Proračun drvene hale

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SVEUČILIŠTE U SPLITU
FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

ZAVRŠNI RAD

Nikica Kraljević

Split, 2018.

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Sažetak:

Na temelju dobivenih podataka, kao što su lokacija građevine, dimenzija glavnih nosača i karakteristike materijala, potrebno je proračunati drvenu okvirnu halu i karakteristične detalje te izraditi radioničke nacrte. Hala je tlocrtnih dimenzija 26x30 m, te visine 10,85 m.

Ključne riječi:

drvo, okvirna konstrukcija, LLD, spojevi

Designing of a timber hall

Abstract:

On the basis of initial information (structure location, its geometry and the quality of the material), the main objective of the thesis is to design a timber frame hall and charasteristic details and make shop drawings. The hall has floor plan dimensions od 26x30 m and it is 10,85 m high.

Keywords:

Timber, frame structure, glulam, connections

SVEUČILIŠTE U SPLITU
FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

Split, Matice hrvatske 15

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

ZADATAK ZA ZAVRŠNI RAD

Tema: Proračun drvene okvirne hale

Opis zadatka: Proračun drvene okvirne hale na temelju dobivenih informacija o lokaciji građevine i karakteristikama materijala. Zadatak uključuje dimenzioniranje svih elemenata hale i pripadajućih spojeva.

U Splitu, rujan 2018.

Voditelj Završnog rada: doc. dr. sc. Neno Torić

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1. Tehnički opis

1.1 Opis konstrukcije

Zadana konstrukcija, tlocrtnih dimenzija 26/30 m i visine 10,85 m, nalazi se na području Zagreba i projektirana je za potrebe skladištenja. Krovna ploha je u odnosu na horizontalnu ravninu nagnuta pod kutem $\alpha = 22°$. Konstrukcija je zamišljena kao okvirni sustav od 7 jednakih okvira razmaknutih za 5,0 m. Statiči sustav okvira je trozglobni okvir ojačan metalnom zategom, a statički sustav sekundarne konstrukcije je prosta greda. Greda je izvedena kao nosač jednostrukog, a stup kao nosač dvostrukog poprečnog presjeka.
Na grede okvira se oslanjaju sekundarni krovni nosači (podrožnice) na međusobnom osnom razmaku od 2,003 (m), a na stupove su oslonjeni sekundarni bočni nosači na razmaku od 2,80 (m).
Stabilizacija hale u smjeru okomitom na glavni nosivi sustav ostvarena je spregovima u krovnim i bočnim ravninama i to u krajnjim poljima (prvom i posljednjem). Kao pokrov koriste se aluminijski sendvič paneli.
Vanjski stupovi konstrukcije su zglobno vezani s temeljom. Greda je upeto vezana za stupove.

Konstruktivni elementi

Krovna greda

Proračunom je odabrana jednodijelna greda poprečnog presjeka 200/760 mm.

Stupovi

Proračunom su odabrani vanjski stupovi dvodijelnog poprečnog presjeka 200/760/200 mm.

Zatega

Proračunom je odabran čelični poprečni presjek RD20. Zatega je u trećinama pridržana za krovnu gredu elementima poprečnog presjeka RD10, kako bi se spriječio vertikalni progib kada je zatega tlačno opterećena.

Podrožnice

Proračunom su odabrane podrožnice poprečnog presjeka 120/240 mm.

Sekundarni bočni nosači

Proračunom su odabrane sekundarni bočni nosači poprečnog presjeka 120/180 mm.

Spregovi

Kao dijagonale krovnog i bočnog sprega odabrane su čelične šipke RD15.

Zabatni stupovi

Proračunom su odabrani zabatni stupovi poprečnog presjeka 220/600 mm

1.2 O proračunu konstrukcije

Proračun reznih sila i pomaka konstrukcije proveden je po EUROCODE-u 5 gdje je konstrukcija analizirana na krajnje granično stanje i granično stanje uporabljivosti za različite kombinacije opterećenja.
Proračun je proveden po teoriji prvoga reda pri čemu nisu uzete u obzir početne imperfekcije konstruktivnih elementa.

Opterećenja koja djeluju na konstrukciju su:

- opterećenje vlastitim težinom,
- opterećenje snijegom,
- opterećenje vjetrom,
  te njihove kombinacije.

Provedeni su proračuni za 4 različite kombinacije opterećenja, te je konstrukcija dimenzionirana na najnepovoljnije rezne sile.
Proračun i dimenzioniranje izvedeni su u programskom paketu SCIA ENGINEER.

1.3 Materijal za izradu konstrukcije

Glavni okvir konstrukcije, kao i sekundarni nosači, izrađeni su od drva LLD Gl24h. Zatega, njezina pridržanja i spregovi izrađeni su od čelika S235.

1.4 Montaža i transport

Predgotovljeni nosači konstrukcije transportiraju se na gradilište u položaju u kojem će kasnije primiti opterećenje, pazeći da se izbjegnu moguća oštećenja.
Izvedba konstrukcije je montažna. Svi elementi konstrukcije predgotovljeni stižu na gradilište te se međusobno vežu vijcima ili trnovima.
Nakon pripremnih radova i betoniranja temelja, prva faza montaže je montaža stupova. Stupovi se zglobno povezuju s temeljima i pridržavaju se u vertikalnom položaju dok se ne povežu s gredama i učvrste zategom. Tada se prva 2 okvira povezujuu krovnim i bočnim spregovima, čime se dobije stabilna konstrukcija na koju se mogu povezivati preostali elementi.

1.5 Primijenjeni propisi

Proračun i dimenzioniranje svih elemenata drvene i čelične konstrukcije provedeni su u skladu sa EUROCODE 5 i EUROCODE 3, a analiza dijelovanja na konstrukciju napravljena je u skladu sa EUROCODE 1.

1.6 Antikorozivna zaštita

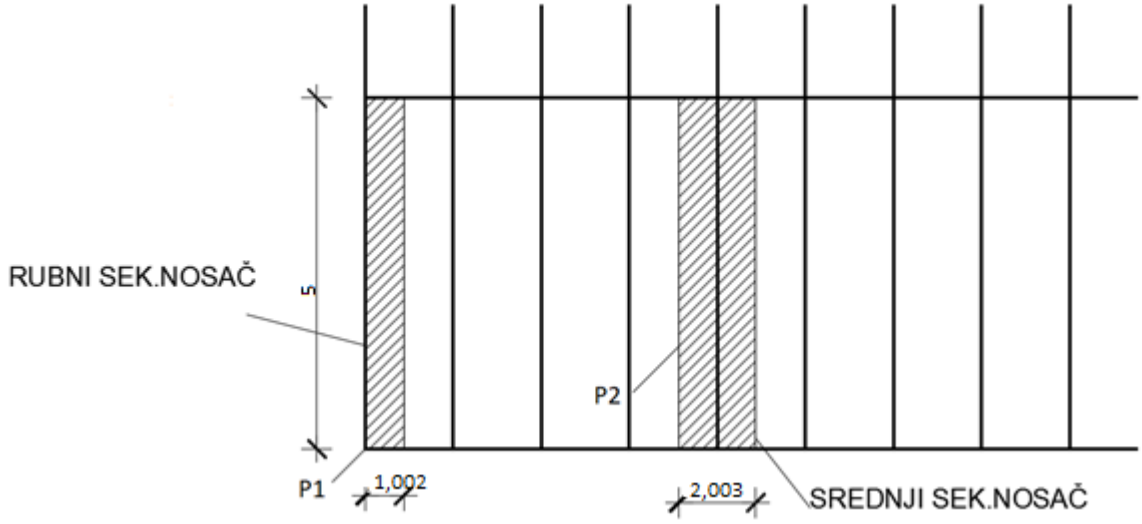
Svi dijelovi spojnih sredstava izrađeni od čelika moraju biti zaštićeni od korozije prema odredbama "Pravilnika o tehničkim mjerama i uvjetima za zaštitu čeličnih konstrukcije od korozije". Odabrana je zaštita vrućim pocinčavanjem i zaštitnim premazom. Ukupna debljina zaštitnog sloja je 200 μm.

1.7 Protupožarna zaštita

Kako bi se spriječilo prerano zagrijavanje nosivih elemenata konstrukcije prilikom požara, svi takvi elementi moraju se zaštiti posebnim premazima otpornim na visoke temperature.
Također je potrebno opremiti objekt uređajima za najavu požara kao i opremom za gašenje.

2.Analiza opterećenja

Prikaz raspodjele opterećenja za sekundarne nosače.



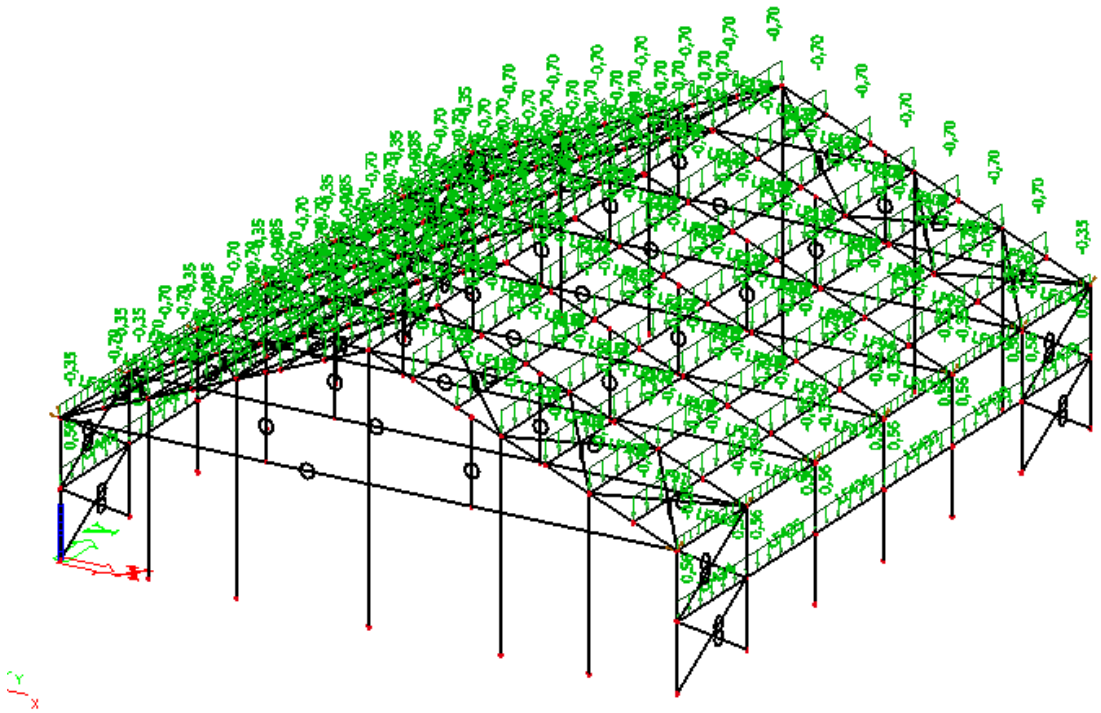
2.1 Stalno opterećenje

- pokrov $g = 0{,}25\ kN/m^2$
- instalacije $g = 0{,}1\ kN/m^2$
- vlastita težina –dodana u sklopu računalnog programa

$$\sum g = 0{,}35\ kN/m^2$$

DODATNO STALNO OPTEREĆENJE NA KROV Δg				
NOSAČ	UTJECAJNA POVRŠINA	Δg (kN/m2)	L(m)	Δg (kN/m)
RUBNI SEK.NOSAČ	P1	0,35	1,002	0,35
SREDNJI SEK.NOSAČ	P2	0,35	2,003	0,70

