)

Klasifikacija profila:

- Hrbat (savijanje + tlak):

$a = \frac{N_{Ed}}{2*t_w*f_y/\gamma_{M0}} = 2.096$ cm ; d = 5.5 m = 550 cm ; $\alpha = \frac{1}{d} * \left(\frac{d}{2} + a\right) = 0.504$

$\frac{d}{t_w} = \frac{h-2*t_f-2*r}{t_w} = 24.50$

Uvjet za klasu 1: $\frac{d}{t_w} \leq \frac{396*\varepsilon}{13*\alpha-1} = 57.78$ Hrbat je klase 1

- Pojasnice (tlak):

$\frac{c}{t_f} = \frac{0.5*(b-2*r-t_w)}{t_f} = 8.62$

Uvjet za klasu 1: $\frac{c}{t_f} \leq 9\ \varepsilon = 8.62$ Pojasnice su klase 1

Poprečni presjek je klase 1.

Otpornost poprečnog presjeka:

- Savijanje:

$M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl,y} * f_y}{\gamma_{m0}} = \frac{1112.5 * 35.5}{1} = 38958.0\ (\mathrm{kNcm}) = 389.58\ (\mathrm{kNm})$

$M_{c,Rd} = 389.58\ (\mathrm{kNm}) \geq M_{Ed} = 68.49\ (\mathrm{kNm})$

Profil zadovoljava na savijanje s iskoristivosti p.p. od 17.57%

- Posmik:

$\frac{h_w}{t_w} = \frac{h-2*t_f}{t_w} = \frac{24.4}{0.8} = 30.5 \leq 72\ \frac{\varepsilon}{\eta} = 72\ \frac{0.81}{1.20} = 69.98$

Nije potrebna kontrola izbočavanja hrpta uslijed djelovanja posmika!

$A_{V,Z} = A - 2*b*t_f + (t_w + 2*r)*t_f = 31.70(cm^2) \geq \eta * h_w * t_w = 23.42\ (cm^2)$ Uvjet zadovoljen!

$V_{Rd}^Z = = V_{Pl,Rd} = \frac{A_{v,z} * f_y}{\sqrt{3} * \gamma_{m0}} = \frac{31.7 * 35.5}{1.7321} = 651.36\ (\mathrm{kN})$

$V_{Rd}^Z = = 651.36\ (\mathrm{kN}) \geq V_{Ed} = 14.07\ (\mathrm{kN})$

Profil zadovoljava na posmik s iskoristivosti p.p. od 2.16%

- Uzdužna tlačna sila

$N_{c,Rd} = N_{pl,Rd} = \frac{A * f_y}{\gamma_{M,0}} = \frac{97.30 * 35.5}{1} = 3454.15\ (\mathrm{kN})$
$N_{c,Rd} = 3454.15\ (\mathrm{kN}) \geq N_{Ed} = 119.06\ (\mathrm{kN})$

Profil zadovoljava na tlačnu silu s iskoristivosti p.p. od 3.43%

- Interakcija M-V-N

$0.25 * N_{c,Rd} = 863.54\ (\mathrm{kN}) \geq N_{Ed} = 119.06\ (\mathrm{kN})$

$0.5 * V_{z,Rd} = 325.68\ (\mathrm{kN}) \geq V_{Ed} = 14.07\ (\mathrm{kN})$

Nema redukcije $M_{c,Rd}$ uslijed interakcije reznih sila!

Otpornost elementa:

- Savijanje:

L_{CR}= 5.5 (m)= 550 (cm) $z_G=\frac{h}{2}$= 13.5 (cm)

k= 1.0 k_W= 1.0 C_1= 1.88 C_2= 0.03

$M_{CR}= C_1*\frac{\pi^2*E*I_z}{(k*L_{CR})^2}*\left[\sqrt{(\frac{k}{k_w})^2*\frac{I_w}{I_z}+\frac{(k*L_{CR})^2*G*I_T}{\pi^2*E*I_z}+(C_2*z_g)^2}-C_2*z_g\right]$=1097.14 (kNm)

$\lambda_{LT}=\sqrt{\frac{W_{Pl,Y}*f_y}{M_{CR}}}$ = 0.60 ≥ $\lambda_{LT,0}$= 0.4 Reduciramo $M_{c,Rd}$ zbog mogućnosti instabiliteta elementa.

Faktor imperfekcije: α_{LT} = 0.21 ← Krivulja izvijanja : a $\begin{cases}\frac{h}{b}=0.96\ \leq 2\\ Vruće\ valjani\ I\ presjek\end{cases}$

$\Phi_{LT}= 0.5*(1+\alpha_{LT}(\lambda_{LT}-0.2)+\lambda_{LT}^2)$= 0.7

$\chi_{LT}=\frac{1}{\Phi_{LT}+\sqrt{\Phi_{LT}^2-\lambda_{LT}^2}}$= 0.99

$M_{B,Rd}= \chi_{LT}*\frac{W_{pl,y}*f_y}{\gamma_{m1}}= 0.99*\frac{1112.5*35.5}{1}$= 38958.0 (kNcm)= 389.58 (kNm) ≥ M_{Ed}= 68.49(kNm)

(17.57%)

- Tlačna sila:

L_i^Z= 0.7*5.5 (m) = 3.85 (m) =385 (cm)

L_i^Y = 2*5.0 (m)= 1100 (cm)

$N_{CR}^Z=\frac{\pi^2*E*I_z}{{L_i}^2}$= 3261.37 (kN)

$N_{CR}^Y=\frac{\pi^2*E*I_y}{{L_i}^2}$= 2341.10 (kN)

Izvijanje oko osi Z-Z: Faktor imperfekcije: α=0.49 ←Linija izvijanja: c $\begin{cases} t_f \leq 100\ (mm) \\ \frac{h}{b} = 0.96 > 1.2 \end{cases}$

Izvijanje oko osi Y-Y: Faktor imperfekcije: α=0.34 ←Linija izvijanja: b $\begin{cases} t_f \leq 100\ (mm) \\ \frac{h}{b} = 0.96 > 1.2 \end{cases}$

$\lambda^Z=\sqrt{\frac{A*f_y}{{N_{CR}}^Z}}$ = 1.03 → Očitano za liniju izvijanja c: χ^Z=0.52

$\lambda^Y=\sqrt{\frac{A*f_y}{{N_{CR}}^Y}}$ = 1.21 → Očitano za liniju izvijanja b: χ^Y=0.47

$N_{B,Rd}=\chi^Y*\frac{A*f_y}{\gamma_{m1}}$ = 1624.23 (kN) ≥ $N_{Ed}^{4.1.1.}$= 119.06 (kN) *(7.28%)*

- Interakcija M_b-N_b (jednoosno savijanje):

$C_{MY}=C_{MLT}$=0.95 ← $0.95+0.05\alpha_h \geq 0.4$ $\begin{cases} \alpha_h = 0 \\ \Psi = 0 \end{cases}$

$k_{yy}=C_{MY}\left(1+(\chi^Y-0.2)\frac{N_{Ed}}{\chi^Y*N_{Rd}}\right) \leq C_{MY}\left(1+0.8\frac{N_{Ed}}{\chi^Y*N_{Rd}}\right)$ k_{yy}= 1.04

$k_{zy}=0.6+\lambda^Z \leq \left(1-\frac{0.1\lambda^Z}{C_{MLT}}*\frac{N_{Ed}*\gamma_{m1}}{\chi^Y*N_{Rk}}\right)$ k_{zy}=0.56

$\frac{N_{Ed}*\gamma_{m1}}{\chi^Y*N_{Rk}}+k_{yy}\frac{{M_{Ed}}^Y*\gamma_{m1}}{\chi^{LT}*{M_{Rk}}^Y}=0.0728+0.1827=0.2555$

Profil HE 280 A zadovoljava otpornost elementa s iskoristivosti od 25.55 %

5.2. Sekundarna nosiva konstrukcija

5.2.1. Zabatni stupovi

PROFIL:		**HEA 160 A**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	16.0	r (cm)	1.5	t_f (cm)	0.7
h (cm)	14.8	A (cm^2)	30.40	t_w (cm)	0.5
$W_{El,Y}$ (cm^3)	185.99	I_y (cm^4)	1280	I_w (cm^6)	23751
$W_{Pl,Y}$ (cm^3)	190.42	I_z (cm^4)	479	I_T (cm^4)	6.33
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritične kombinacije (GSN 4.1.2.) za mjerodavni zabatni stup:

M_{Ed}= 33.05(kNm)
V_{Ed}= 17.95(kN)
N_{Ed}= 0(kN) → zanemarena vlastita težina

Klasifikacija profila:

- Hrbat (savijanje):

$$\frac{d}{t_w} = \frac{h-2*t_f-2*r}{t_w} = 20.8$$

Uvjet za klasu 1: $\frac{d}{t_w} \leq 72$ ε= 58.32 Hrbat je klase 1

- Pojasnice (tlak):

$$\frac{c}{t_f} = \frac{0.5*(b-2*r-t_w)}{t_f} = 8.92$$

Uvjet za klasu 3: $\frac{c}{t_f} \leq 14$ ε= 11.34 Pojasnice su klase 3

Poprečni presjek je klase 3.

Otpornost poprečnog presjeka:

- Savijanje:

$$M_{c,Rd} = M_{pl,Rd} = \frac{W_{El,y}*f_y}{\gamma_{m0}} = \frac{185.99*35.5}{1} = 66.02\ (\mathrm{kNm})$$

$M_{c,Rd} = 66.02\ (\mathrm{kNm}) \geq M_{Ed}$ = 33.05 (kNm)

Profil zadovoljava na savijanje s iskoristivosti p.p. od 50.06%

- Posmik:

$\frac{h_w}{t_w} = \frac{h-2*t_f}{t_w} = 26.8 \leq 72\,\frac{\varepsilon}{\eta} = 72\,\frac{0.81}{1.20} = 48.60$

Nije potrebna kontrola izbočavanja hrpta uslijed djelovanja posmika!

$A_{V,Z}$= A - 2*b*t_f +(t_w+2*r)*t_f= 10.45 (cm^2) ≥ $\eta * h_w * t_w$= 9.18 (cm^2) Uvjet zadovoljen!

V_{Rd}^Z= = $V_{Pl,Rd}$ = $\frac{A_{v,z}*f_y}{\sqrt{3}*\gamma_{m0}} = \frac{10.45*35.5}{1.7321} = 214.18\ (\mathrm{kN})$

V_{Rd}^Z= $= 214.18\ (\mathrm{kN}) \geq V_{Ed}$= 17.95 (kN)

Profil zadovoljava na posmik s iskoristivosti p.p. od 8.38%

- Interakcija M-V-N:

N_{Ed}= 0(kN)

0.5*$V_{z,Rd}$ = 107.09 (kN) ≥ V_{Ed}= 17.09 (kN)

Nema redukcije $M_{c,Rd}$uslijed interakcije reznih sila!

Otpornost elementa:

- Savijanje:

L_{CR}= 7.364 (m)≈ 700 (cm) $z_G = \frac{h}{2}$= 9.5 (cm)

k= 1.0 C_1= 1.127

k_W= 1.0 C_2= 0.454

$M_{CR} = C_1 * \frac{\pi^2 * E * I_z}{(k*L_{CR})^2} * \left[\sqrt{\left(\frac{k}{k_w}\right)^2 * \frac{I_w}{I_z} + \frac{(k*L_{CR})^2 * G * I_T}{\pi^2 * E * I_z} + (C_2 * z_g)^2} - C_2 * z_g\right]$= 37.42 (kNm)

$\lambda_{LT} = \sqrt{\frac{W_{El,Y} * f_y}{M_{CR}}}$ = 1.33 ≥ $\lambda_{LT,0}$= 0.4 Reduciramo $M_{c,Rd}$zbog mogućnosti instabiliteta elementa.

Faktor imperfekcije: α_{LT} = 0.34 ← Krivulja izvijanja : b $\begin{cases} \frac{h}{b} = 1.08 \leq 2 \\ Vruće\ valjani\ I\ presjek \end{cases}$

Φ_{LT}= 0.5*(1+α_{LT}(λ_{LT}-0.2) + λ_{LT}^2)= 1.58

$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \lambda_{LT}^2}}$= 0.51

$M_{B,Rd} = \chi_{LT} * \frac{W_{pl,y} * f_y}{\gamma_{m1}} = 0.51 * \frac{185.99 * 35.5}{1}$ = 34.02 (kNm) ≥ M_{Ed}= 33.05 (kNm)

Profil HEA 160 A zadovoljava otpornost elementa s iskoristivosti od 97.14%

5.2.2. Krovni spregovi (zatege)

PROFIL:		**RD 14**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
d (cm)	1.4	r (cm)	0.7	A (cm^2)	1.54
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritične kombinacije:

M_{Ed}= 0(kNm)
V_{Ed}= 0(kN)
N_{Ed}= +39.80 (kN)

Otpornost poprečnog presjeka:

Vlačna sila:

$$N_{pl,Rd} = \frac{A*f_y}{\gamma_{M,0}} = \frac{1.54*35.5}{1} = 54.62\ (kN) \geq N_{Ed} = 39.80\ (kN)$$

$$N_{u,Rd} = \frac{0.9*A*f_u}{\gamma_{M,2}} = \frac{0.9*1.54*49.0}{1.25} = 54.28\ (kN) \geq N_{Ed} = 39.80\ (kN)$$

$$N_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd}) = \min(54.62, 54.28) = 54.28 kN$$

Profil zadovoljava na vlačnu silu s iskoristivosti p.p. od 73.32 %

5.2.3. Bočni spregovi (zatege)

PROFIL:		**RD 14**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
d (cm)	1.4	r (cm)	0.7	A (cm^2)	1.54
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritične kombinacije:

M_{Ed}= 0(kNm)
V_{Ed}= 0(kN)
N_{Ed}= +36.38(kN)

Otpornost poprečnog presjeka:

Vlačna sila:

$$N_{pl,Rd} = \frac{A*f_y}{\gamma_{M,0}} = \frac{1.54*35.5}{1} = 54.62\ (kN) \geq N_{Ed} = 36.38\ (kN)$$

$$N_{u,Rd} = \frac{0.9*A*f_u}{\gamma_{M,2}} = \frac{0.9*1.54*49.0}{1.25} = 54.28\ (kN) \geq N_{Ed} = 36.38\ (kN)$$

$$N_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd}) = \min(54.62, 54.28) = 54.28 kN$$

Profil zadovoljava na vlačnu silu s iskoristivosti p.p. od 67.02 %

5.2.4. Krovne podrožnice

PROFIL:		**IPE 160**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	8.2	r (cm)	0.9	t_f (cm)	0.7
h (cm)	16.0	A (cm^2)	20.1	t_w (cm)	0.5
$W_{El,Y}$ (cm^3)	109.0	I_y (cm^4)	869	I_w (cm^6)	3960
$W_{Pl,Y}$ (cm^3)	124.0	I_z (cm^4)	68.3	I_T (cm^4)	3.6
$W_{El,Z}$ (cm^3)	16.70	$A_{V,Z}$ (cm^2)	8.12		
$W_{Pl,Z}$ (cm^3)	26.1	$A_{V,Y}$ (cm^2)	12.61		
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritične kombinacije (GSN 4.1.3.):

Y-Y	**Z-Z**
$M_{Ed,Y}$=15.00 (kNm)	$M_{Ed,Z}$= 1.20(kNm)
$V_{Ed,Y}$= 1.28 (kN)	$V_{Ed,Z}$= 15.95 (kN)

Klasifikacija profila:

- Hrbat (savijanje):

$$\frac{d}{t_w} = \frac{h-2*t_f-2*r}{t_w} = 25.6$$

Uvjet za klasu 1: $\frac{d}{t_w} \leq 72\varepsilon$= 58.32 Hrbat je klase 1

- Pojasnice (tlak):

$$\frac{c}{t_f} = \frac{0.5*(b-2*r-t_w)}{t_f} = 4.21$$

Uvjet za klasu 1: $\frac{c}{t_f} \leq 9$ ε= 7.29 Pojasnice su klase 1

Poprečni presjek je klase 1.