DODATNO STALNO OPTEREĆENJE NA BOČNU PODROŽNICU Δg				
NOSAČ	UTJECAJNA POVRŠINA	Δg (kN/m2)	L(m)	Δg (kN/m)
RUBNI SEK.NOSAČ	P1	0,2	2,8	0,56



Opterećenje modela dodatnim stalnim opterećenjem

2.2 Snijeg

Opterećenje snijegom na krovu

$s = \mu_1 \cdot C_e \cdot C_t \cdot s_k$

- μ_1 - koef. oblika za opterećenje snijegom

krov nagiba $0^\circ \le \alpha \le 30^\circ \Rightarrow \mu_1 = 0{,}8$

- s_k - karakteristična vrijednost opterećenja na tlu u $\left[kN/m^2\right]$

zona Zagreba, područje 3. (kontinentalna Hrvatska), nadmorska visina do 100 m $\Rightarrow s_k = 1{,}00\ kN/m^2$

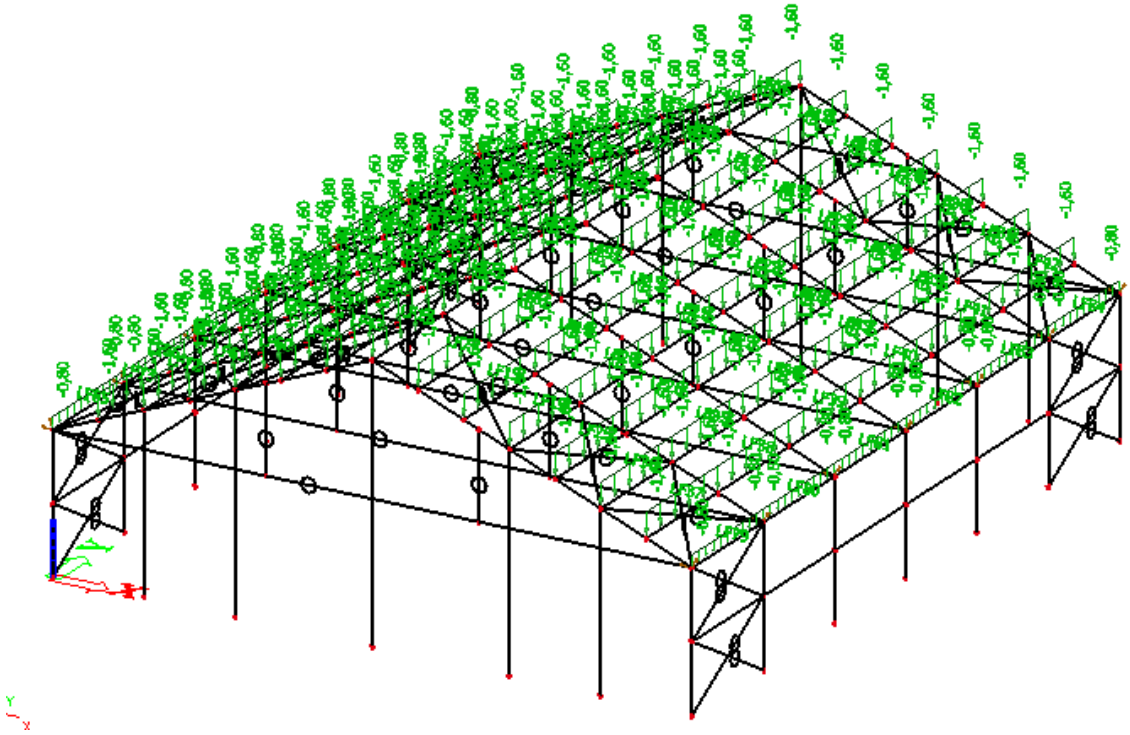


Slika 2.1.. *Karta područja za opterećenja snijegom*

- C_e - koef. izloženosti $\Rightarrow C_e = 1{,}0$
- C_t - toplinski koef. $\Rightarrow C_t = 1{,}0$

$\Rightarrow s = 0{,}8 \cdot 1{,}0 \cdot 1{,}0 \cdot 1{,}0 = 0{,}8\ \left[kN/m^2\right]$

OPTEREĆENJE SNIJEGOM S				
NOSAČ	UTJECAJNA POVRŠINA	S (kN/m2)	L(m)	S (kN/m)
RUBNI SEK.NOSAČ	P1	0,8	1,002	0,80
SREDNJI SEK.NOSAČ	P2	0,8	2,003	1,60



Opterećenje modela snijegom

2.3 Vjetar

- pritisak vjetra na vanjske površine: $w_e = q_p * c_e(z_e) * c_{pe}$ [kN/m^2]
- pritisak vjetra na unutarnje površine: $w_i = q_p * c_e(z_i) * c_{pi}$ [kN/m^2]

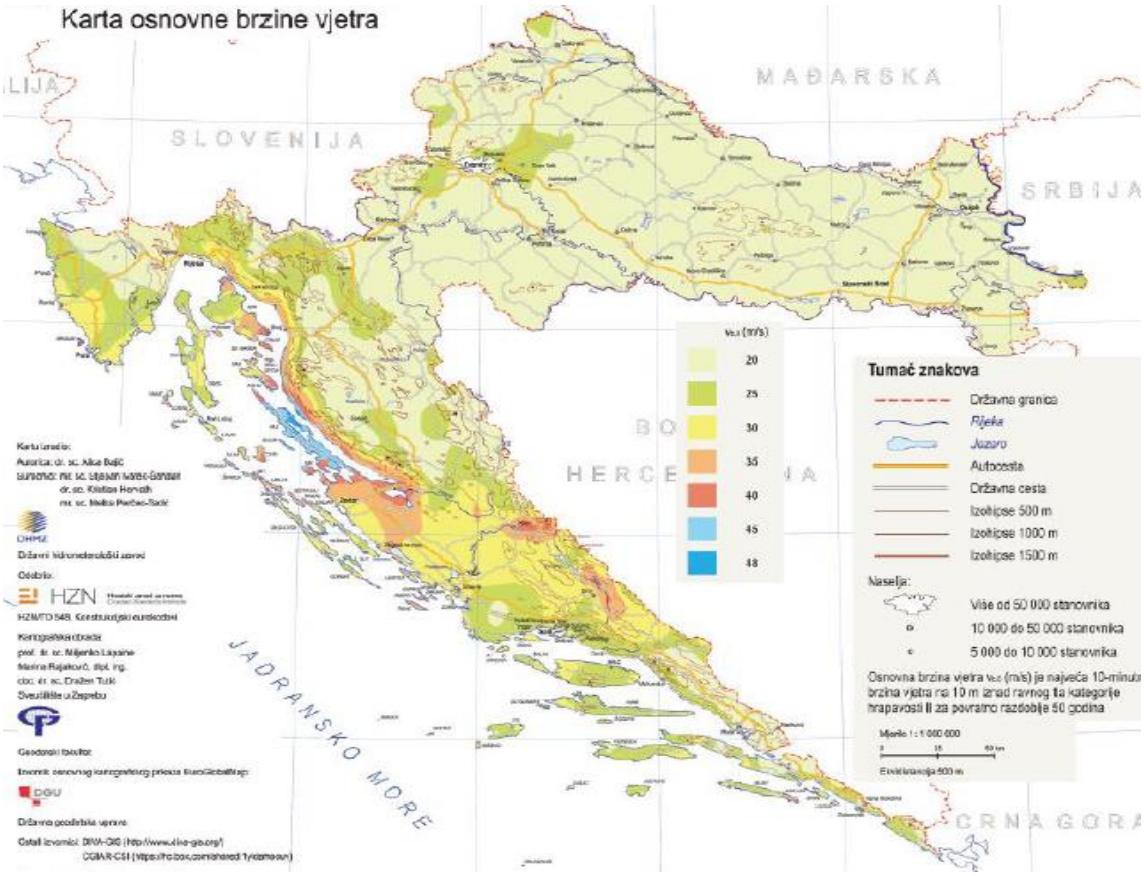
gdje je:

q_{ref} – poredbeni tlak vjetra pri srednjoj brzini vjetra

$C_e(z_e)$;$C_e(z_i)$ – koeficijenti izloženosti koji uzimaju u obzir neravnine terena

z_e;z_i – poredbene visine za lokalni ili unutarnji tlak

c_{pe};c_{pi} – vanjski i unutarnji koeficijent pritiska



Zemljovid područja opterećenja vjetrom

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

gdje je:

v_b – osnovna brzina vjetra

ρ – gustoća zraka (ρ=1,25 kg/m^3)

Osnovna brzina vjetrav_b ,dana je izrazom:

$v_b = c_{dir} * c_{season} * v_{b0}$

gdje je:

v_b – osnovna brzina vjetra

c_{dir} – koeficijent smjera vjetra (obično uzima vrijednost 1,0)

c_{season} – koeficijent ovisan o godišnjem dobu (obično uzima vrijednost 1,0)

Osnovni pritisak vjetra:

$v_b = 20{,}0(\frac{m}{s}) \rightarrow$

očitano za Zagreb

$C_{dir} = C_{season} = 1{,}0$

$v_b = v_{b,0} \cdot C_{dir} \cdot C_{season} = 20 \cdot 1{,}0 \cdot 1{,}0 = 20{,}0(\frac{m}{s})$

$\rho = 1{,}25 \frac{kg}{m^3}$

$q_b = \frac{\rho}{2} \cdot v_b^2 = \frac{1{,}25}{2} \cdot 20{,}0^2 = 250{,}0(\frac{N}{m^2}) = 0{,}25(\frac{kN}{m^2})$

Faktor terena k_r -za kategoriju terena IV :

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07} = 0{,}19 \cdot \left(\frac{1{,}0}{0{,}05}\right)^{0{,}07} = 0{,}234$$

$$C_{r(z)} = k_r \cdot \ln\left(\frac{z}{z_0}\right) = 0{,}234 \cdot \ln\left(\frac{10{,}85}{1{,}0}\right) = 0{,}558$$

$$C_{0(z)} = 1{,}0$$

Srednja brzina vjetra iznad terena:

$$v_{m(11{,}84)} = v_b \cdot C_{r(z)} \cdot C_{0(z)} = 20 \cdot 1{,}00 \cdot 0{,}558 = 11{,}16(\frac{m}{s})$$

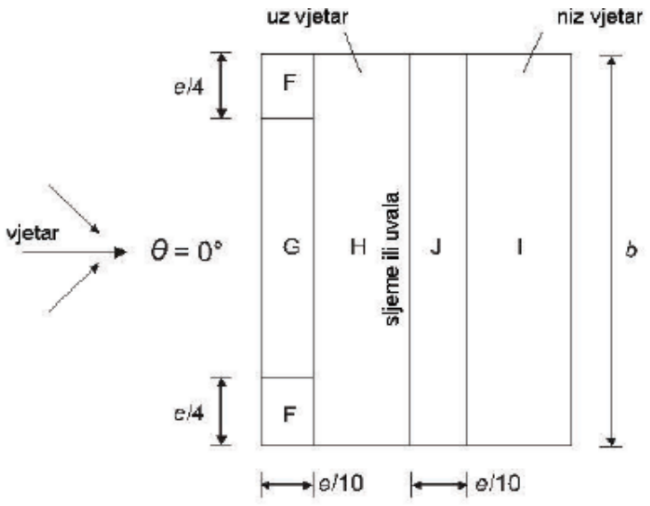
Intezitet turbulencije:

$$I_{v(z)} = \frac{k_I}{C_{0(z)} \cdot \ln\left(\frac{z}{z_0}\right)} = \frac{1}{1 \cdot \ln\left(\frac{10{,}85}{1{,}0}\right)} = 0{,}419$$

Pritisak brzine vjetra pri udaru:

$q_{p(z)} = \left[1 + 7 \cdot I_{v(z)}\right] \cdot 0{,}5 \cdot \rho \cdot v_m^2 = [1 + 7 \cdot 0{,}419] \cdot 0{,}5 \cdot 1{,}25 \cdot 11{,}16^2 \cdot 10^{-3} = 0{,}306$ kN/m^2

Određivanje pritiska na halu za područja dvostrešnog krova Θ=0



Rezultirajuće djelovanje vjetra za dvostrešni krov

e=min$\{b_i, 2h\}$ =min[30;2*10,85=21,7] =21,7 m

Koeficijenti vanjskog pritiska na halu s krovom nagiba α = 22° za područja dvostrešnog krova Θ=0 dobiveni su interpolacijom između vrijednosti za 15° i 30°.

Nagib α	Područje za smjer vjetra $\theta = 0°$									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
– 45°	– 0,6		– 0,6		– 0,8		– 0,7		– 1,0	– 1,5
– 30°	– 1,1	– 2,0	– 0,8	– 1,5	– 0,8		– 0,6		– 0,8	– 1,4
– 15°	– 2,5	– 2,8	– 1,3	– 2,0	– 0,9	– 1,2	– 0,5		– 0,7	– 1,2
– 5°	– 2,3	– 2,5	– 1,2	– 2,0	– 0,8	– 1,2	+ 0,2		+ 0,2	
							– 0,6		– 0,6	
5°	– 1,7	– 2,5	– 1,2	– 2,0	– 0,6	– 1,2	– 0,6		+ 0,2	
	+ 0,0		+ 0,0		+ 0,0				– 0,6	
15°	– 0,9	– 2,0	– 0,8	– 1,5	– 0,3		– 0,4		– 1,0	– 1,5
	+ 0,2		+ 0,2		+ 0,2		+ 0,0		+ 0,0	+ 0,0
30°	– 0,5	– 1,5	– 0,5	– 1,5	– 0,2		– 0,4		– 0,5	
	+ 0,7		+ 0,7		+ 0,4		+ 0,0		+ 0,0	
45°	– 0,0		– 0,0		– 0,0		– 0,2		– 0,3	
	+ 0,7		+ 0,7		+ 0,6		+ 0,0		+ 0,0	
60°	+ 0,7		+ 0,7		+ 0,7		– 0,2		– 0,3	
75°	+ 0,8		+ 0,8		+ 0,8		– 0,2		– 0,3	

NAPOMENA 1: Pri $\theta = 0°$ tlak se naglo mijenja između pozitivnih i negativnih vrijednosti na strani uz vjetar oko kuta $\alpha = -5°$ do $+45°$, stoga su navedene i pozitivne i negativne vrijednosti. Za takve krovove treba uzeti u obzir četiri slučaja gdje su najmanje vrijednosti svih područja F, G i H kombinirane s najvećim ili najmanjim vrijednostima područja I i J. Nije dopušteno miješanje pozitivnih i negativnih vrijednosti na istom pročelju.

NAPOMENA 2: Smije se upotrebljavati linearna interpolacija vrijednosti istog predznaka za međuvrijednosti kutova nagiba istog predznaka. (Ne interpolira se za kutove između $\alpha = -5°$ i $\alpha = +5°$ već se upotrebljavaju podaci za ravne krovove iz točke 7.2.3). Vrijednosti 0,0 dane su za potrebe interpolacije.

Tablica 6. Vrijednosti koeficijenata vanjskog pritiska za područja dvostrešnog krova (θ=0)

Za koeficijent unutarnjeg tlaka c_{pi} uzete su preporučene vrijednosti +0.2 i -0.3.



Koeficijenti unutrašnjeg tlaka

Pritisak vjetra na vanjske površine: $w_e = q_p * c_{pe}$ [kN/m^2]

Područje	q_p(kN/m2)	c_{pe}	W_{e1}(kN/m2)
F	0,306	-0,514	-0,157
G	0,306	-0,66	-0,202
H	0,306	-0,253	-0,077
I	0,306	-0,4	-0,122
J	0,306	-0,767	-0,235

Područje	q_p(kN/m2)	c_{pi}	W_{e2}(kN/m2)
F	0,306	0,433	0,132
G	0,306	0,433	0,132
H	0,306	0,293	0,09
I	0,306	0,0	0,0
J	0,306	0,0	0,0

Pritisak vjetra na vanjske površine

Pritisak vjetra na unutarnje površine: $w_i = q_p * c_{pi}$ [kN/m^2]

Područje	$q_{p(kN/m2)}$	c_{pi}	$W_{i1(kN/m2)}$
F	0,306	0,2	0,061
G	0,306	0,2	0,061
H	0,306	0,2	0,061
I	0,306	0,2	0,061
J	0,306	0,2	0,061

Područje	$q_{p(kN/m2)}$	c_{pi}	$W_{i2(kN/m2)}$
F	0,306	-0,3	-0,092
G	0,306	-0,3	-0,092
H	0,306	-0,3	-0,092
I	0,306	-0,3	-0,092
J	0,306	-0,3	-0,092

Pritisak vjetra na unutarnje površine

REZULTIRAJUĆE DJELOVANJE VJETRA (kN/m2)				
Područje	Vjetar 1=We1+Wi1	Vjetar 2=We1+Wi2	Vjetar 3=We2+Wi1	Vjetar 4=We2+Wi2
F	-0,218	-0,065	0,071	0,224
G	-0,263	-0,11	0,071	0,224
H	-0,138	0,015	0,029	0,182
I	-0,183	-0,03	-0,061	0,092
J	-0,296	-0,143	-0,061	0,092

Rezultirajuće djelovanje vjetra

Djelovanje vjetra na krovnu plohu prenosi se na sekundarne nosače koji prenose opterećenje na glavni nosač.
Djelovanje se u modelu nanosi linijski što će biti prikazano u sljedećim proračunima.
Za daljni proračun u obzir će se uzeti vrijednosti za VJETAR 1 koji će se u kombinacijama opterećenja označavati s „vjetar o“ i VJETAR 4 koji će se u kombinacijama opterećenja označavati s „vjetar p“.

Djelovanje vjetra na sekundarne nosače:

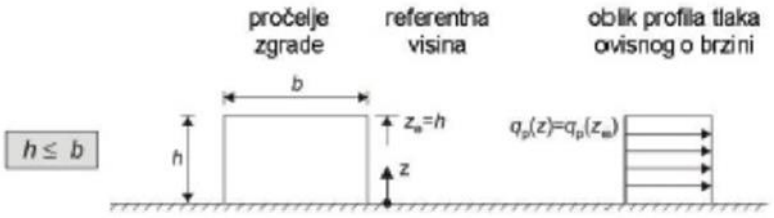
REZULTIRAJUĆE DJELOVANJE ZA VJETAR 1 (odižući)			
PODROŽNICA	OPTEREĆENJE (kN/m')	PODROŽNICA	OPTEREĆENJE (kN/m')
1	-0,22	9	-0,30
2	-0,37	10	-0,50
3	-0,28	11	-0,36
4	-0,28	12	-0,36
5	-0,28	13	-0,36
6	-0,28	14	-0,36
7	-0,28	15	-0,36
8	-0,14	16	-0,18

Prikaz linijskog djelovanja vjetra na sekundarne nosače

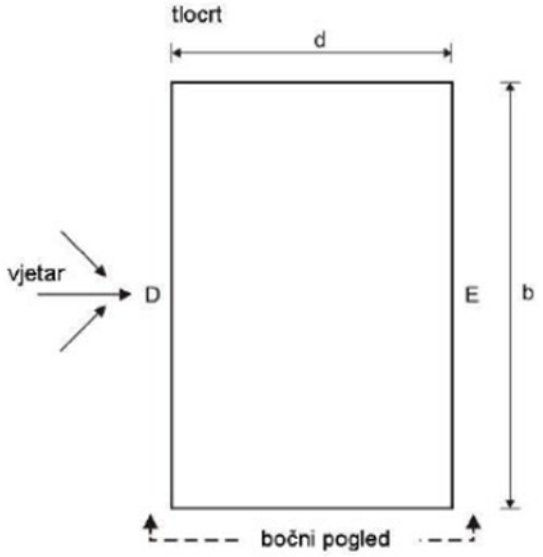
REZULTIRAJUĆE DJELOVANJE ZA VJETAR 4 (pritiskajući)			
PODROŽNICA	OPTEREĆENJE (kN/m')	PODROŽNICA	OPTEREĆENJE (kN/m')
1	0,22	9	0,09
2	0,41	10	0,18
3	0,36	11	0,18
4	0,36	12	0,18
5	0,36	13	0,18
6	0,36	14	0,18
7	0,36	15	0,18
8	0,18	16	0,09

Prikaz linijskog djelovanja vjetra na sekundarne nosače

Djelovanje vjetra na zidove konstrukcije:



Referentna visina i odgovvarajuća raspodjela tlaka



Djelovanje vjetra na vertikalne zidove

e=min $\{b_i, 2h\}$ =min [30;2·10,85=21,7] =21,7 m, d=26,0 m

Područje	$q_{p(kN/m2)}$	c_{pe}	W_e(kN/m2)
D	0,306	0,733	0,224
E	0,306	-0,367	-0,112

Pritisak vjetra na vanjske površine

Područje	$q_{p(kN/m2)}$	c_{pi}	W_{i1}(kN/m2)
D	0,306	0,20	0,061
E	0,306	0,20	0,061

Područje	$q_{p(kN/m2)}$	c_{pi}	W_{i2}(kN/m2)
D	0,306	-0,30	-0,092
E	0,306	-0,30	-0,092

Pritisak vjetra na unutarnje površine

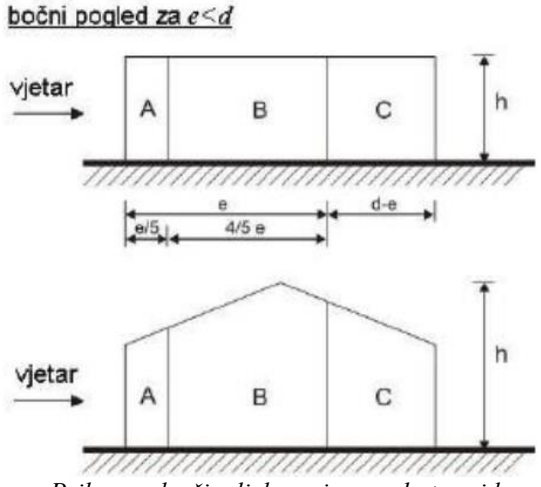
REZULTIRAJUĆE DJELOVANJE VJETRA(kN/m2)		
Područje	VJETAR 1= W_e+W_{i1}	VJETAR 2= W_e+W_{i2}
D	0,163	0,316
E	-0,173	-0,03