Otpornost poprečnog presjeka:

- Savijanje (Y-Y):

$M_{c,Rd}^{Y} = M_{pl,Rd} = \frac{W_{pl,y} * f_y}{\gamma_{m0}} = \frac{124.*35.5}{1} = 4402\ (\mathrm{kNcm}) = 44.02(\mathrm{kNm})$

$M_{c,Rd}^{Y} = 44.02\ (\mathrm{kNm}) \geq M_{Ed}^{Y} = 15.00(\mathrm{kNm})$ *(34.08%)*

- Savijanje (Z-Z):

$M_{c,Rd}^{Z} = M_{pl,Rd} = \frac{W_{pl,z} * f_y}{\gamma_{m0}} = \frac{26.1*35.5}{1} = 926.55\ (\mathrm{kNcm}) = 9.27\ (\mathrm{kNm})$

$M_{c,Rd}^{Z} = 9.27\ (\mathrm{kNm}) \geq M_{Ed}^{Z} = 1.20(\mathrm{kNm})$ *(12.94 %)*

Profil zadovoljava na jednoosno savijanje s iskoristivosti p.p. od 34.08 %

- Posmik (Z)

$\frac{h_w}{t_w} = \frac{h-2*t_f}{t_w} = 29.2 \leq 72\ \frac{\varepsilon}{\eta} = 72\ \frac{0.81}{1.20} = 48.6$

Nije potrebna kontrola izbočavanja hrpta uslijed djelovanja posmika!

$A_{V,Z} = A - 2*b*t_f + (t_w + 2*r)*t_f = 10.23\ (cm^2) \geq \eta * h_w * t_w = 8.76\ (cm^2)$ Uvjet zadovoljen!

$V_{Rd}^{Z} = V_{Pl,Rd} = \frac{A_{v,z} * f_y}{\sqrt{3} * \gamma_{m0}} = \frac{10.23*35.5}{1.7321} = 209.67(\mathrm{kN})$

$V_{Rd}^{Z} = 209.67\ (\mathrm{kN}) \geq V_{Ed}^{Z} = 15.95\ (\mathrm{kN})$ *(7.61 %)*

- Posmik (Y)

$\frac{h_w}{t_w} = \frac{h-2*t_f}{t_w} = 29.2 \leq 72\ \frac{\varepsilon}{\eta} = 72\ \frac{0.81}{1.20} = 48.6$

Nije potrebna kontrola izbočavanja hrpta uslijed djelovanja posmika!

$A_{V,Y} = 2*b*t_f = 11.48\ (cm^2) \geq \eta * h_w * t_w = 8.76\ (cm^2)$ Uvjet zadovoljen!

$V_{Rd}^{Y} = V_{Pl,Rd} = \frac{A_{v,y} * f_y}{\sqrt{3} * \gamma_{m0}} = \frac{11.48*35.5}{1.7321} = 235.29\ (\mathrm{kN})$

$V_{Rd}^{Y} = 235.92\ (\mathrm{kN}) \geq V_{Ed}^{Y} = 1.28\ (\mathrm{kN})$ *(0,01 %)*

Profil zadovoljava na posmik s iskoristivosti p.p. od 7.61 %

- Interakcija M-V-N:

Nema redukcije $M_{c,Rd}$uslijed interakcije reznih sila!

Otpornost elementa:

- Savijanje:

L_{CR}= 5.40 (m)= 540 (cm) $z_G=\frac{h}{2}$= 8.0 (cm)

k= 1.0 C_1= 1.66

k_W= 1.0 C_2= 0.78

$M_{CR}=C_1*\frac{\pi^2*E*I_z}{(k*L_{CR})^2}*\left[\sqrt{(\frac{k}{k_w})^2*\frac{I_w}{I_z}+\frac{(k*L_{CR})^2*G*I_T}{\pi^2*E*I_z}+(C_2*z_g)^2}-C_2*z_g\right]$= 20.68 (kNm)

$\lambda_{LT}=\sqrt{\frac{W_{Pl,Y}*f_y}{M_{CR}}}$ = 1.46 ≥ $\lambda_{LT,0}$= 0.4 Reduciramo $M_{c,Rd}$zbog mogućnosti instabiliteta elementa.

Faktor imperfekcije: α_{LT} = 0.34 ← Krivulja izvijanja : ab $\begin{cases}\frac{h}{b}=1.8\ \leq 2\\ Vruće\ valjani\ I\ presjek\end{cases}$

Φ_{LT}= 0.5*(1+α_{LT}(λ_{LT}-0.2) + λ_{LT}^2)= 1.78

$\chi_{LT}=\frac{1}{\Phi_{LT}+\sqrt{\Phi_{LT}^2-\lambda_{LT}^2}}$= 0.45

$M_{B,Rd}=\chi_{LT}*\frac{W_{pl,y}*f_y}{\gamma_{m1}}$ = 19.89 (kNm) ≥ M_{Ed}^{Y}= 15.00 (kNm) *(75,41%)*

- Interakcija M_b-V-N_b (dvoosno savijanje):

$C_{MY}=C_{MZ}=C_{MLT}$= 1.00 ← $1.00+0.05\alpha_s \geq 0.4$ $\begin{cases}\alpha_s=0\\ \Psi=0\end{cases}$

k_{yy}= 1.02

k_{zz}=1.00

k_{yz}=0.83

k_{zy}=0.52

$\frac{N_{Ed}*\gamma_{m1}}{\chi^Y*N_{Rk}}+k_{yy}\frac{M_{Ed}^{Y}*\gamma_{m1}}{\chi^{LT}*M_{Rk}^{Y}}+k_{yz}\frac{M_{Ed}^{Y}*\gamma_{m1}}{M_{Rk}^{Z}}=0.88$

$\frac{N_{Ed}*\gamma_{m1}}{\chi^Z*N_{Rk}}+k_{zy}\frac{M_{Ed}^{Y}*\gamma_{m1}}{\chi^{LT}*M_{Rk}^{Y}}+k_{zz}\frac{M_{Ed}^{Y}*\gamma_{m1}}{M_{Rk}^{Z}}=0.52$

Profil IPE 160 zadovoljava otpornost elementa s iskoristivosti od 88.00 %

5.2.5. Bočne podrožnice

PROFIL:		**IPE 100**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	5.5	r (cm)	0.7	t_f (cm)	0.6
h (cm)	10.0	A (cm^2)	10.30	t_w (cm)	0.4
$W_{El,Y}$ (cm^3)	34.2	I_y (cm^4)	171.0	I_w (cm^6)	350
$W_{Pl,Y}$ (cm^3)	39.4	I_z (cm^4)	15.90	I_T (cm^4)	1.20
$W_{El,Z}$ (cm^3)	5.79	$A_{V,Z}$ (cm^2)	4.20		
$W_{Pl,Z}$ (cm^3)	9.20	$A_{V,Y}$ (cm^2)	6.74		
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	ν	0.30

Rezne sile uslijed kritične kombinacije:

M_{Ed} = 5.08 (kNm)
V_{Ed} = 5.40 (kN)
N_{Ed} = 0 (kN)

Klasifikacija profila:

- Hrbat (savijanje):

$$\frac{d}{t_w} = \frac{h-2*t_f-2*r}{t_w} = 18.5$$

Uvjet za klasu 1: $\frac{d}{t_w} \leq 72\varepsilon$= 58.32 Hrbat je klase 1

- Pojasnice (tlak):

$$\frac{c}{t_f} = \frac{0.5*(b-2*r-t_w)}{t_f} = 3.08$$

Uvjet za klasu 1: $\frac{c}{t_f} \leq 9\ \varepsilon$= 7.29 Pojasnice su klase 1

Poprečni presjek je klase 1.

Otpornost poprečnog presjeka:

- Savijanje:

$$M_{c,Rd} = M_{pl,Rd} = \frac{W_{Pl,y}*f_y}{\gamma_{m0}} = \frac{39.4*35.5}{1} = 13.99\ (\text{kNm})$$

$M_{c,Rd}$= 13.99 (kNm) ≥ M_{Ed} = 5.08 (kNm)

Profil zadovoljava na savijanje s iskoristivosti p.p. od 36.31%

- Posmik:

$$\frac{h_w}{t_w} = \frac{h-2*t_f}{t_w} = 22 \leq 72\ \frac{\varepsilon}{\eta} = 72\ \frac{0.81}{1.20} = 48.60$$

Nije potrebna kontrola izbočavanja hrpta uslijed djelovanja posmika!

$A_{V,Z}$= A - 2*b*t_f +(t_w+2*r)*t_f= 4.78 (cm^2) ≥ $\eta * h_w * t_w$= 4.22 (cm^2) Uvjet zadovoljen!

V_{Rd}^Z= = $V_{Pl,Rd}$ = $\frac{A_{v,z}*f_y}{\sqrt{3}*\gamma_{m0}} = \frac{4.78*35.5}{1.7321} = 97.97\ (\mathrm{kN})$

V_{Rd}^Z= $= 97.97\ (\mathrm{kN}) \geq V_{Ed}$= 5.40 (kN)

Profil zadovoljava na posmik s iskoristivosti p.p. od 5.51%

- Interakcija M-V-N:

N_{Ed}= 0(kN)

0.5*$V_{z,Rd}$ = 48.96 (kN) ≥ V_{Ed}= 5.40 (kN)

Nema redukcije $M_{c,Rd}$uslijed interakcije reznih sila!

Otpornost elementa:

- Savijanje:

L_{CR}= 5.40 (m)≈ 540 (cm) $z_G = \frac{h}{2}$= 2.7 (cm)

k= 1.0 C_1= 1.67

k_W= 1.0 C_2= 0.78

$M_{CR} = C_1 * \frac{\pi^2 * E * I_z}{(k * L_{CR})^2} * \left[\sqrt{\left(\frac{k}{k_w}\right)^2 * \frac{I_w}{I_z} + \frac{(k * L_{CR})^2 * G * I_T}{\pi^2 * E * I_z} + (C_2 * z_g)^2} - C_2 * z_g \right]$= 5.58 (kNm)

$\lambda_{LT} = \sqrt{\frac{W_{El,Y} * f_y}{M_{CR}}}$ = 1.58 ≥ $\lambda_{LT,0}$= 0.4 Reduciramo $M_{c,Rd}$zbog mogućnosti instabiliteta elementa.

Faktor imperfekcije: α_{LT} = 0.34 ← Krivulja izvijanja : b $\begin{cases} \frac{h}{b} = 1.08 \leq 2 \\ Vruće\ valjani\ I\ presjek \end{cases}$

Φ_{LT}= 0.5*(1+α_{LT}(λ_{LT}-0.2) + λ_{LT}^2)= 1.98

$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \lambda_{LT}^2}}$= 0.39

$M_{B,Rd}$= χ_{LT}* $\frac{W_{pl,y} * f_y}{\gamma_{m1}}$= 0.39*$\frac{39.4*35.5}{1}$ = 5.50 (kNm) ≥ M_{Ed}= 5.08 (kNm)

Profil IPE 100 zadovoljava otpornost elementa s iskoristivosti od 92.36%

5.2.6. Vertikale sprega

PROFIL:		**CFRHS 70x70x4.0**		ε= 0.81	
KVALITETA ČELIKA:	S355	f_y= 35.5 (kN/cm^2)		f_u= 49.0 (kN/cm^2)	
GEOMETRIJSKI PODATCI PROFILA:					
b (cm)	7.0	t (cm)	0.4	b (cm)	4.0
h (cm)	7.0	A (cm^2)	10.15	h (cm)	8.0
$W_{Pl,Y}$ (cm^3)	24.76	I_y (cm^4)	72.12	$W_{Pl,Y}$ (cm^3)	20.91
$W_{Pl,Z}$ (cm^3)	24.76	I_z (cm^4)	72.12	$W_{Pl,Z}$ (cm^3)	12.77
MEHANIČKI PODATCI ČELIKA:					
E (kN/cm^2)	21000	G (kN/cm^2)	8077	E (kN/cm^2)	21000

Rezne sile uslijed kritične kombinacije:

M_{Ed}= 0 (kNm)
V_{Ed}= 0 (kN)
N_{Ed}= -328.72 (kN)

Klasifikacija poprečnog presjeka:

- Hrbat:

$$\frac{d}{t} = \frac{h-3*t}{t} = 9.5$$

Uvjet za klasu 1: $\frac{d}{t} \leq 33$ ε=26.73 Hrbat je klase 1

Poprečni presjek je klase 1.