Prikaz rezultirajućeg djelovanja vjetra (V(kN/m^2))

REZULTIRAJUĆE DJELOVANJE VJETRA NA BOČNE NOSAČE			
ODIŽUĆI		PRITISKAJUĆI	
1	0,9	1	0,79
2	-0,95	2	-0,11

Prikaz rezultirajućeg djelovanja vjetra na stupove (kN/m')

Djelovanje vjetra na zabatni zid :



Prikaz područja djelovanja za zabatne zidove

Područje	$q_{p(kN/m2)}$	c_{pe}	W_e(kN/m2)
A	0,306	-1,2	-0,367
B	0,306	-0,8	-0,245
C	0,306	-0,5	-0,153

Prikaz djelovanja na vanjske površine

Područje	$q_{p(kN/m2)}$	c_{pi}	W_{i1}(kN/m2)
A	0,306	0,2	0,061
B	0,306	0,2	0,061
C	0,306	0,2	0,061
Područje	$q_{p(kN/m2)}$	c_{pi}	W_{i2}(kN/m2)
A	0,306	-0,3	-0,092
B	0,306	-0,3	-0,092
C	0,306	-0,3	-0,092

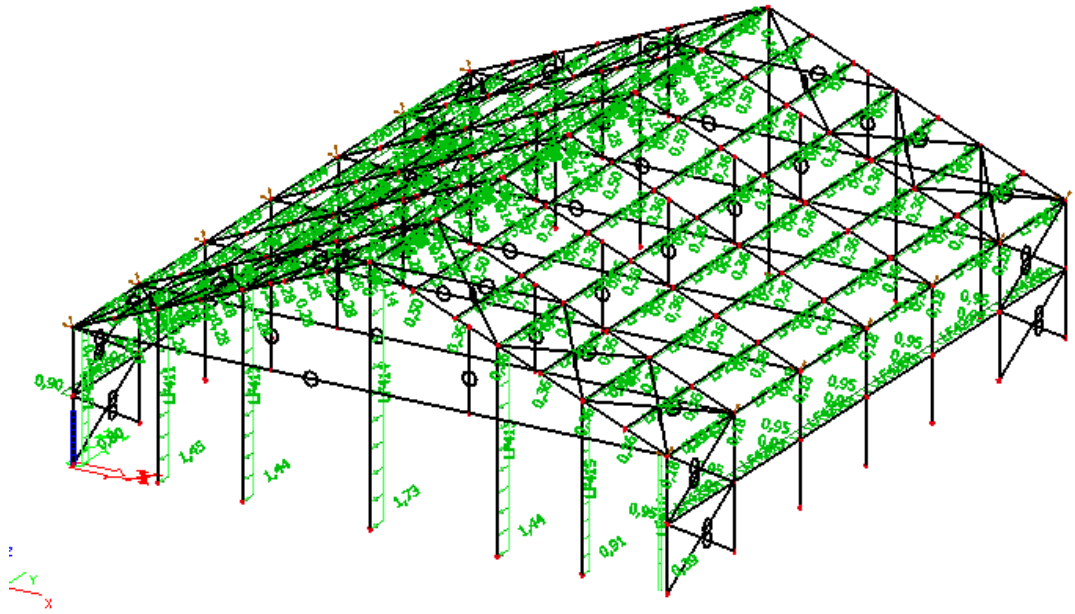
Prikaz djelovanja na unutarnje površine

REZULTIRAJUĆE DJELOVANJE VJETRA(kN/m2)				
PODRUČJE	VJETAR 1=	$W_{e+}W_{i1}$	VJETAR 2=	$W_{e-}W_{i2}$
A	-0,42		-0,27	
B	-0,30		-0,15	
C	-0,21		-0,06	

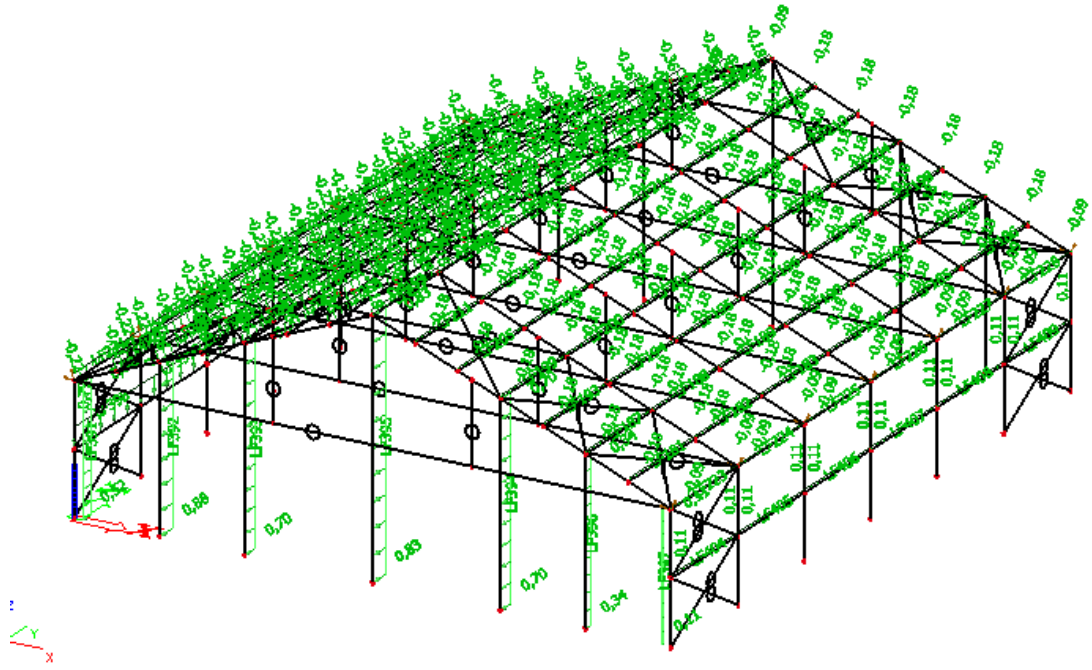
Prikaz rezultirajućeg djelovanja vjetra

REZULTIRAJUĆE DJELOVANJE VJETRA NA STUPOVE			
ODIŽUĆI VJETAR (kN/m')		PRITISKAJUĆI VJETAR	
1	-0,9	1	-0,52
2	-1,45	2	-0,88
3	-1,44	3	-0,7
4	-1,73	4	-0,83
5	-1,44	5	-0,70
6	-0,91	6	-0,34
7	-0,39	7	-0,11

Rezultirajuće djelovanje vjetra na stupove



Opterećenje modela odižućim vjetrom

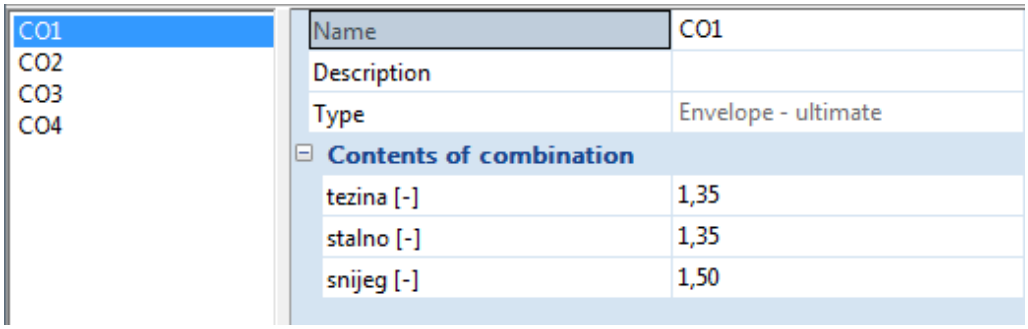


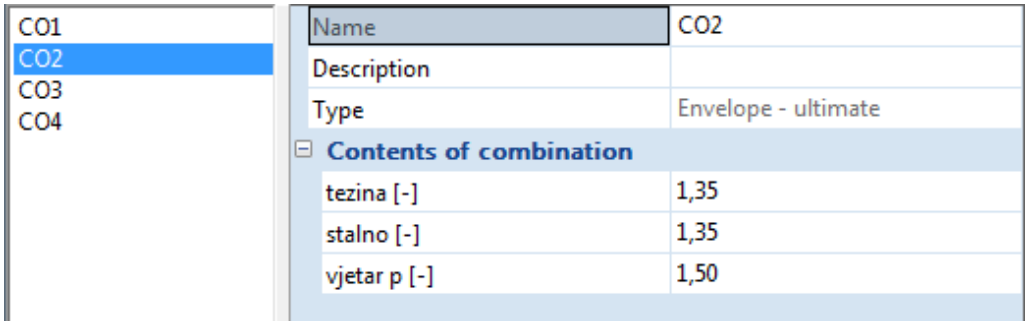
Opterećenje modela pritiskajućim vjetrom

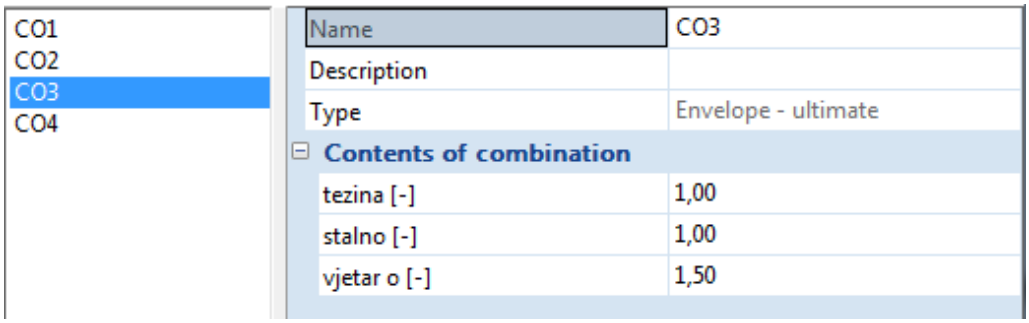
3. Proračun konstrukcije

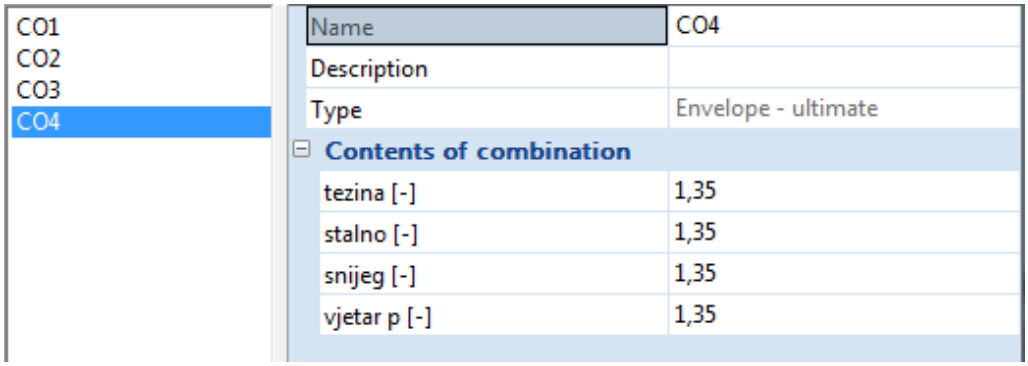
Proračun konstrukcije izvršen je u programskom paketu Scia Enginner 2014. sa prostornim modelom konstrukcije.