Otpornost poprečnog presjeka:

- Uzdužna tlačna sila

$$N_{c,Rd} = N_{pl,Rd} = \frac{A*f_y}{\gamma_{M,0}} = \frac{8.55*35.5}{1} = 303.53\ (kN) \geq N_{Ed} = 102.84\ (kN)$$

Profil zadovoljava na tlačnu silu s iskoristivosti p.p. od 33.88%

Otpornost elementa:

- Tlačna sila:

L_i=1.47 (m)= 147 (cm)

$N_{CR}{}^{Z}=\frac{\pi^2 * E * I_z}{L_i{}^2}$= 206.68 (kN)

Izvijanje oko osi: Y-Y ili Z-Z

Faktor imperfekcije: α=0.49 ←Linija izvijanja: a ← Vruće dogotovljeni

$\lambda_z=\sqrt{\frac{A * f_y}{N_{CR}}}$ = 1.21 → Očitano za liniju izvijanja a: χ_z=0.43

$N_{B,Rd}=\chi * \frac{A * f_y}{\gamma_{m1}}$ = 129.96(kN) ≥ N_{Ed}= 102.84(kN)

Profil CFRHS 80/40/4 zadovoljava otpor. elementa s iskoristivosti od 79.13%

6. PRORAČUN SPOJEVA

6.1. Proračun spoja temelj - stup

6.2. Proračun vlačnog nastavka rešetke

6.3. Proračun spoja stup - rešetka

Project:
Project no:
Author:

IDEA StatiCa
Calculate yesterday's estimates

Project data

Project name	
Project number	
Author	
Description	
Date	14/09/2022
Design code	EN

Material

Steel	S 355
Concrete	C25/30

Project item stup-temelj

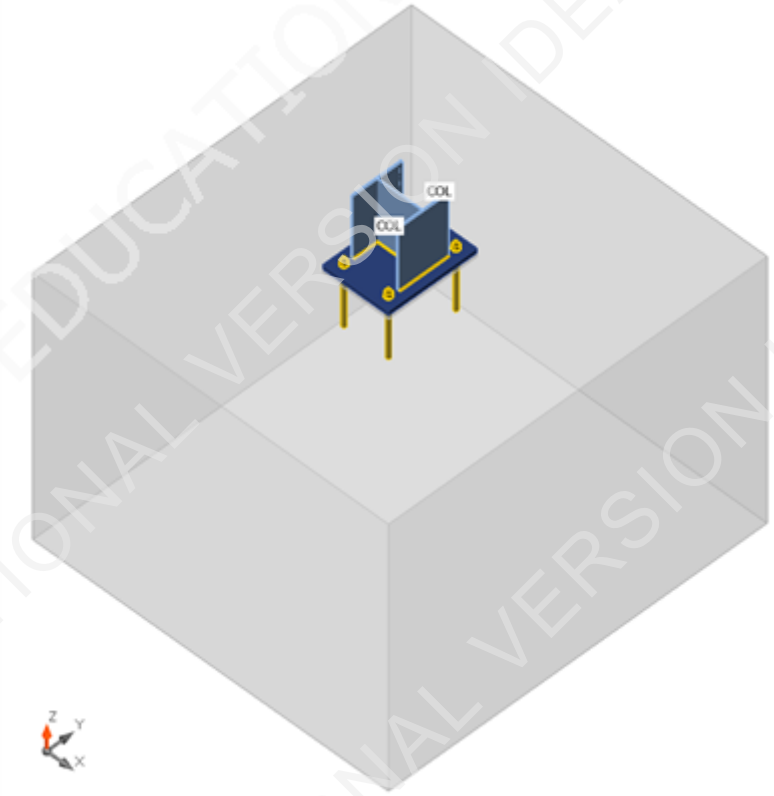
Design

Name	stup-temelj
Description	
Analysis	Stress, strain/ loads in equilibrium

Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
COL	2 - HEA280	0.0	-90.0	0.0	0	0	0	Node



Cross-sections

Name	Material
2 - HEA280	S 355

Anchors

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M24 8.8	M24 8.8	24	800.0	452

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	COL	-118.3	0.0	14.1	0.0	68.4	0.0

Foundation block

Item	Value	Unit
CB 1		
Dimensions	2130 x 2000	mm
Depth	1500	mm
Anchor	M24 8.8	
Anchoring length	300	mm
Shear force transfer	Anchors	
Mortar joint	20	mm

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Anchors	93.1 < 100%	OK
Welds	99.5 < 100%	OK
Concrete block	27.8 < 100%	OK
Buckling	Not calculated	

Plates

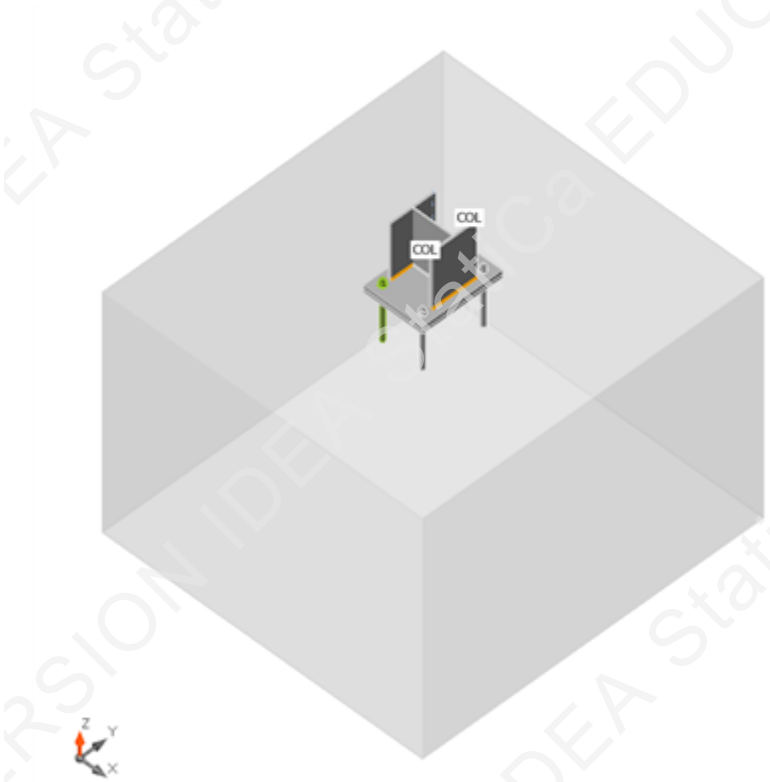
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
COL-bfl 1	13.0	LE1	177.2	0.0	0.0	OK
COL-tfl 1	13.0	LE1	174.2	0.0	0.0	OK
COL-w 1	8.0	LE1	98.7	0.0	0.0	OK
BP1	25.0	LE1	250.2	0.0	0.0	OK

Design data

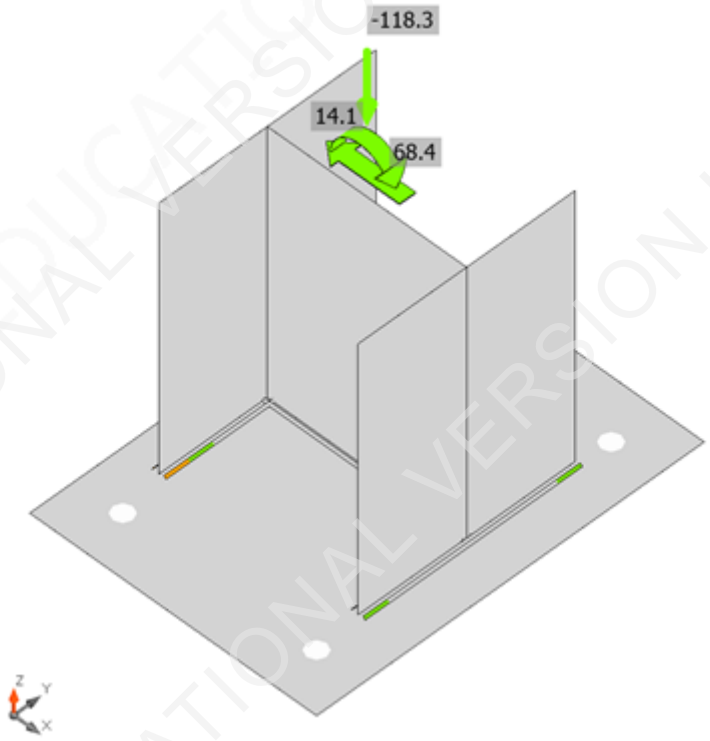
Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

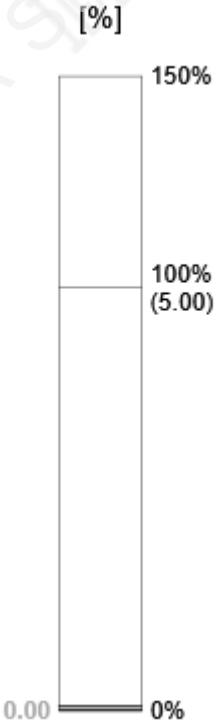
Symbol explanation

ε_{Pl}	Strain
σ_{Ed}	Eq. stress
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain

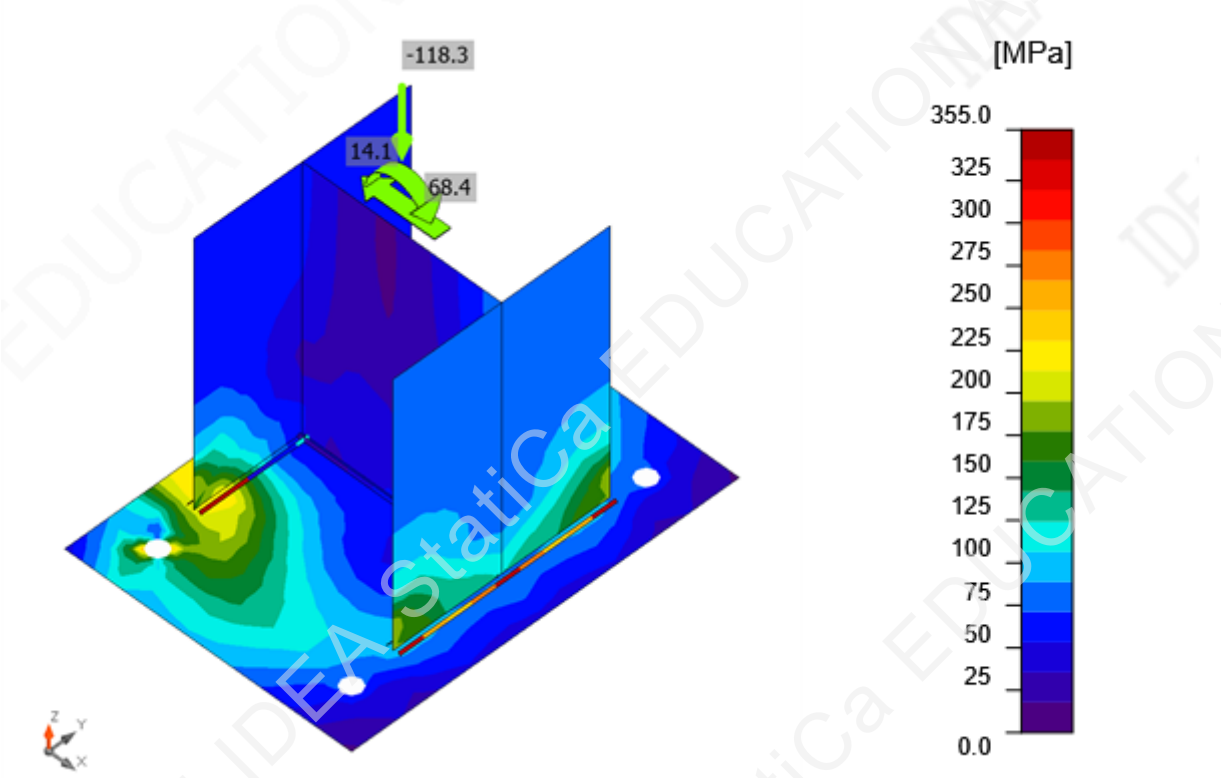


Overall check, LE1





Strain check, LE1



Equivalent stress, LE1

Anchors

Shape	Item	Loads	N_{Ed} [kN]	V_{Ed} [kN]	$N_{Rd,c}$ [kN]	$V_{Rd,s}$ [kN]	$V_{Rd,c}$ [kN]	$V_{Rd,cp}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Status
	A1	LE1	108.1	4.0	232.4	10.5	169.4	484.4	93.1	38.6	92.2	OK
	A2	LE1	108.2	4.0	232.4	10.5	169.4	484.4	93.1	38.7	92.2	OK
	A3	LE1	0.0	3.5	-	32.3	-	484.4	0.0	10.8	1.2	OK
	A4	LE1	0.0	3.5	-	32.3	-	484.4	0.0	10.8	1.2	OK

Design data

Grade	$N_{Rd,s}$ [kN]
M24 8.8 - 1	160.0

Symbol explanation

N_{Ed}	Tension force
V_{Ed}	Resultant of bolt shear forces Vy and Vz in shear planes
$N_{Rd,c}$	Design resistance in case of concrete cone failure under tension load - EN1992-4 - Cl. 7.2.1.4
$V_{Rd,s}$	Design shear resistance in case of steel failure - EN1992-4 - Cl.7.2.2.3.2
$V_{Rd,c}$	Design resistance in case of concrete cone failure under shear load - EN1992-4 - Cl. 7.2.2.5
$V_{Rd,cp}$	Design resistance in case of concrete pryout failure - EN1992-4 - Cl. 7.2.2.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Utilization in tension and shear
$N_{Rd,s}$	Design tensile resistance of a fastener in case of steel failure - EN1992-4 - Cl. 7.2.1.3

Welds

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
BP1	COL-bfl 1	◢ 4.0 ◣	280	LE1	376.6	0.0	-125.8	-121.6	-165.0	86.5	46.9	OK
		◢ 4.0 ◣	280	LE1	427.0	0.1	-193.2	143.3	166.8	98.0	70.4	OK
BP1	COL-tfl 1	◢ 4.0 ◣	280	LE1	433.2	3.7	196.2	114.1	191.6	99.5	58.0	OK
		◢ 4.0 ◣	280	LE1	433.0	3.5	189.5	-112.7	-194.5	99.4	52.4	OK
BP1	COL-w 1	◢ 4.0 ◣	257	LE1	75.9	0.0	37.6	5.5	37.7	17.4	11.5	OK
		◢ 4.0 ◣	257	LE1	75.5	0.0	37.5	-5.6	-37.4	17.3	11.5	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.90	435.6	352.8

Symbol explanation

◢	Fillet weld
ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Concrete block

Item	Loads	c [mm]	A_{eff} [mm^2]	σ [MPa]	k_j [-]	F_{jd} [MPa]	Ut [%]	Status
CB 1	LE1	47	37487	9.3	3.00	33.5	27.8	OK

Symbol explanation

c	Bearing width
A_{eff}	Effective area
σ	Average stress in concrete
k_j	Concentration factor
F_{jd}	The ultimate bearing strength of the concrete block
Ut	Utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_C	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	14/09/2022
Design code	EN

Material

Steel	S 355

Project item CON1

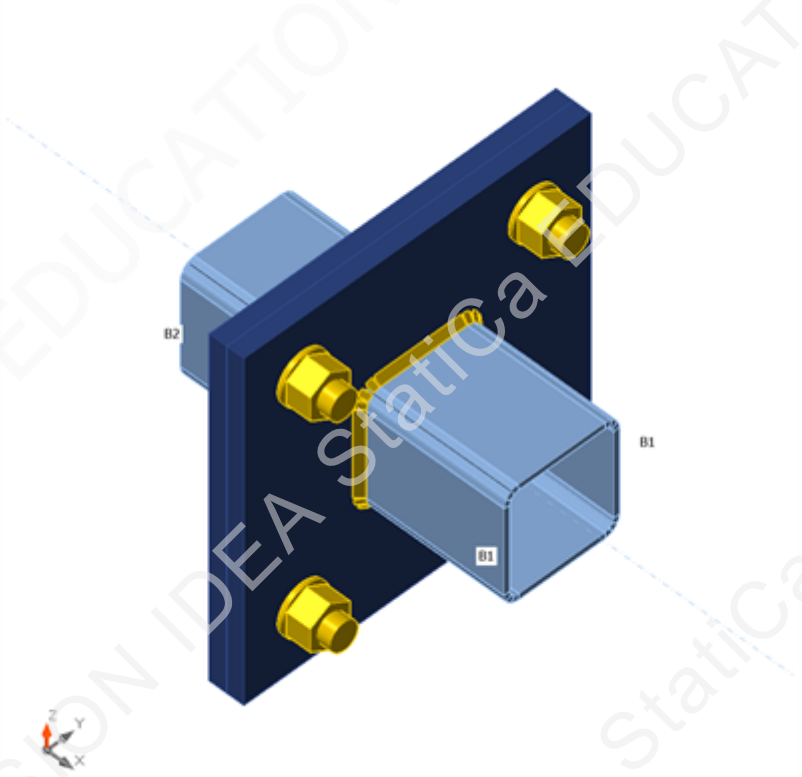
Design

Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
B1	3 - SHS100/100/5.0	0.0	0.0	0.0	0	0	0	Node
B2	3 - SHS100/100/5.0	180.0	0.0	0.0	0	0	0	Node



Cross-sections

Name	Material
3 - SHS100/100/5.0	S 355

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M24 8.8	M24 8.8	24	800.0	452

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B1	268.9	0.0	0.0	0.0	0.0	0.0
	B2	0.0	0.0	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.3 < 5.0%	OK
Bolts	80.7 < 100%	OK
Welds	99.1 < 100%	OK
Buckling	Not calculated	
GMNA	Calculated	

Plates

Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
B1	5.0	LE1	354.0	0.1	0.0	OK
B2	5.0	LE1	354.0	0.1	0.0	OK
PP1a	15.0	LE1	355.6	0.3	105.2	OK
PP1b	15.0	LE1	355.6	0.3	105.2	OK

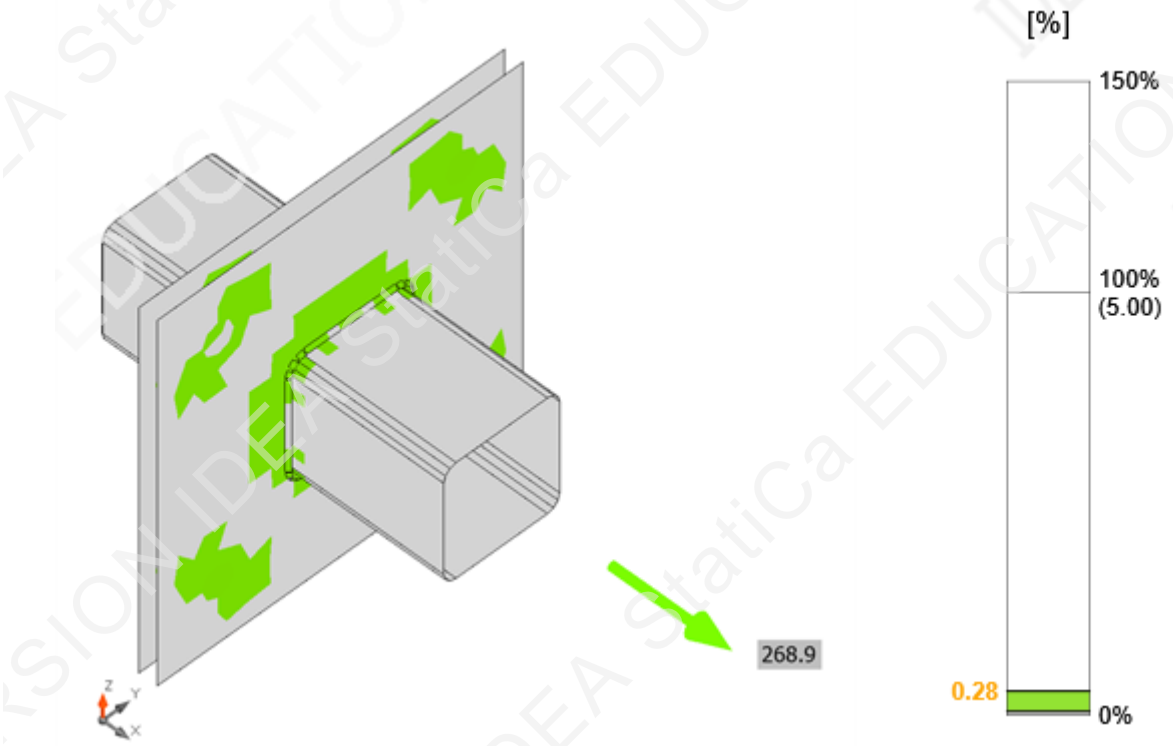
Design data

Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

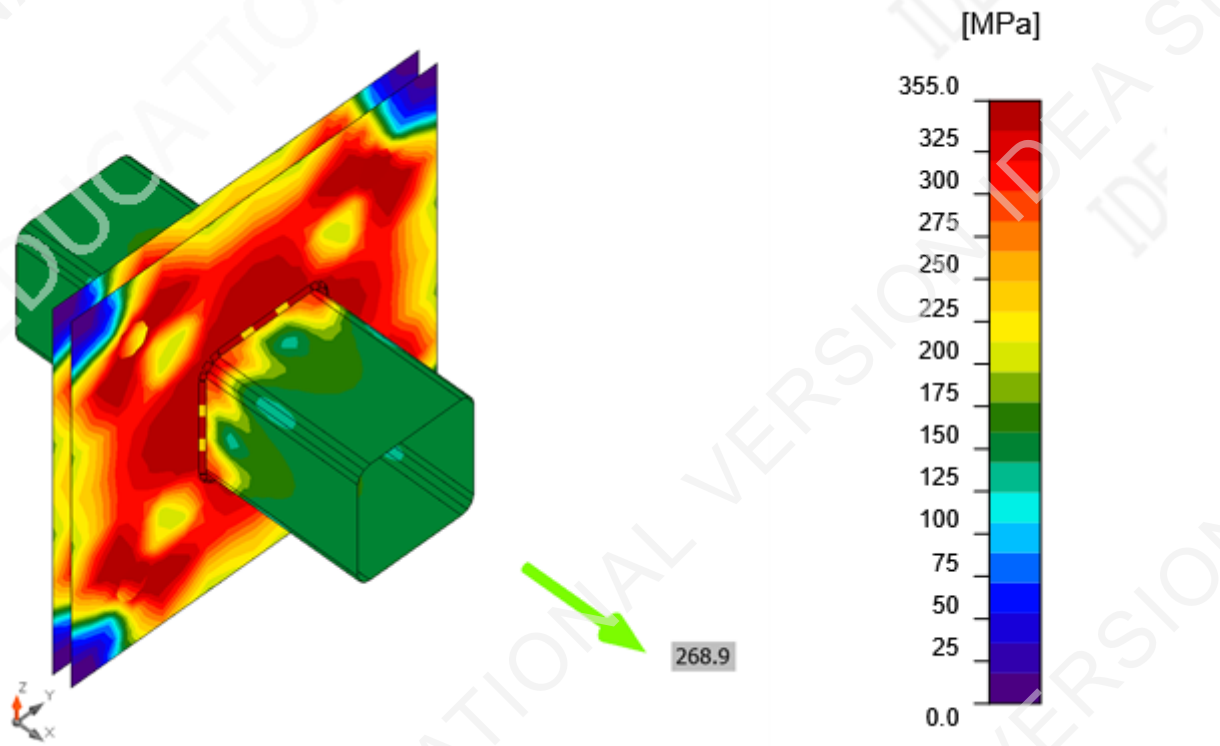
Symbol explanation

ε_{Pl}	Strain
σ_{Ed}	Eq. stress
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain

Overall check, LE1

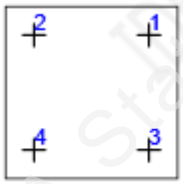


Strain check, LE1



Equivalent stress, LE1

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE1	164.1	0.0	80.7	231.8	0.0	57.6	OK
	B2	LE1	164.1	0.0	80.7	233.3	0.0	57.6	OK
	B3	LE1	164.1	0.0	80.7	231.7	0.0	57.6	OK
	B4	LE1	164.1	0.0	80.7	233.5	0.0	57.6	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M24 8.8 - 1	203.3	421.1	135.6

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
PP1a	B2	◢ 4.0	362	LE1	431.5	2.7	317.8	-98.4	-136.8	99.1	88.9	OK
PP1b	B1	◢ 4.0	362	LE1	431.5	2.7	317.7	98.3	-136.9	99.1	88.9	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.90	435.6	352.8

Symbol explanation

◢	Fillet weld
ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	Spoj stup-greda
Project number	
Author	Ivan Delaš
Description	
Date	14/09/2022
Design code	EN

Material

Steel	S 275, S 355

Project item CON1

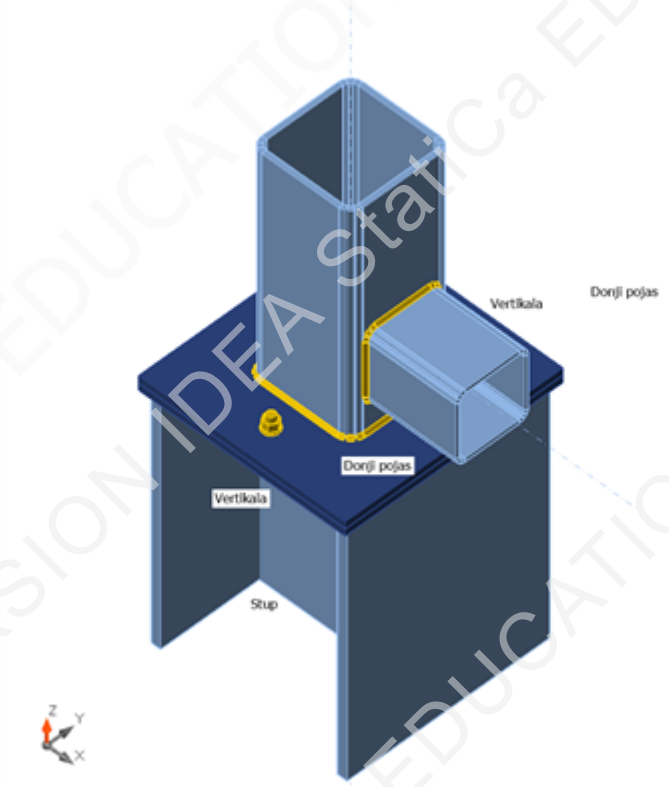
Design

Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
Stup	1 - HEA280	0.0	90.0	0.0	0	0	0	Node
Donji pojas	3 - SHS100/100/5.0	0.0	0.0	0.0	0	0	100	Node
Vertikala	4 - MQ140/140/7.1	0.0	-90.0	0.0	-420	0	0	Node



Cross-sections

Name	Material
1 - HEA280	S 355
3 - SHS100/100/5.0	S 355
4 - MQ140/140/7.1	S 355

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M12 8.8	M12 8.8	12	800.0	113

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	Stup	0.0	0.0	0.0	0.0	0.0	0.0
	Donji pojas	-6.7	0.0	0.0	0.0	0.0	0.0
	Vertikala	-129.8	0.0	0.0	0.0	0.0	0.0
LE2	Stup	0.0	0.0	0.0	0.0	0.0	0.0
	Donji pojas	6.4	0.0	0.0	0.0	0.0	0.0
	Vertikala	6.1	0.0	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	20.2 < 100%	OK
Welds	98.1 < 100%	OK
Buckling	Not calculated	