3.1 Kombinacije djelovanja







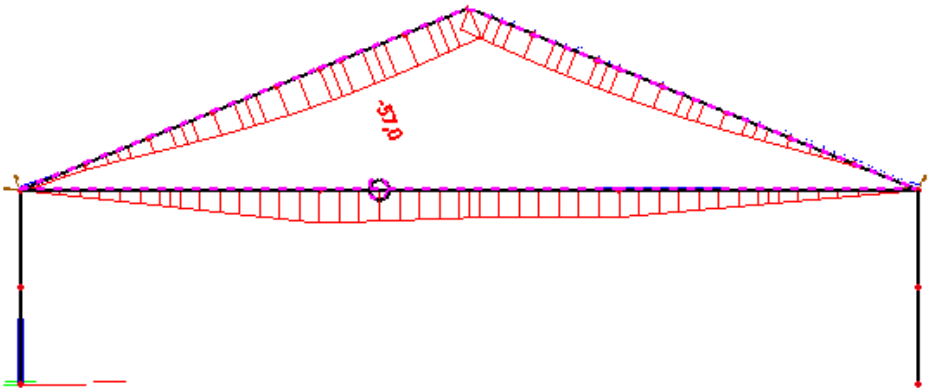


4. Dimenzioniranje elemenata konstrukcije

4.1 Pomaci konstrukcije

Progibi se provjeravaju na krajnje granično stanje.

Vertikalni pomak konstrukcije



Vertikalni pomak

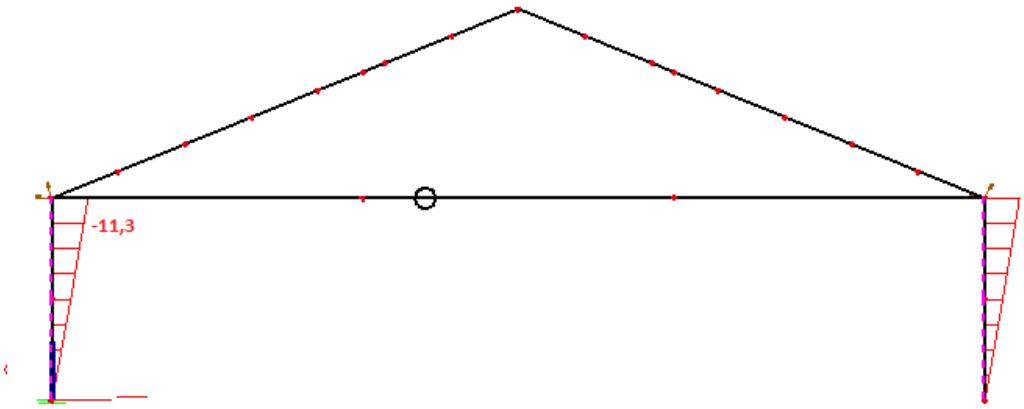
Vertikalni pomak: $u_z = 57{,}0\ mm$

Dopušteni vertikalni pomak:

$$u_{dop} = \frac{l}{300} = \frac{26 \cdot 1000}{300} = 86{,}67\ mm$$

$$u_{z,fin} = u_z * (1 + \psi_2 \cdot k_{def}) = 57 < u_{dop}$$

Horizontalni pomak konstrukcije



Horizontalni pomak (opterećenje)

Horizontalni pomak: $u_x = 11{,}3\ mm$

Dopušteni horizontalni pomak :

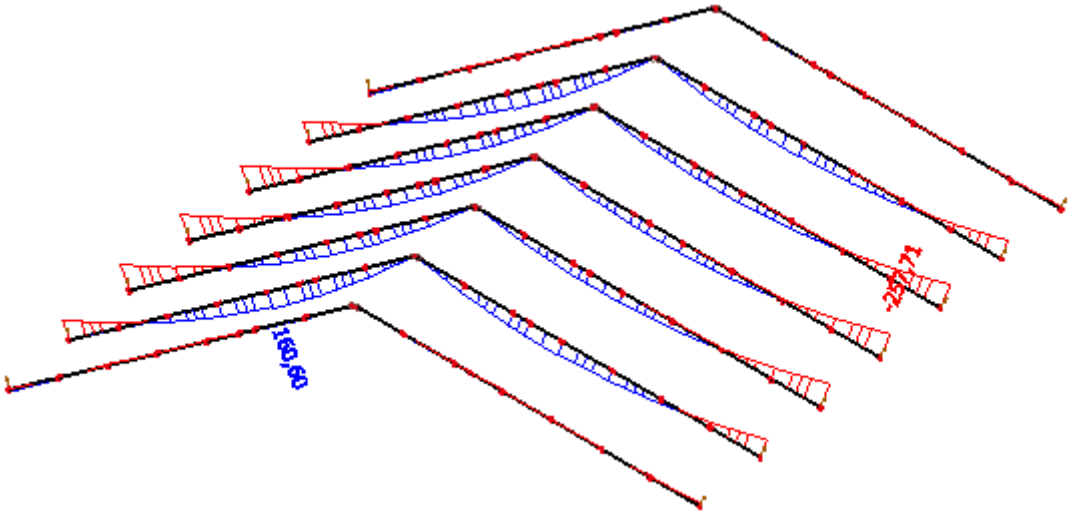
$$u_{dop} = \frac{h}{200} = \frac{5{,}6 \cdot 1000}{200} = 28{,}0\ mm$$

$$u_{x,fin} = u_x * (1 + \psi_2 \cdot k_{def}) = 11{,}3 < u_{dop}$$

4.2 Dimenzioniranje grede (poz. G1 i G2)

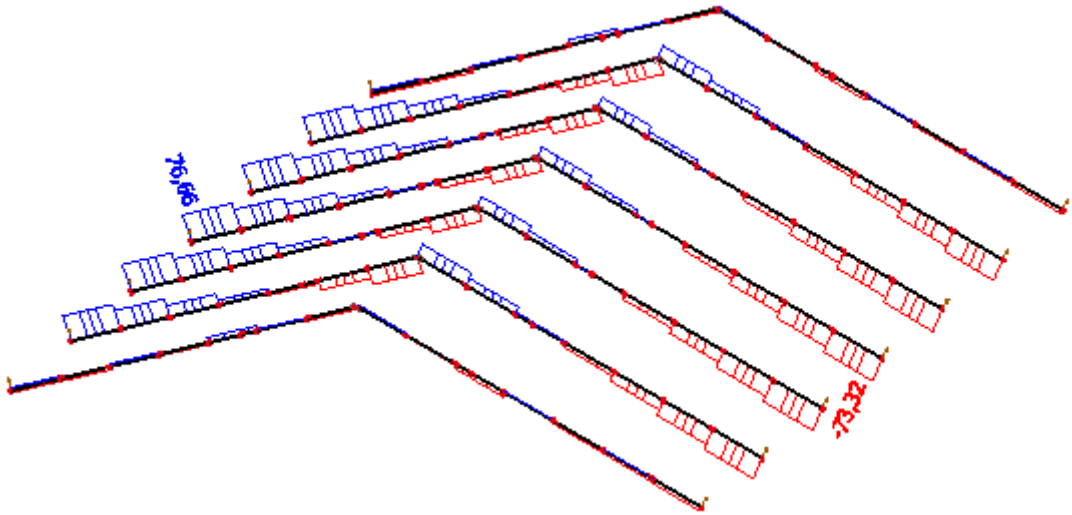
Dimenzioniranje konstrukcijskih elemenata provedeno je softwerom Scia Enginner 2014 pomoću modula Timber.

Moment savijanja u gredi (My)



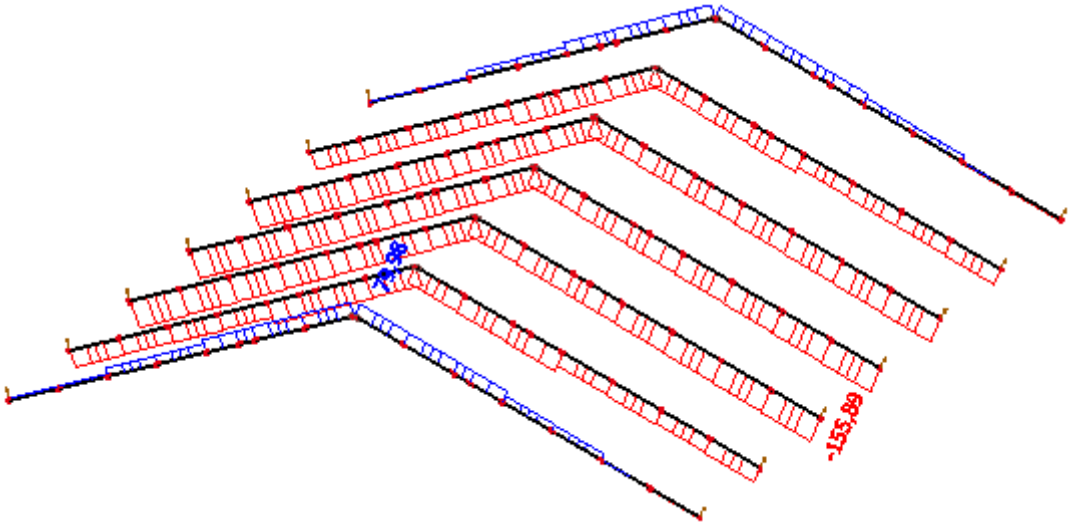
Dijagram momenata savijanja (My)

Poprečne sile u gredi (Vz)



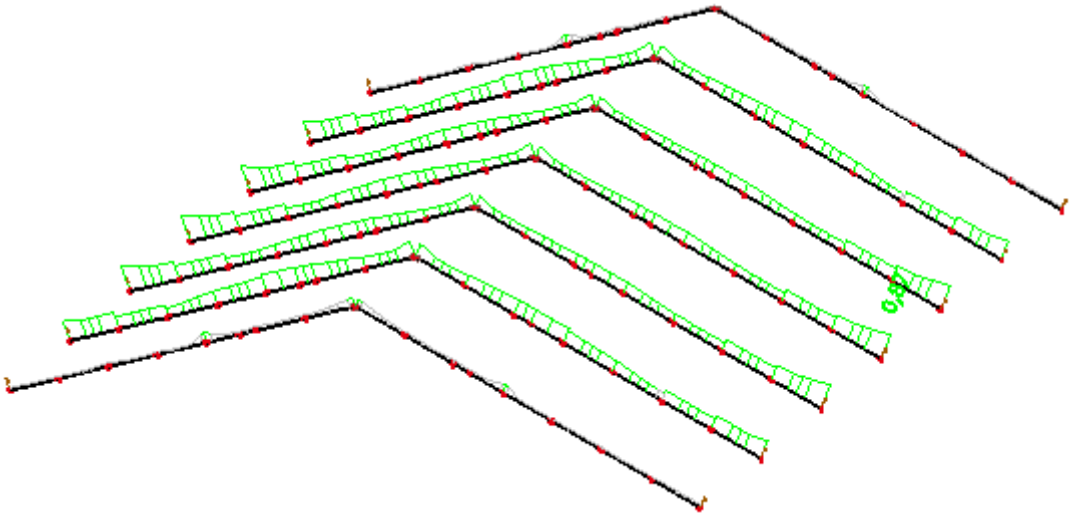
Dijagram poprečnih sila (Vz)

Uzdužna sila u gredi (N)



Dijagram uzudžnih sila (N)

Iskoristivost grede:



Prikaz iskoristivosti grednog nosača

Timber ULS check

Linear calculation, Extreme : Cross-section
Selection : All
Class : All ULS
Cross-section : greda - RECT (200; 760)

EN 1995-1-1 Code Check

Beam B21	**14,020 m**	**greda - RECT (200; 760)**	**GL24h**	**All ULS**	**0,87 -**

Combination key
All ULS / 1.35*tezina + 1.35*stalno + 1.35*snijeg + 1.35*vjetar p

Basic data	
Partial safety factor γM for Glued laminated timber	1,25

Material data		
Bending (fm,k)	24,0	MPa
Tension (ft,0,k)	16,5	MPa
Tension (ft,90,k)	0,4	MPa
Compression (fc,0,k)	24,0	MPa
Compression (fc,90,k)	2,7	MPa
Shear (fv,k)	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 14,020 m.