Plates

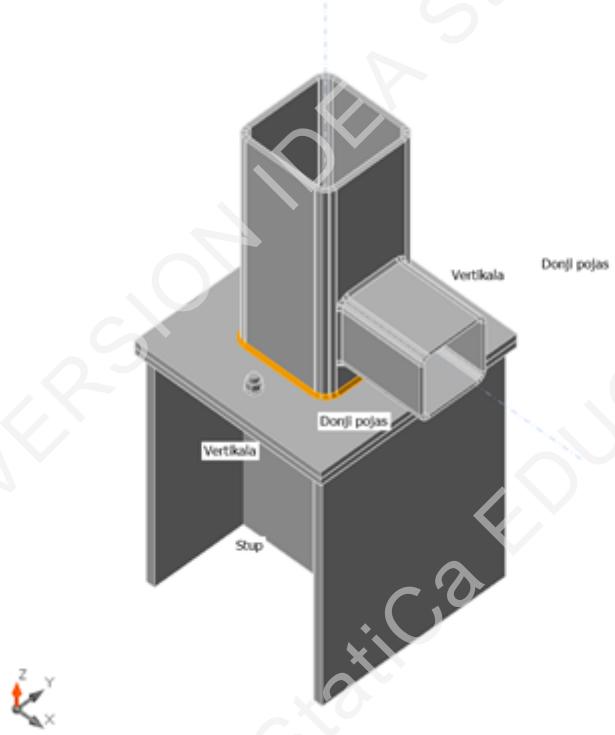
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
Stup-bfl 1	13.0	LE1	18.5	0.0	0.0	OK
Stup-tfl 1	13.0	LE1	13.5	0.0	0.0	OK
Stup-w 1	8.0	LE1	85.3	0.0	0.0	OK
Donji pojas	5.0	LE1	49.5	0.0	0.0	OK
Vertikala	7.1	LE1	114.6	0.0	0.0	OK
PP1a	10.0	LE2	109.9	0.0	9.2	OK
PP1b	10.0	LE2	87.9	0.0	9.2	OK

Design data

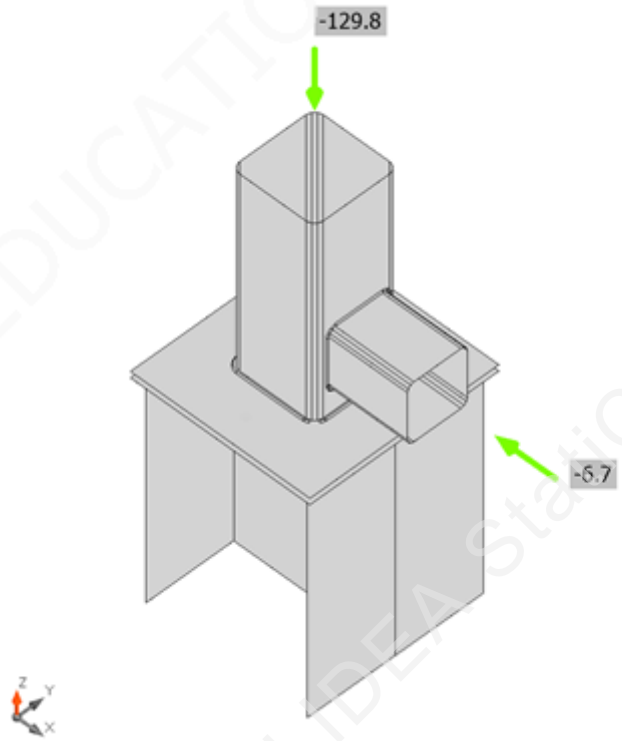
Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

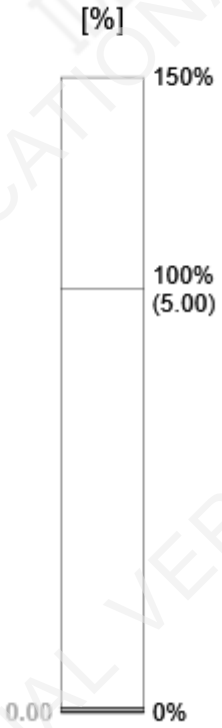
Symbol explanation

ε_{Pl}	Strain
σ_{Ed}	Eq. stress
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain

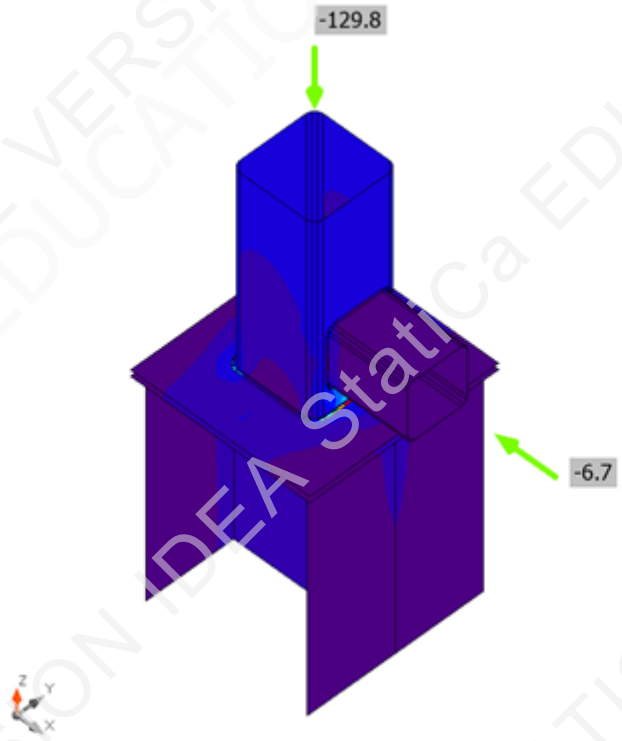


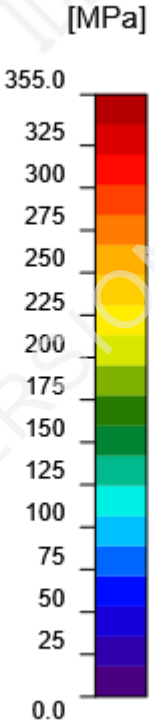
Overall check, LE1





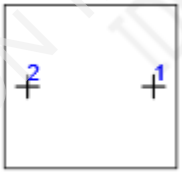
Strain check, LE1





Equivalent stress, LE1

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE2	7.0	3.2	14.4	117.6	9.9	20.2	OK
	B2	LE2	7.0	3.2	14.4	117.6	9.9	20.2	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 8.8 - 1	48.6	140.5	32.4

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
PP1b	Vertikala	◢ 3.0	508	LE1	427.1	0.1	-211.4	1.8	214.2	98.1	33.0	OK
Vertikala-w 1	Donji pojas	◢ 3.0	362	LE1	69.1	0.0	-29.9	-36.0	1.2	15.9	6.4	OK
PP1a	Stup-bfl 1	◢ 3.0	280	LE1	56.6	0.0	-12.1	0.0	31.9	13.0	5.1	OK
PP1a	Stup-tfl 1	◢ 3.0	280	LE1	43.0	0.0	-9.7	0.0	-24.2	9.9	4.2	OK
PP1a	Stup-w 1	◢ 3.0	257	LE1	427.2	0.2	-213.4	7.1	213.5	98.1	55.5	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.90	435.6	352.8

Symbol explanation

◢	Fillet weld
ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_C	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

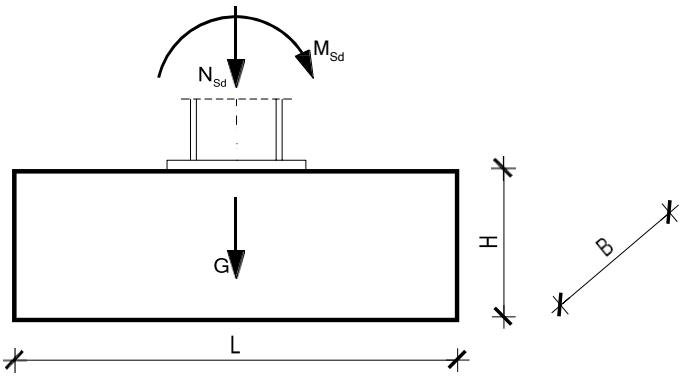
7. PRORAČUN TEMELJA

<u>Odabrane dimenzije temelja:</u>

L = 2m = 200cm

B = 2m = 200cm

H = 1.5m = 150cm



<u>Materijal:</u>

- Temeljno tlo: $\sigma_{tem,lim}$ = 300 kN/m^2
- Beton C 25/30: f_{ck} = 2.5 kN/cm^2
- Čelik B500B: f_{yk} = 5.0 kN/cm^2

REZNE SILE:

M_{Ed}= 68.44 (kNm)
V_{Ed}= 14.06 (kN)
N_{Ed}= -118.31 (kN)

Površina temeljne stope: A = L * B = 2 * 2 = 4 m^2
Težina temeljne stope: G = L * B * H * γ = 2 * 2 * 1.5 * 25 = 150 kN
Moment otpora temeljne stope:

$W = \frac{B * L^2}{6} = \frac{2 * 2^2}{6}$ = 1.3333 m^3

Naprezanje u tlu ispod temeljne stope na dubini temeljenja:

$\sigma_{1,2} = \frac{N_{Ed}+G}{A} \pm \frac{M_{Ed}}{W} = \frac{118.31+150}{4} \pm \frac{68.44}{1.3333} \rightarrow \sigma_1$ = 118.41 kN/m^2 ; σ_2 = 15.75 kN/m^2

$e = \frac{M_{Ed}}{N_{Ed}+G} = \frac{68.44}{118.31+150}$ = 0.26

$\frac{L}{2} = e + \frac{L'}{3} \rightarrow L' = 3 * (\frac{L}{2} - e) = 3 * (\frac{2}{2} - 0.26)$ = 2.22 m

$\sigma_{ekv} = \frac{2*(N_{Ed}+G)}{L'*B} = \frac{2*(118.31+150)}{2.22*2}$ = 120.86 kN/m^2 < σ_{dop} = 300 kN/m^2

Proračun armature temelja:

$L_1 = \frac{L-h_{stup}}{2} = \frac{2-0.27}{2} = 0.87$ m

$\frac{\sigma_{ekv}}{L'-L_1} = \frac{\sigma_{ekv}}{L'} \rightarrow \sigma_{1\text{-}1} = \frac{L'-L_1}{L'} * \sigma_{ekv} = \frac{2.22-0.87}{2.22} * 120.86 = 73.50$ kN/m^2

$M_{Ed}^{1-1} = \gamma * (\sigma_{1\text{-}1} * \frac{L_1^2}{2} * B + \frac{\sigma_{ekv}-\sigma_{1-1}}{2} * L_1 * B * \frac{2}{3} * L_1)$

$M_{Ed}^{1-1} = 1.4 * (73.50 * \frac{0.87^2}{2} * 2 + \frac{120.86-73.50}{2} * 0.87 * 2 * \frac{2}{3} * 0.87) = 111.34$ kNm

Krak unutarnjih sila:

$z \approx 0.8 * H = 0.8 * 1.5 = 1.2$

Potrebna površina armature:

$A_{S1} = \frac{M_{Ed}^{1-1}}{z * \frac{f_{yk}}{\gamma_S}} = \frac{111.34}{1.2 * \frac{50}{1.15}} = 2.13$ cm^2 < $A_{S1,min} = \frac{0.1}{100} * B * H = 30$ cm^2

Odabrana je minimalna armatura.

Odabrano:

Glavna armatura → Ø12/15

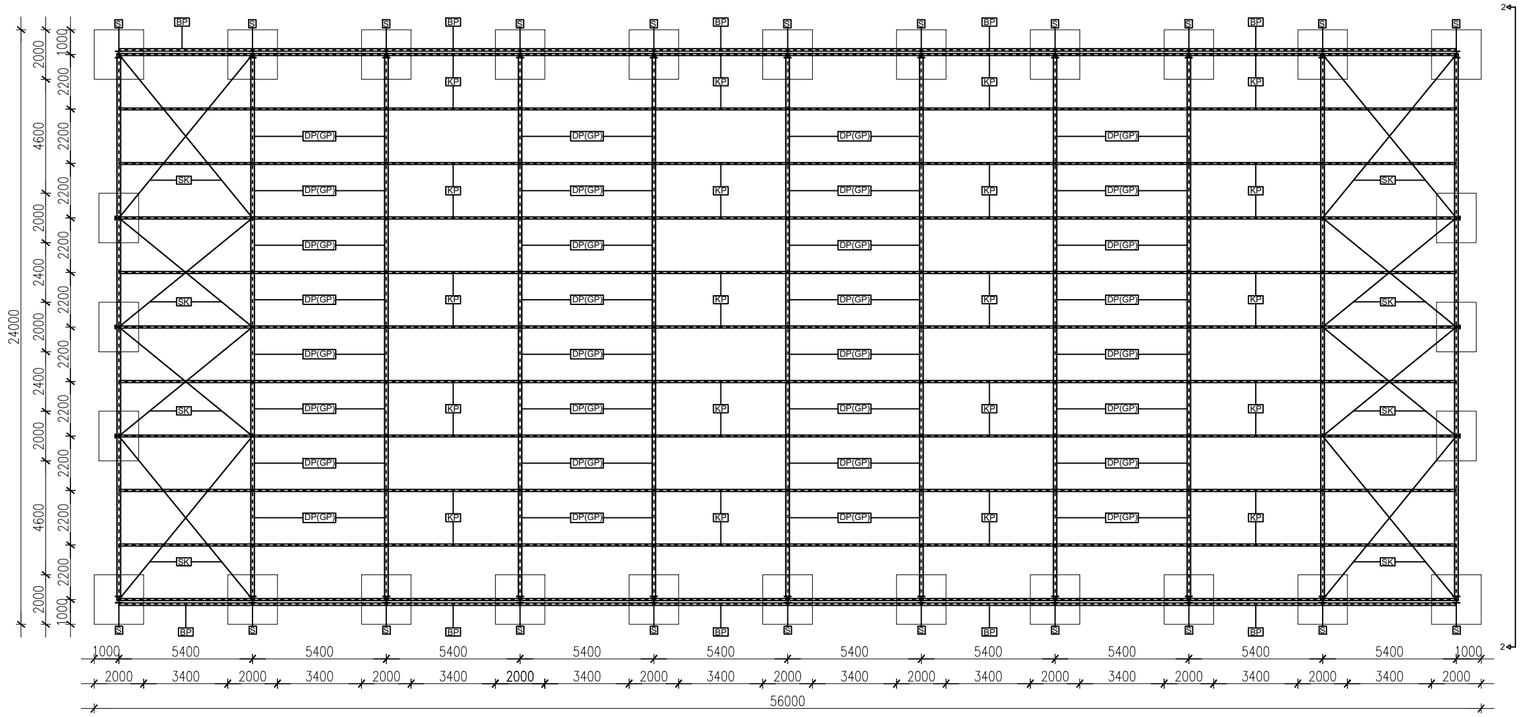
Razdjelna armatura → Ø8/25

8. NACRTI

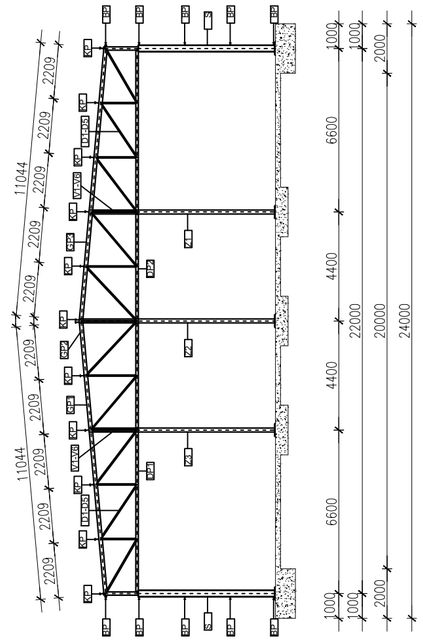
8.1. GENERALNI PLAN POZICIJA
8.2. PRESJEK KROZ GLAVNI OKVIR
8.3. RADIONIČKI NACRT GLAVNOG NOSAČA
8.4. RADIONIČKI NACRT SEKUNDARNE KONSTRUKCIJE
8.5. DETALJI SPOJEVA