Internal forces		
NEd	-155,89	kN
Vy,Ed	-0,15	kN
Vz,Ed	-73,32	kN
TEd	0,02	kNm
My,Ed	-257,71	kNm
Mz,Ed	-0,23	kNm

Modification factor	
Service Class	1
Load duration	Short term
Modification factor kmod	0,90

..:: SECTION CHECK ::..

Compression parallel to the grain
According to EN 1995-1-1 article 6.1.4 and formula (6.2)

σc,0,d	1,0	MPa
fc,0,d	17,3	MPa
Unity check	0,06	-

Compression perpendicular to the grain
According to EN 1995-1-1 article 6.1.5 and formula (6.3)

Fc,90,d	73,32	kN
l	760	mm
lef	790	mm
b	200	mm
Aef	158000	mm^2
σc,90,d	0,5	MPa
Support condition	Discrete	
h	760	mm
kc,90	1,00	-
fc,90,d	1,9	MPa
Unity check	0,24	-

Bending
According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

σm,y,d	13,4	MPa
kh,y	1,00	
fm,y,d	17,3	MPa
σm,z,d	0,0	MPa
kh,z	1,00	
fm,z,d	17,3	MPa
km	0,70	

Unity check (6.11) = 0,77 + 0,00 = 0,78 -
Unity check (6.12) = 0,54 + 0,00 = 0,54 -

Shear
According to EN 1995-1-1 article 6.1.7 and formula (6.13)

kcr	0,67	
τy,d	0,0	MPa
τz,d	1,1	MPa
fv,d	1,9	MPa
Unity check τy	0,00	-
Unity check τz	0,56	-
Unity check Interaction	0,31	-

Note: The interaction equation has been added as a NCCI.

Torsion
According to EN 1995-1-1 article 6.1.8 and formula (6.14)

τtor,d	0,0	MPa
kshape	1,57	
fv,d	1,9	MPa
Unity check	0,00	-
Unity check Interaction Shear	0,31	-

Note: The interaction equation has been added as a NCCI.

Combined Bending and Axial Compression
According to EN 1995-1-1 article 6.2.4 and formula (6.19),(6.20)

fc,0,d	17,3	MPa
fm,y,d	17,3	MPa
fm,z,d	17,3	MPa
km	0,70	

Unity check (6.19) = 0,00 + 0,77 + 0,00 = 0,78 -
Unity check (6.20) = 0,00 + 0,54 + 0,00 = 0,55 -

The member satisfies the section check.
..:: STABILITY CHECK ::..

Columns subjected to compression or combined compression and bending
According to EN 1995-1-1 article 6.3.2 and formula (6.23),(6.24)

Buckling parameters	yy	zz	
Sway type	sway	non-sway	
System length L	9,346	2,003	m
Buckling factor k	1,74	0,94	
Buckling length Lcr	16,235	1,880	m
Slenderness λ	74,00	32,56	-
Relative slenderness λ	1,19	0,52	-
Limit slenderness	0,30	0,30	-
Imperfection βc	0,10	0,10	-
Reduction factor kc	0,61	0,97	-

Unity check (6.23) = 0,10 + 0,77 + 0,00 = 0,87 -
Unity check (6.24) = 0,06 + 0,54 + 0,00 = 0,61 -

Beams subjected to bending or combined bending and compression
According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

LTB Parameters		
Elastic critical moment My,crit	3785,37	kNm
Critical bending stress σm,crit	196,6	MPa
Relative slenderness λrel,m	0,35	-
Reduction factor kcrit	1,00	-

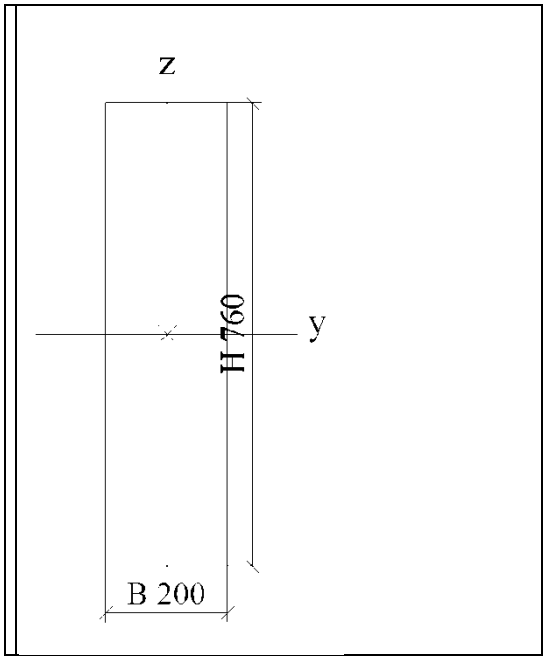
Unity check (6.33) = 0,77 -
Unity check (6.35) = 0,60 + 0,06 = 0,66 -

My,crit Parameters		
G0,05	587,5	MPa
LTB length L	2,003	m
Lef/L	0,90	
Effective length Lef	1,802	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek nosača:

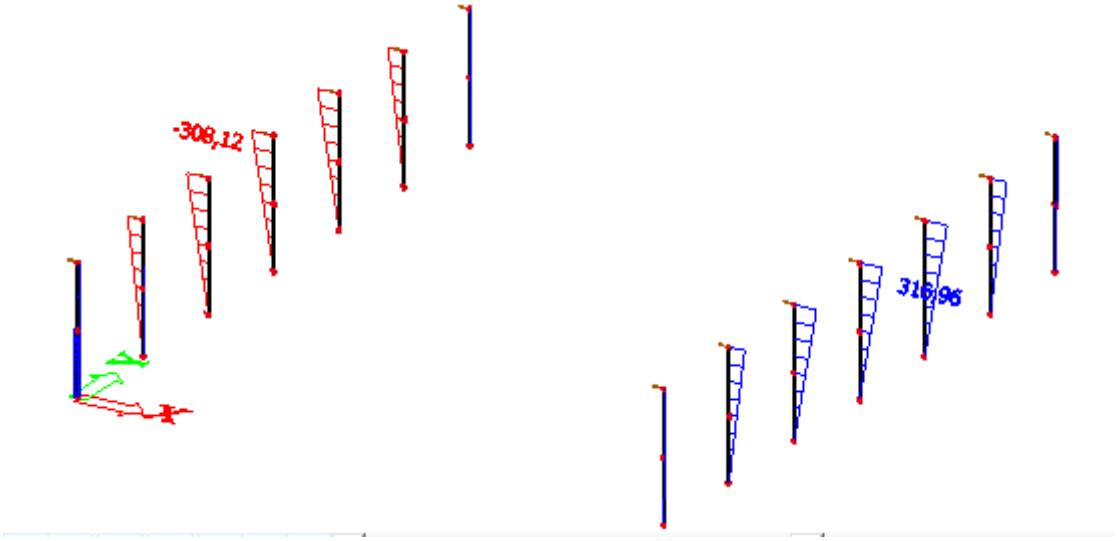
Name	greda
Type	RECT
Detailed	200; 760
Item material	GL24h
Fabrication	timber
Use 2D FEM analysis	✓



A [m_2]	1,5200e-01	
A y, z [m_2]	1,2667e-01	1,2667e-01
I y, z [m_4]	7,3163e-03	5,0667e-04
I w [m_6], t [m_4]	1,7996e-05	1,6857e-03
Wel y, z [m_3]	1,9253e-02	5,0667e-03
Wpl y, z [m_3]	2,3532e-02	6,1926e-03
d y, z [mm]	0	0
c YUCS, ZUCS [mm]	100	380
α [deg]	0,00	
A L, D [m_2/m]	1,9200e+00	1,9200e+00
Mply +, - [Nm]	5,65e+05	5,65e+05
Mplz +, - [Nm]	1,49e+05	1,49e+05

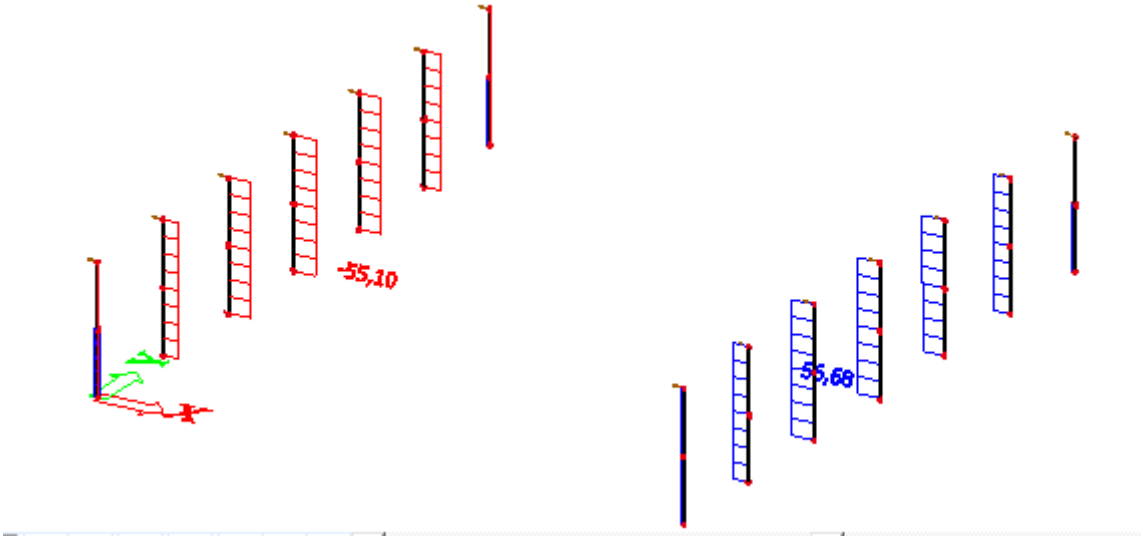
4.3 Dimenzioniranje stupa (poz. S)