GENERALNI PLAN POZICIJA
M 1:200

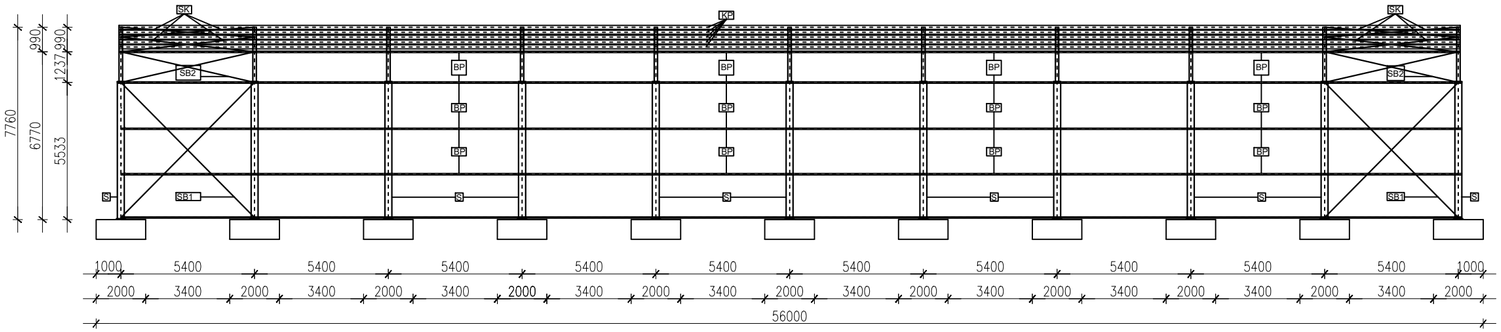
TLOCRTNI POGLED



POPREČNI POGLED 2-2



BOČNI POGLED



PRIKAZ I OPIS POZICIJA		
POZICIJA	PROFIL	NAZIV
STUP (S)	HEA280	Stup glavne konstrukcije
DONJI POJAS (DP)	CFRHS 100/100/5	Donji pojas krovne rešetke
GORNJI POJAS (GP)	CFRHS 140/140/7.1	Gornji pojas krovne rešetke
UNUTARNJE VERT. (V)	CFRHS 80/40/4.0	Unutarnje vertikalne ispune krovne rešetke
VANJSKE VERT. (V1)	CFRHS 140/140/7.1	Vanjske vertikalne ispune krovne rešetke
DIJAGONALE (K)	CFRHS 80/40/4.0	Dijagonalne ispune krovne rešetke
KROVNA PODR. (KP)	IPE 160	Sekundarna krovna konstrukcija
BOČNA PODR. (BP)	IPE 100	Sekundarna bočna konstrukcija
KROVNI SPREG (SK)	RD 14	Krovna dijagonala vjetrovnog sprega
BOČNI SPREG (SB)	RD 14	Bočna dijagonala vjetrovnog sprega
ZABAT (Z)	HEA160A	Sekundarna konstrukcija na zabatu hale
VERTIK. SPREGA (VS)	CFRHS 70/70/4.0	Sekundarna krovna i bočna konstrukcija

Svi elementi su klase čelika S355

Sveučilište u Splitu
Fakultet Građevinarstva, Arhitekture i Geodezije
21000 SPLIT, MATICE HRVATSKE 15

STUDENT:
Ivan Delaš

ZAVRŠNI RAD

ZADATAK: Projektiranje i dimenzioniranje hale

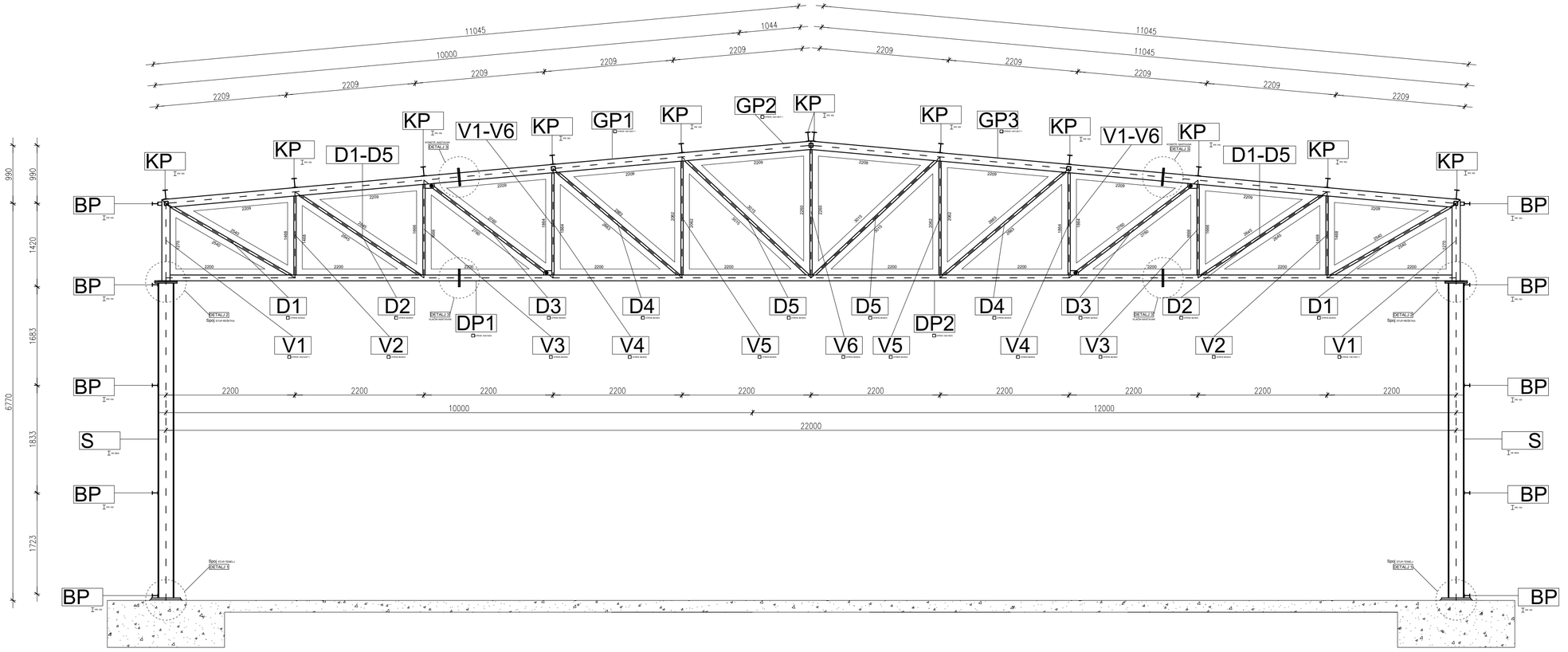
SADRŽAJ: Generalni plan pozicija

MJERILO: M 1:200

DATUM: 22.09.2022.

BROJ PRILOGA: 1

PRESJEK KROZ GLAVNI OKVIR
M 1:50

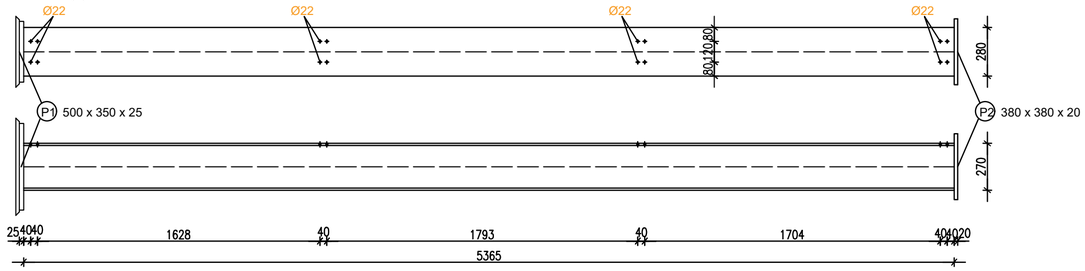


Svi elementi su klase čelika S355

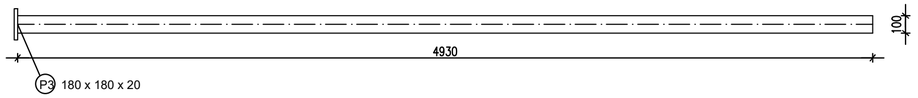
Sveučilište u Splitu Fakultet Građevinarstva, Arhitekture i Geodezije 21000 SPLIT, MATICE HRVATSKE 15	ZAVRŠNI RAD
	ZADATAK: Projektiranje i dimenzioniranje hale
	SADRŽAJ: Presjek kroz glavni okvir
STUDENT: Ivan Delaš	MJERILO: M 1:50
	DATUM: 22.09.2022.
	BROJ PRILOGA: 2

RADIONIČKI NACRT
REŠETKE I STUPA
M 1:25

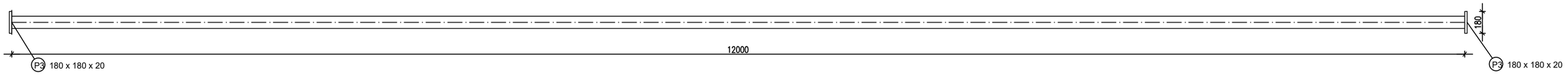
STUP (S) HEA 280 l=5500mm



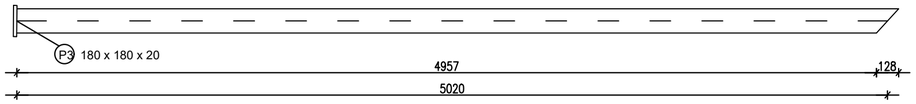
DONJI POJAS (DP1) 100 x 100 x 5 l=4930mm



DONJI POJAS (DP2) 100 x 100 x 5 l=12000mm

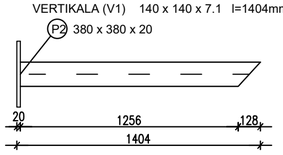


GORNJI POJAS (GP1) 140 x 140 x 7.1 l=5020mm

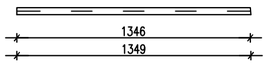


GORNJI POJAS (GP2) 140 x 140 x 7.1 l=6024mm

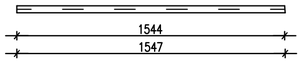
VERTIKALA (V1) 140 x 140 x 7.1 l=1404mm



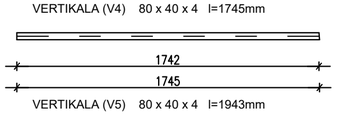
VERTIKALA (V2) 80 x 40 x 4 l=1349mm



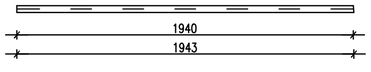
VERTIKALA (V3) 80 x 40 x 4 l=1547mm



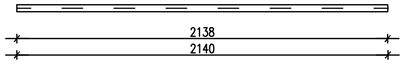
VERTIKALA (V4) 80 x 40 x 4 l=1745mm



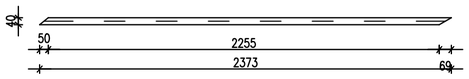
VERTIKALA (V5) 80 x 40 x 4 l=1943mm



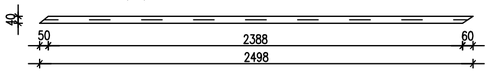
VERTIKALA (V6) 80 x 40 x 4 l=2140mm



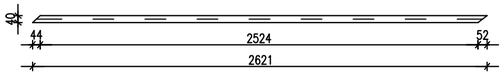
DIJAGONALA (K1) 80 x 40 x 4 l=2373mm



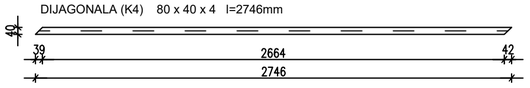
DIJAGONALA (K2) 80 x 40 x 4 l=2498mm



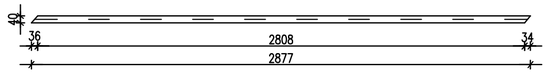
DIJAGONALA (K3) 80 x 40 x 4 l=2621mm



DIJAGONALA (K4) 80 x 40 x 4 l=2746mm



DIJAGONALA (K5) 80 x 40 x 4 l=2877mm



Element	Poprečni presjek	Površina(mm²)	Duljina (mm)	Masa (kg/m')	Broj komada	Masa (kg)
S	HEA 280	9730	5365	76,4	22	9017,5
DP1	CFRHS 100/5	1836	4930	14,4	22	1561,8
DP2	CFRHS 100/5	1836	12000	14,4	11	1900,8
GP1	CFRHS 140/7.1	3601	5020	28,3	22	3125,5
GP2	CFRHS 140/7.1	3601	6024	28,3	22	3750,5
V1	CFRHS 140/7.1	3601	1404	28,3	22	874,1
V2	CFRHS 80/40/4	855	1349	6,71	22	199,3
V3	CFRHS 80/40/4	855	1547	6,71	22	228,8
V4	CFRHS 80/40/4	855	1745	6,71	22	258,3
V5	CFRHS 80/40/4	855	1943	6,71	22	286,8
V6	CFRHS 80/40/4	855	2140	6,71	11	158,0
K1	CFRHS 80/40/4	855	2373	6,71	22	350,3
K2	CFRHS 80/40/4	855	2498	6,71	22	369,1
K3	CFRHS 80/40/4	855	2621	6,71	22	386,9
K4	CFRHS 80/40/4	855	2746	6,71	22	406,0
K5	CFRHS 80/40/4	855	2877	6,71	22	424,7
						Σ= 23298,4