Moment savijanja u stupu (My)



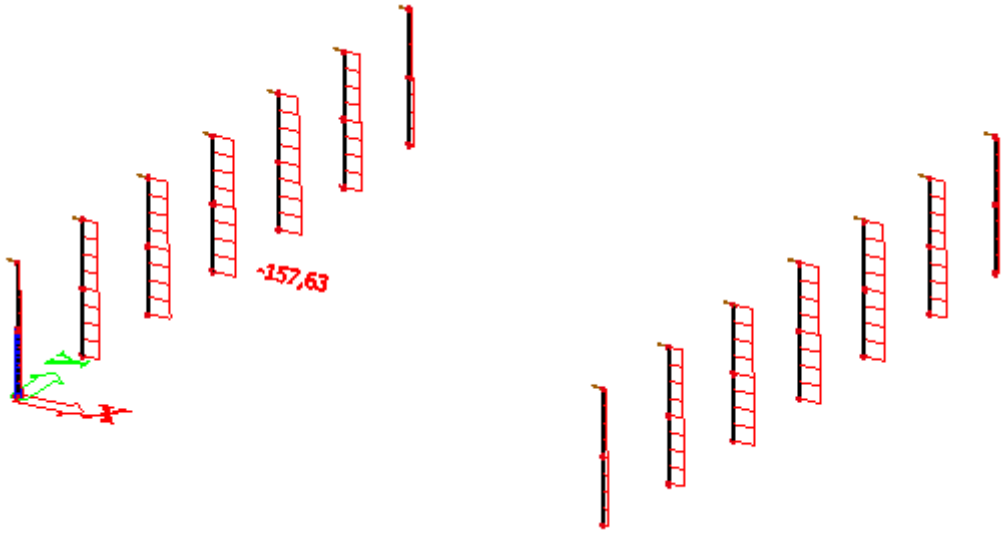
Dijagran momenata savijanja (My)

Poprečna sila (Vz)



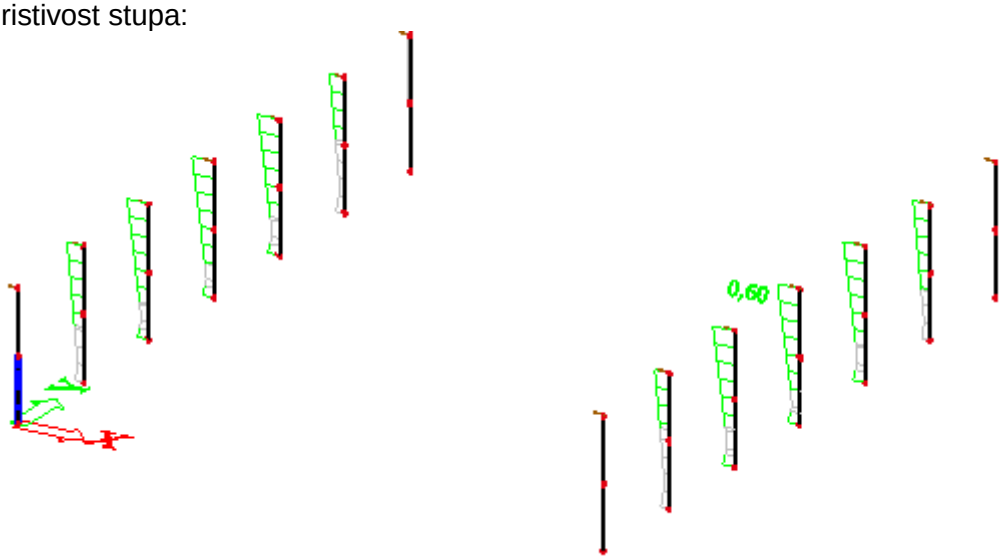
Dijagram poprečnih sila (Vz)

Uzdužna sila (N)



Dijagram uzdužnih sila(N)

Iskoristivost stupa:



Prikaz iskoristivosti stupa

Timber ULS check

Linear calculation, Extreme : Cross-section
Selection : All
Class : All ULS
Cross-section : stup - 2 Rect (200; 760; 200)

EN 1995-1-1 Code Check

Beam B18	**5,600 m**	**2 - 2 Rect (200; 760; 200)**	**GL24h**	**All ULS**	**0,60 -**

Combination key
All ULS / 1.35*tezina + 1.35*stalno + 1.35*snijeg + 1.35*vjetar p

Basic data	
Partial safety factor γM for Glued laminated timber	1,25

Material data		
Bending (fm,k)	24,0	MPa
Tension (ft,0,k)	16,5	MPa
Tension (ft,90,k)	0,4	MPa
Compression (fc,0,k)	24,0	MPa
Compression (fc,90,k)	2,7	MPa
Shear (fv,k)	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 5,600 m.

Internal forces		
NEd	-135,51	kN
Vy,Ed	0,02	kN
Vz,Ed	56,52	kN
TEd	-0,07	kNm
My,Ed	316,96	kNm
Mz,Ed	0,01	kNm

Modification factor	
Service Class	1
Load duration	Short term
Modification factor kmod	0,90

..:: SECTION CHECK ::..

Compression parallel to the grain
According to EN 1995-1-1 article 6.1.4 and formula (6.2)

σc,0,d	0,4	MPa
fc,0,d	17,3	MPa
Unity check	0,03	-

Compression perpendicular to the grain
According to EN 1995-1-1 article 6.1.5 and formula (6.3)

Fc,90,d	56,52	kN
l	760	mm
lef	790	mm
b	400	mm
Aef	316000	mm^2
σc,90,d	0,2	MPa
Support condition	Discrete	
h	760	mm
kc,90	1,00	-
fc,90,d	1,9	MPa
Unity check	0,09	-

Bending
According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

σm,y,d	8,2	MPa
kh,y	1,00	
fm,y,d	17,3	MPa
σm,z,d	0,0	MPa
kh,z	1,00	
fm,z,d	17,3	MPa
km	1,00	

Unity check (6.11) = 0,48 + 0,00 = 0,48 -
Unity check (6.12) = 0,48 + 0,00 = 0,48 -

Shear
According to EN 1995-1-1 article 6.1.7 and formula (6.13)

kcr	0,67	
τy,d	0,0	MPa
τz,d	0,4	MPa
fv,d	1,9	MPa
Unity check τy	0,00	-
Unity check τz	0,21	-
Unity check Interaction	0,05	-

Note: The interaction equation has been added as a NCCI.

Torsion
According to EN 1995-1-1 article 6.1.8 and formula (6.14)

τtor,d	0,0	MPa
kshape	1,00	
fv,d	1,9	MPa
Unity check	0,00	-
Unity check Interaction Shear	0,05	-

Note: The interaction equation has been added as a NCCI.

Combined Bending and Axial Compression
According to EN 1995-1-1 article 6.2.4 and formula (6.19),(6.20)

fc,0,d	17,3	MPa
fm,y,d	17,3	MPa
fm,z,d	17,3	MPa
km	1,00	

Unity check (6.19) = 0,00 + 0,48 + 0,00 = 0,48 -
Unity check (6.20) = 0,00 + 0,48 + 0,00 = 0,48 -

The member satisfies the section check.
..:: STABILITY CHECK ::..

Columns subjected to compression or combined compression and bending
According to EN 1995-1-1 article 6.3.2 and formula (6.23),(6.24)

Buckling parameters	yy	zz	
Sway type	sway	non-sway	
System length L	5,600	2,800	m
Buckling factor k	5,14	0,99	
Buckling length Lcr	28,778	2,770	m
Slenderness λ	131,17	13,31	-
Relative slenderness λ	2,11	0,21	-
Limit slenderness	0,30	0,30	-
Imperfection βc	0,10	0,10	-
Reduction factor kc	0,21	1,00	-

Unity check (6.23) = 0,12 + 0,48 + 0,00 = 0,60 -
Unity check (6.24) = 0,03 + 0,48 + 0,00 = 0,50 -

Beams subjected to bending or combined bending and compression
According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

LTB Parameters		
Elastic critical moment My,crit	17551,01	kNm
Critical bending stress σm,crit	455,8	MPa
Relative slenderness λrel,m	0,23	-
Reduction factor kcrit	1,00	-

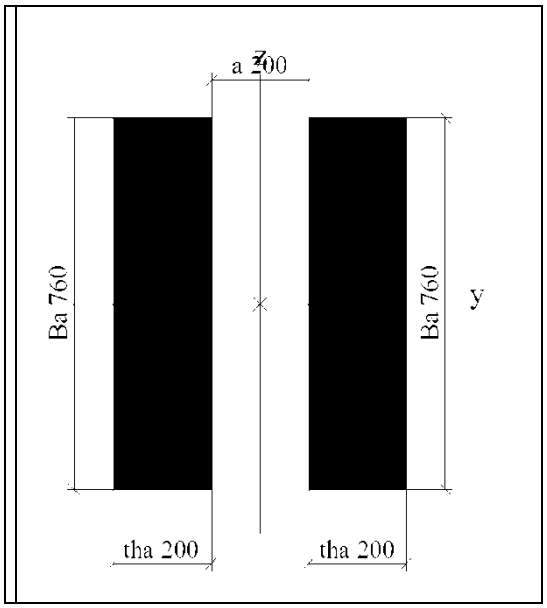
Unity check (6.33) = 0,48 -
Unity check (6.35) = 0,23 + 0,03 = 0,25 -

My,crit Parameters		
G0,05	587,5	MPa
LTB length L	2,800	m
Lef/L	1,00	
Effective length Lef	2,800	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek stupa:

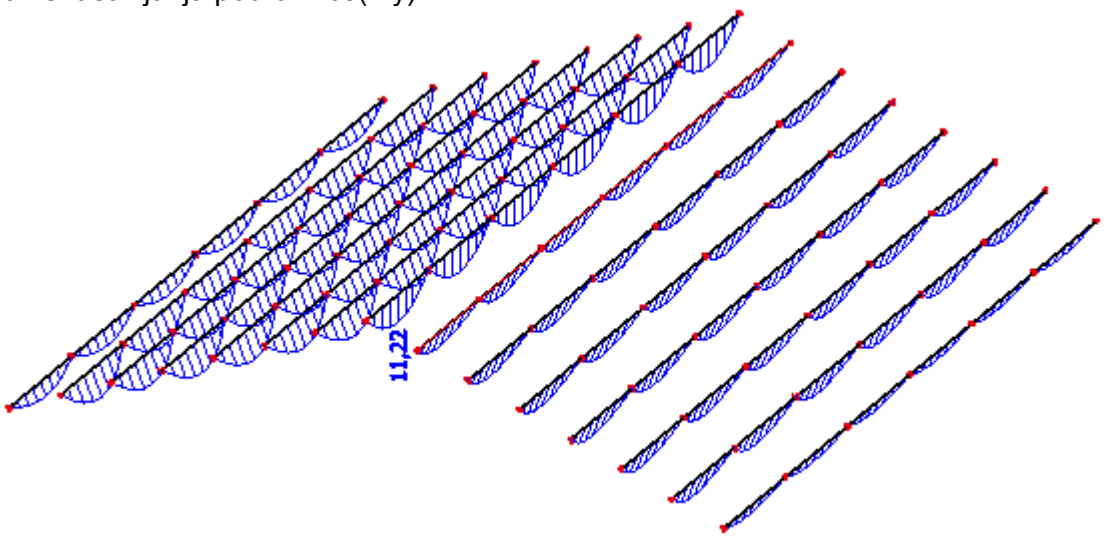
Name	stup
Type	2 Rect
Detailed	200; 760; 200
Item material	GL24h
Fabrication	timber
Use 2D FEM analysis	✓