Svi elementi su klase čelika S355

Sveučilište u Splitu
Fakulet Građevinarstva, Arhitekture i Geodezije
21000 SPLIT, MATICE HRVATSKE 15

ZAVRŠNI RAD

ZADATAK: Projektiranje i dimenzioniranje hale

SADRŽAJ: Radionički nacrt rešetke i stupa

STUDENT: Ivan Delaš

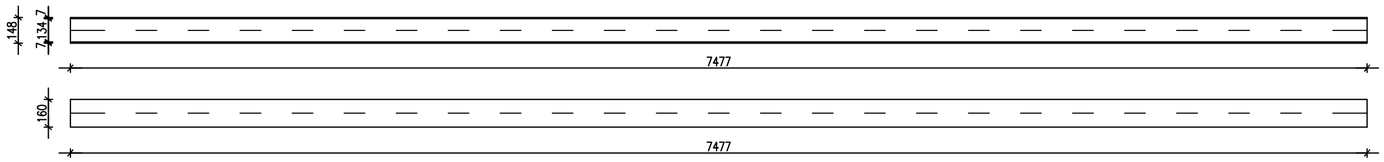
MJERILO: M 1:25

DATUM: 22.09.2022.

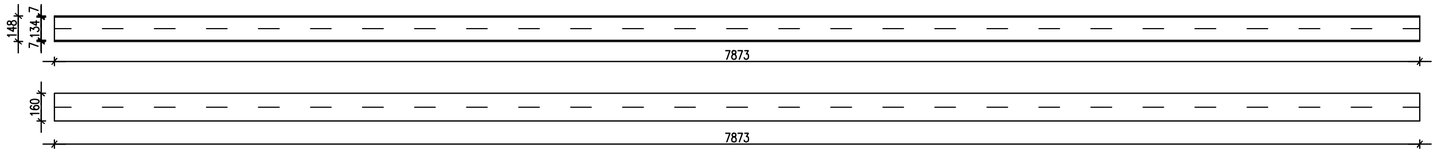
BROJ PRILOGA: 3

RADIONIČKI NACRT SEKUNDARNIH ELEMENATA
M 1:25

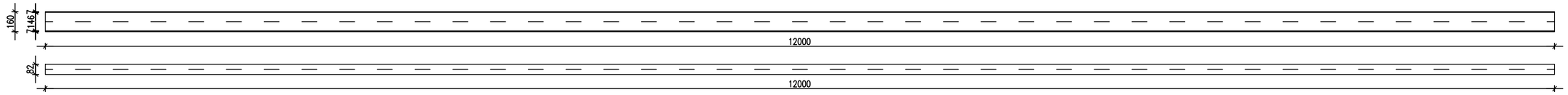
ZABATNI STUP (Z1) HEA160A l=7477mm



ZABATNI STUP (Z2) HEA160A l=7873mm

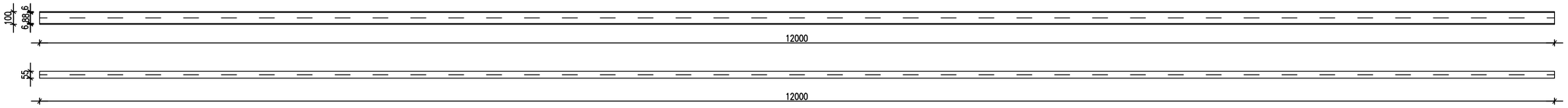


KROVNA PODROŽNICA (KP1) IPE160 l=12000mm

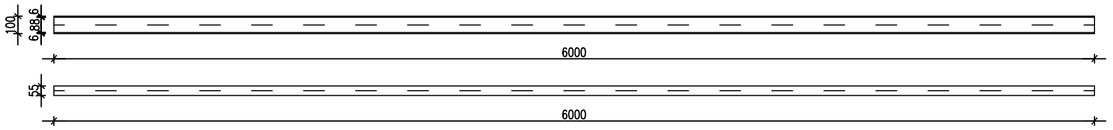


KROVNA PODROŽNICA (KP2) IPE160 l=6000mm

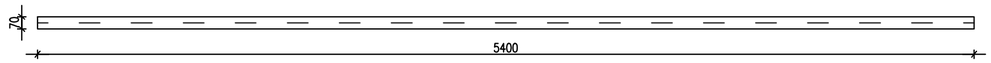
BOČNA PODROŽNICA (BP1) IPE100 l=12000mm



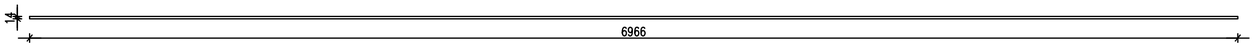
BOČNA PODROŽNICA (BP2) IPE100 l=6000mm



VERTIKALA SPREGA (VS) CFRHS 70 x 70 x 4 l=5400mm



KROVNI SPREGOVI (SK1) RND14 l=6736mm



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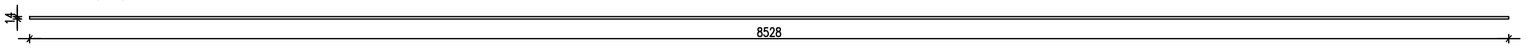
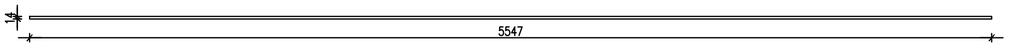


BOČNI SPREGOVI (SB1) RND14 l=5547mm



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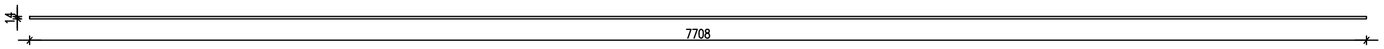


Element	Poprečni presjek	Površina(mm^2)	Duljina (mm)	Masa (kg/m')	Broj komada	Masa (kg)
Z1	HEA160A	3040	7477	38,23	4	1143,38
Z2	HEA160A	3040	7873	38,23	2	571,69
SK1	RND 14	154	6736	1,21	8	65,20
SK2	RND 14	154	8528	1,21	8	82,55
SB1	RND 14	154	5547	1,21	8	53,69
SB2	RND 14	154	7708	1,21	8	74,61
KP1	IPE 160	2010	12000	15,6	48	8985,6
KP2	IPE 160	2010	6000	15,6	12	1123,2
BP1	IPE 100	1030	12000	8,1	40	3888
BP2	IPE 100	1030	6000	8,1	10	486
VS	CFRHS 70/4	1015	5400	7,97	10	430,38
						Σ= 16904,3

Svi elementi su klase čelika S355

Sveučilište u Splitu
Fakulet Građevinarstva, Arhitekture i Geodezije
21000 SPLIT, MATICE HRVATSKE 15

ZAVRŠNI RAD

ZADATAK: Projektiranje i dimenzioniranje hale

SADRŽAJ: Radionički nacrt sekundarnih elemenata

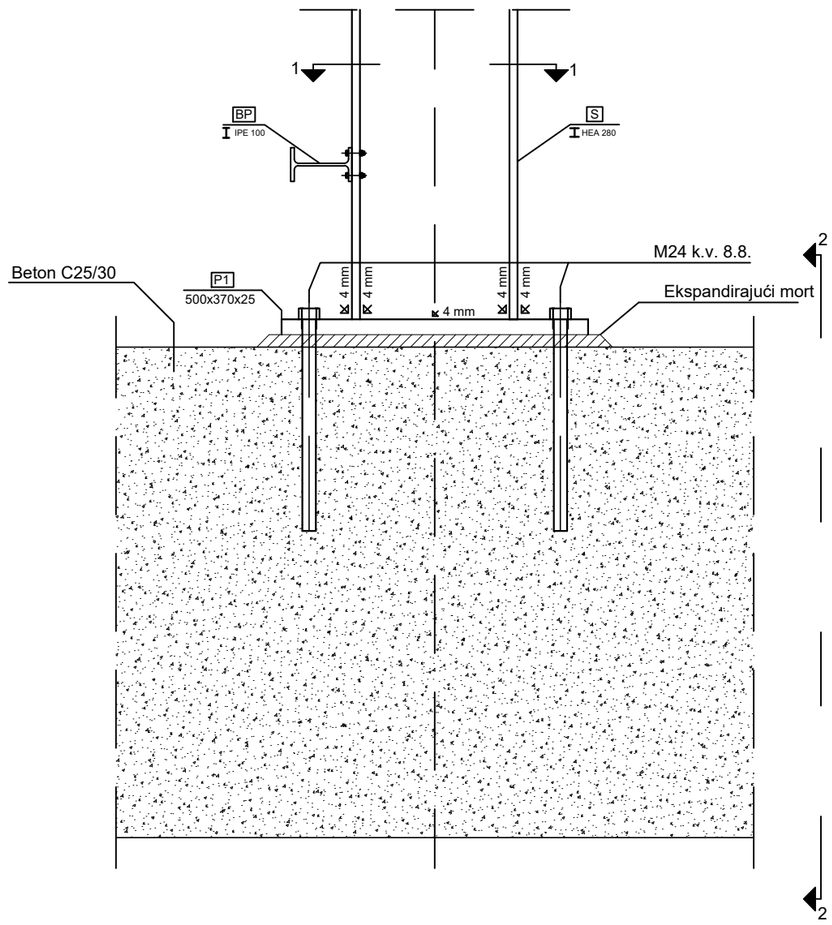
STUDENT: Ivan Delaš

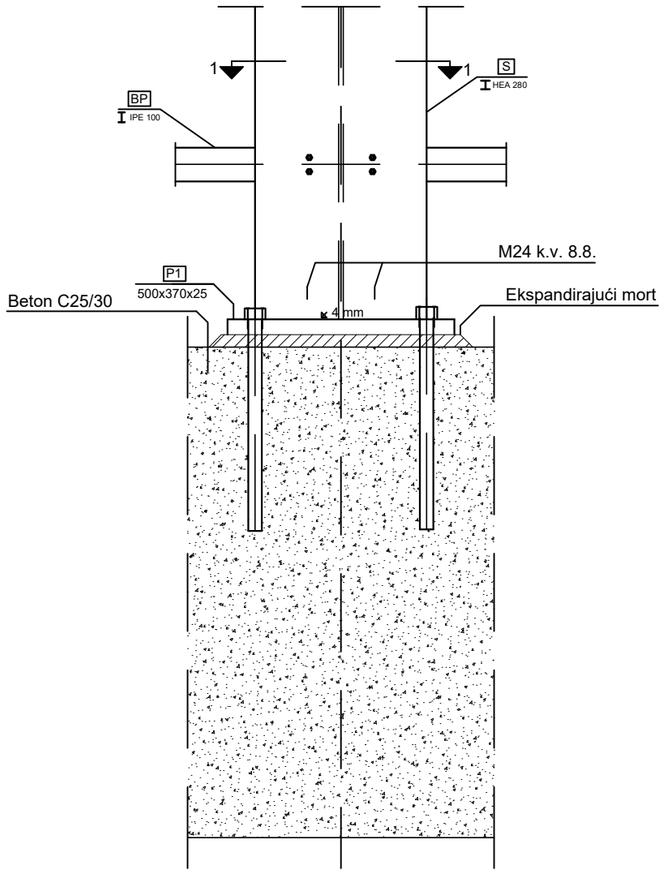
MJERILO: M 1:25

DATUM: 22.09.2022.

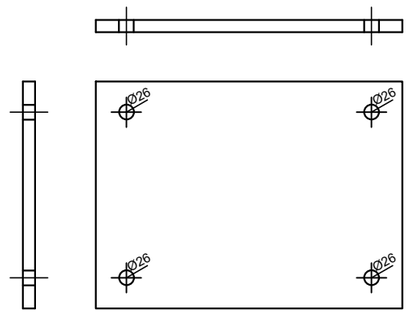
BROJ PRILOGA: 4

DETALJ 1
Spoj STUP-TEMELJ
M 1:10

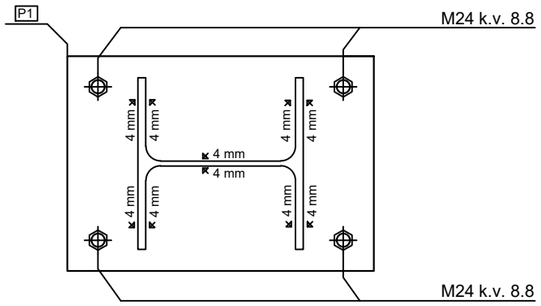




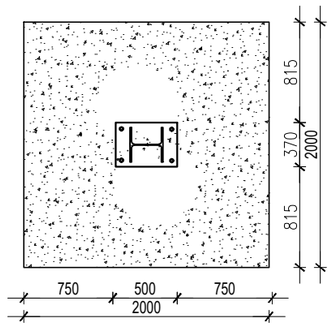
Pločica



Presjek 1-1



Tlocrt temelja M 1:50

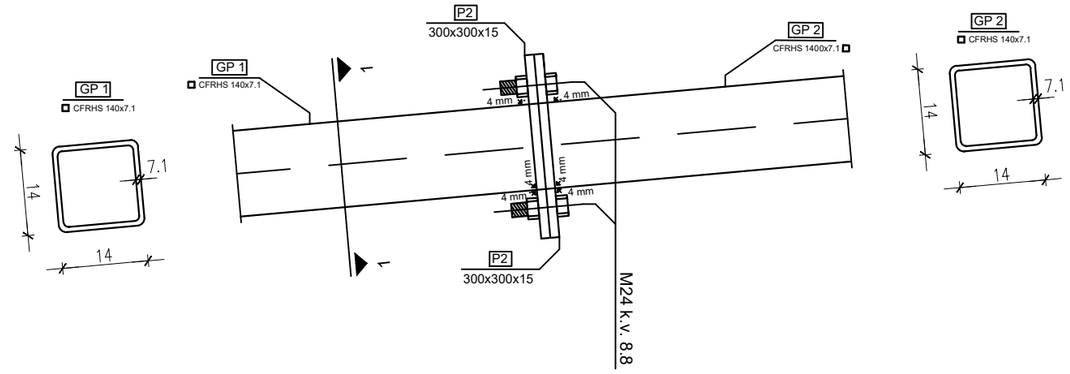


Svi varovi su a= 4 (mm).
Svi varovi minimalno su kvalitete S355
Svi elementi su klase čelika S355

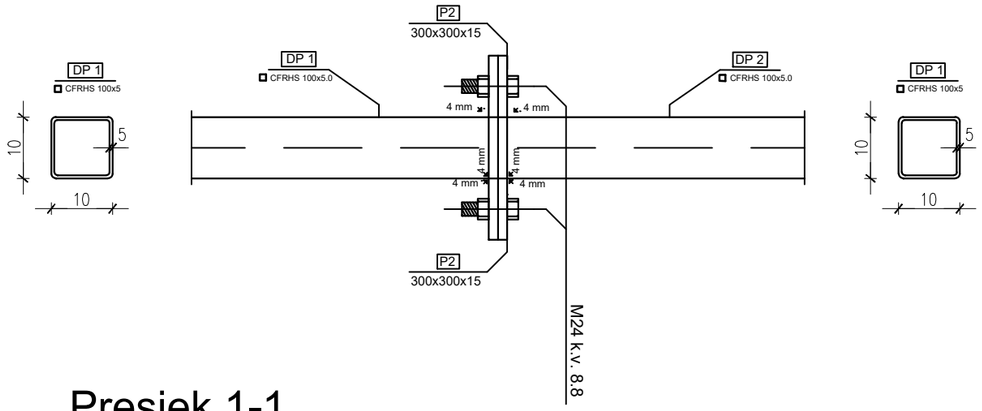
Sveučilište u Splitu Fakulet Građevinarstva, Arhitekture i Geodezije 21000 SPLIT, MATICE HRVATSKE 15	ZAVRŠNI RAD	
	ZADATAK: Projektiranje i dimenzioniranje hale	
	SADRŽAJ: Detalj spoja 1	
STUDENT: Ivan Delaš	MJERILO: M 1:10	
	DATUM: 22.09.2022.	BROJ PRILOGA: 5

DETALJ 2
Spoj VLAČNI NASTAVAK
M 1:10

Konstruktivni nastavak GP

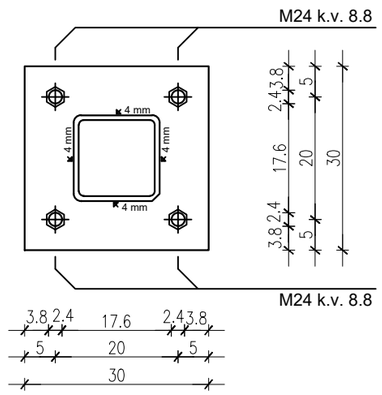


Vlačni nastavak DP



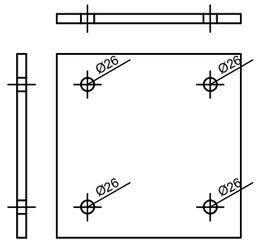
Presjek 1-1

P2 300x300x15 mm 2 kom/spoj



Pločica

P2 300x300x15 mm 2 kom/spoj

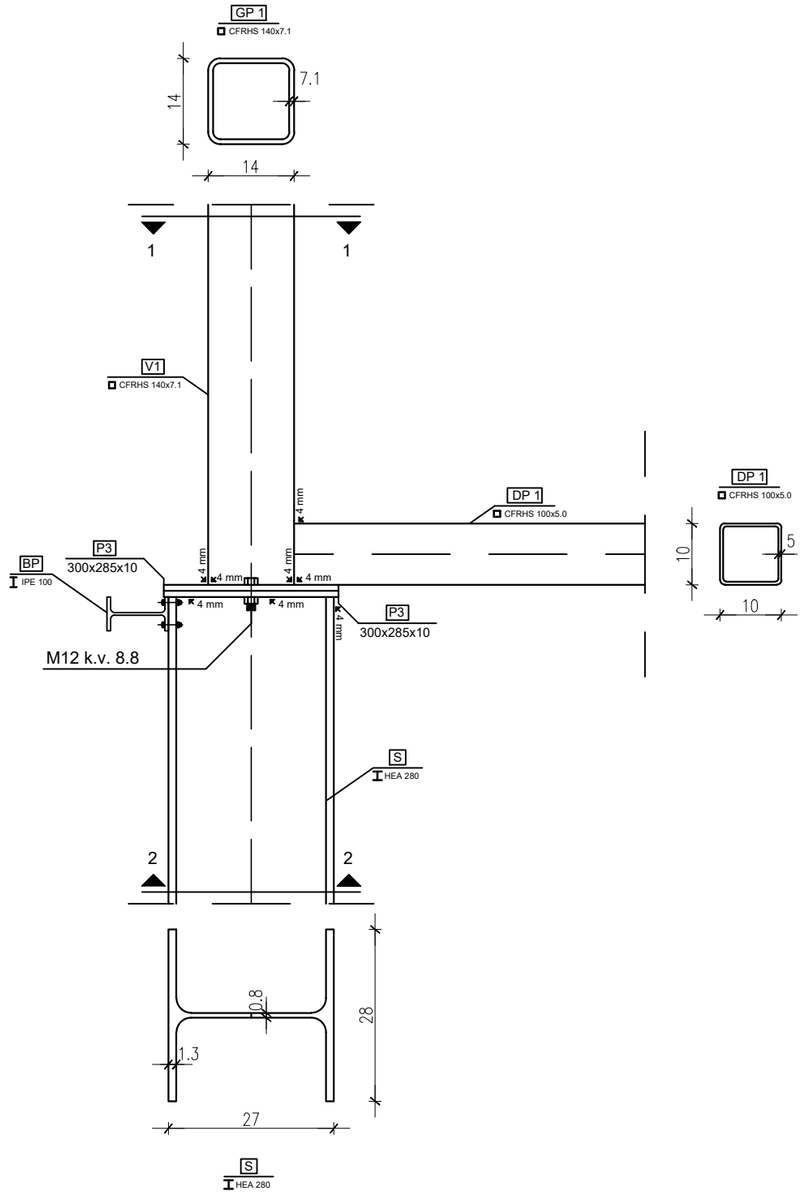


Svi elementi su kvalitete čelika S355

Svi varovi su a= 4 (mm), kvalitete min. S355

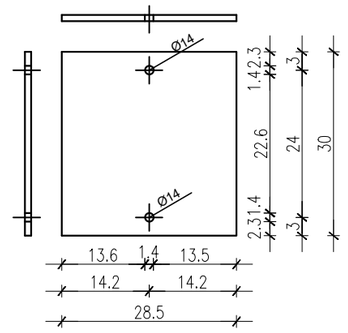
Sveučilište u Splitu Fakulet Građevinarstva, Arhitekture i Geodezije 21000 SPLIT, MATICE HRVATSKE 15	ZAVRŠNI RAD	
	ZADATAK: Projektiranje i dimenzioniranje hale	
	SADRŽAJ: Detalj spoja 2	
STUDENT: Ivan Delaš	MJERILO: M 1:10	
	DATUM: 22.09.2022.	BROJ PRILOGA: 6

DETALJ 3
Spoj STUP-REŠETKA
M 1:10

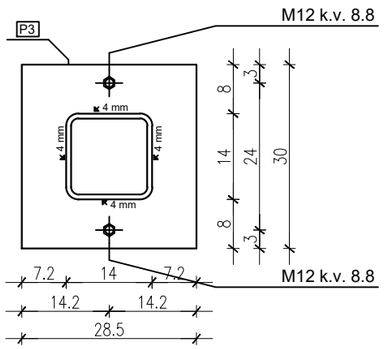


Pločica

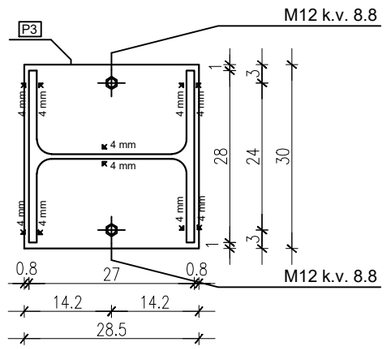
P3 300x285x10 mm 2 kom/spoj



Presjek 1-1



Presjek 2-2



Svi elementi su kvalitete čelika S355

Svi varovi su a= 4 (mm), kvalitete min. S355

Sveučilište u Splitu Fakulet Građevinarstva, Arhitekture i Geodezije 21000 SPLIT, MATICE HRVATSKE 15	ZAVRŠNI RAD	
	ZADATAK: Projektiranje i dimenzioniranje hale	
	SADRŽAJ: Detalj spoja 3	
STUDENT: Ivan Delaš	MJERILO: M 1:10	
	DATUM: 22.09.2022.	BROJ PRILOGA: 7

9. PREDMJER MATERIJALA ZA CIJELU KONSTRUKCIJU

TABLICA PREDMJERA MATERIJALA ZA CIJELU KONSTRUKCIJU

POZICIJA	PROFIL	DUŽINA (mm)	KOMADA	JED. TEŽINA (kg/m)	UKUPNA TEŽINA (kg)
Stup (S)	HEA280	5365	22	76,4	9017,5
Donji pojas (DP1)	CFRHS 100x100x5	4930	22	14,4	1561,8
Donji pojas (DP2)	CFRHS 100x100x5	12000	11	14,4	1900,8
Gornji pojas (GP1)	CFRHS 140x140x7.1	5020	22	28,3	3125,5
Gornji pojas (GP2)	CFRHS 140x140x7.1	6024	22	28,3	3750,5
Vertikala (V1)	CFRHS 140x140x7.1	1404	22	28,3	874,1
Vertikala (V2)	CFRHS 80x40x4	1349	22	6,71	199,3
Vertikala (V3)	CFRHS 80x40x4	1547	22	6,71	228,8
Vertikala (V4)	CFRHS 80x40x4	1745	22	6,71	258,3
Vertikala (V5)	CFRHS 80x40x4	1943	22	6,71	286,8
Vertikala (V6)	CFRHS 80x40x4	2140	11	6,71	158,0
Dijagonala (K1)	CFRHS 80x40x4	2373	22	6,71	350,3
Dijagonala (K2)	CFRHS 80x40x4	2498	22	6,71	369,1
Dijagonala (K3)	CFRHS 80x40x4	2621	22	6,71	386,9
Dijagonala (K4)	CFRHS 80x40x4	2746	22	6,71	406,0
Dijagonala (K5)	CFRHS 80x40x4	2877	22	6,71	424,7
Pločica (P1)	500x370x25	Proračun preko zapremnine	28	7850 (kg/m³)	1016,59
Pločica (P2)	300x300x15	Proračun preko zapremnine	88	7850 (kg/m³)	932,58
Pločica (P3)	300x285x10	Proračun preko zapremnine	44	7850 (kg/m³)	295,32
Zabatni stup(Z1)	HEA160A	7477	4	38,23	1143,38
Zabatni stup(Z2)	HEA160A	7873	2	38,23	571,69
Kr. spreg (KS1)	RND Ø14	6736	8	1,21	65,20
Kr. spreg (KS2)	RND Ø14	8528	8	1,21	82,55
Boč. spreg (BS)	RND Ø14	5547	8	1,21	53,69
Boč. spreg (BS)	RND Ø14	7708	8	1,21	74,61
Krovna podrožnica (KP1)	IPE 160	12000	48	15,6	8985,6
Krovna podrožnica (KP2)	IPE 160	6000	12	15,6	1123,2
Bočna podrožnica (BP1)	IPE 100	12000	40	8,10	3888
Bočna podrožnica (BP2)	IPE 100	6000	10	8,10	486
Vertikala sprega (VS)	CFRHS 70x70x4	5400	10	7,97	430,38

Ukupno (kg) +2,0% spojna sredstva	42447,19 848,94
UKUPNO (kg)	43296,13
UKUPNO (kg/m²)	36,44

Sveučilište u Splitu
Fakulet Građevinarstva, Arhitekture i Geodezije
21000 SPLIT, MATICE HRVATSKE 15

ZAVRŠNI RAD

ZADATAK: Projektiranje i dimenzioniranje hale

SADRŽAJ: Predmjer materijala

STUDENT: Ivan Delaš

MJERILO:

DATUM: 22.09.2022.

BROJ PRILOGA: 8

10. LITERATURA

[1] Prof.dr sc. Ivica Boko: Predavanja

[2] FGAG repozitorij: Repozitorij Fakulteta građevinarstva, arhitekture i geodezije, Sveučilište u Splitu

[3] EN 1991 Eurocode 1

- EN 1991-1-1:2002 Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings

-EN 1991-1-3:2003 Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads

-EN 1991-1-4:2005 Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions

[4] EN 1992 Eurocode 2

- EN 1992-1-1:2004 Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings

[5] EN 1993 Eurocode 3

- EN 1993-1-1:2005 Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings

- EN 1993-1-8:2005 Eurocode 3: Design of steel structures - Part 1-8: Design of joints