A [m_2]	3,0400e-01	
A y, z [m_2]	2,5333e-01	2,5333e-01
I y, z [m_4]	1,4633e-02	1,3173e-02
I w [m_6], t [m_4]	6,1957e-04	3,3635e-03
Wel y, z [m_3]	3,8507e-02	4,3911e-02
Wpl y, z [m_3]	4,7064e-02	4,5670e-02
d y, z [mm]	0	0
c YUCS, ZUCS [mm]	300	380
α [deg]	0,00	
A L, D [m_2/m]	3,8400e+00	3,8400e+00
Mply +, - [Nm]	1,13e+06	1,13e+06
Mplz +, - [Nm]	1,10e+06	1,10e+06

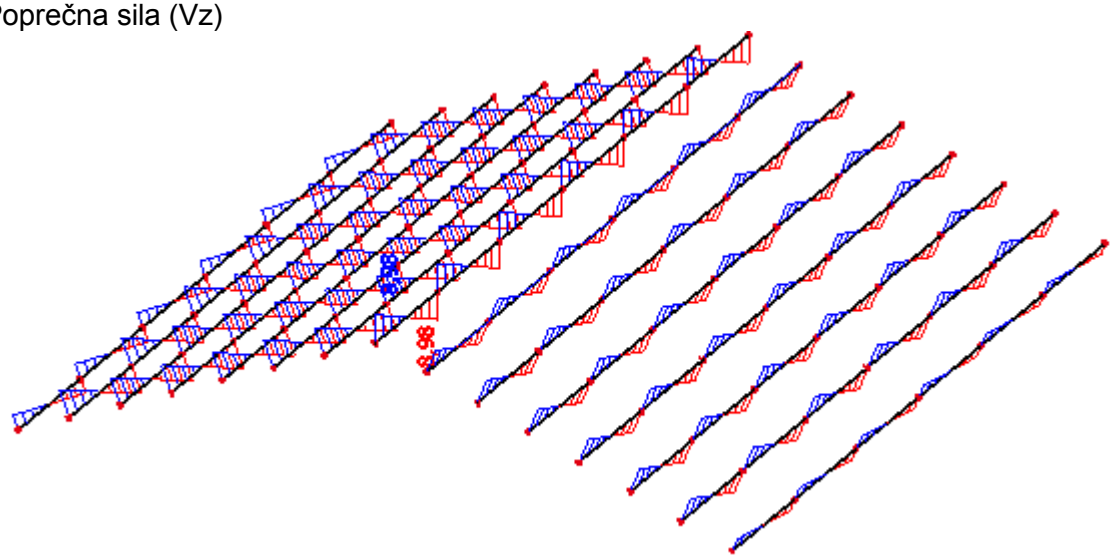
4.4 Dimnezioniranje krovne podrožnice (poz. KP1 i KP2)

Moment savijanja podrožnice(My)



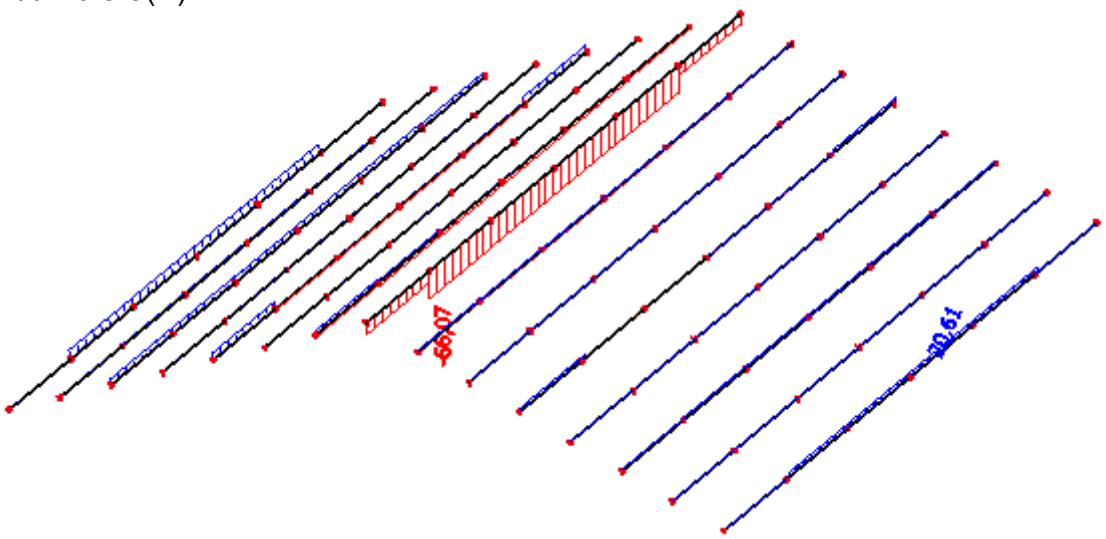
Dijagram momenata savijanja (My)

Poprečna sila (Vz)



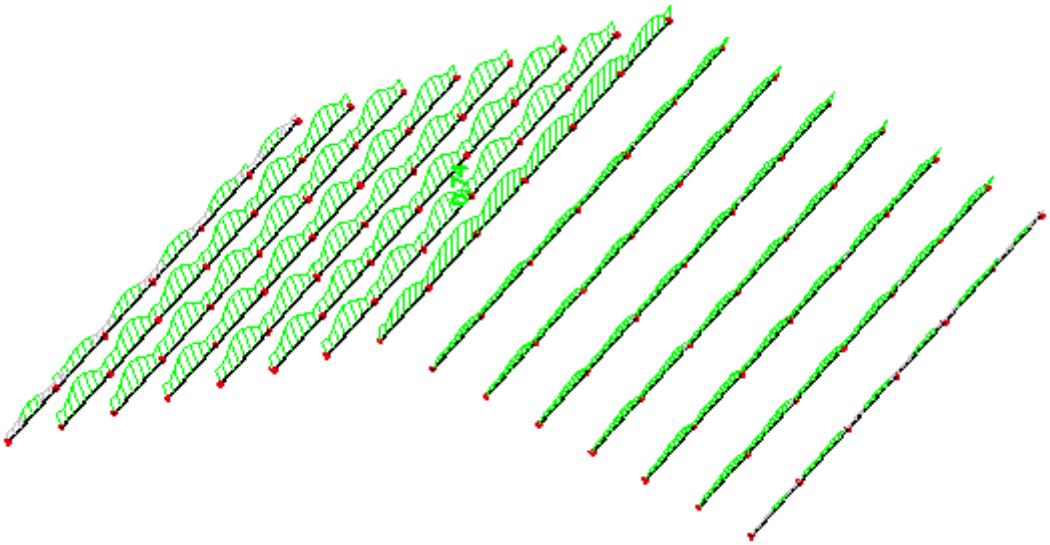
Dijagram poprečnih sila (Vz)

Uzdužna sila(N)



Dijagram uzdužnih sila (N)

Iskoristivost :



Prikaz iskoristivosti presjeka

Timber ULS check

Linear calculation, Extreme : Cross-section
Selection : All
Class : All ULS
Cross-section : krovna podr - RECT (120; 240)

EN 1995-1-1 Code Check

Beam B46	**5,000 m**	**krovna podr - RECT (120; 240)**	**GL24h**	**All ULS**	**0,74 -**

Combination key
All ULS / 1.35*tezina + 1.35*stalno + 1.35*snijeg + 1.35*vjetar p

Basic data	
Partial safety factor γM for Glued laminated timber	1,25

Material data		
Bending (fm,k)	24,0	MPa
Tension (ft,0,k)	16,5	MPa
Tension (ft,90,k)	0,4	MPa
Compression (fc,0,k)	24,0	MPa
Compression (fc,90,k)	2,7	MPa
Shear (fv,k)	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 3,125 m.

Internal forces		
NEd	-66,07	kN
Vy,Ed	0,92	kN
Vz,Ed	-2,24	kN
TEd	-0,73	kNm
My,Ed	10,52	kNm
Mz,Ed	0,62	kNm

Modification factor	
Service Class	1
Load duration	Short term
Modification factor kmod	0,90

..:: SECTION CHECK ::..

Compression parallel to the grain
According to EN 1995-1-1 article 6.1.4 and formula (6.2)

σc,0,d	2,3	MPa
fc,0,d	17,3	MPa
Unity check	0,13	-

Bending
According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

σm,y,d	9,1	MPa
kh,y	1,10	
fm,y,d	18,9	MPa
σm,z,d	1,1	MPa
kh,z	1,00	
fm,z,d	17,3	MPa
km	0,70	

Unity check (6.11) = 0,48 + 0,04 = 0,53 -
Unity check (6.12) = 0,34 + 0,06 = 0,40 -

Shear
According to EN 1995-1-1 article 6.1.7 and formula (6.13)

kcr	0,67	
τy,d	0,1	MPa
τz,d	0,2	MPa
fv,d	1,9	MPa
Unity check τy	0,04	-
Unity check τz	0,09	-
Unity check Interaction	0,01	-

Note: The interaction equation has been added as a NCCI.

Torsion
According to EN 1995-1-1 article 6.1.8 and formula (6.14)

τtor,d	0,9	MPa
kshape	1,30	
fv,d	1,9	MPa
Unity check	0,34	-
Unity check Interaction Shear	0,35	-

Note: The interaction equation has been added as a NCCI.

Combined Bending and Axial Compression
According to EN 1995-1-1 article 6.2.4 and formula (6.19),(6.20)

fc,0,d	17,3	MPa
fm,y,d	18,9	MPa
fm,z,d	17,3	MPa
km	0,70	

Unity check (6.19) = 0,02 + 0,48 + 0,04 = 0,54 -
Unity check (6.20) = 0,02 + 0,34 + 0,06 = 0,42 -

The member satisfies the section check.
..:: STABILITY CHECK ::..

Columns subjected to compression or combined compression and bending
According to EN 1995-1-1 article 6.3.2 and formula (6.23),(6.24)

Buckling parameters	yy	zz	
Sway type	sway	non-sway	
System length L	5,000	5,000	m
Buckling factor k	1,00	0,51	
Buckling length Lcr	5,000	2,549	m
Slenderness λ	72,17	73,57	-
Relative slenderness λ	1,16	1,18	-
Limit slenderness	0,30	0,30	-
Imperfection βc	0,10	0,10	-
Reduction factor kc	0,63	0,61	-

Unity check (6.23) = 0,21 + 0,48 + 0,04 = 0,74 -
Unity check (6.24) = 0,22 + 0,34 + 0,06 = 0,62 -

Beams subjected to bending or combined bending and compression
According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

LTB Parameters		
Elastic critical moment My,crit	93,85	kNm
Critical bending stress σm,crit	81,5	MPa
Relative slenderness λrel,m	0,54	-
Reduction factor kcrit	1,00	-

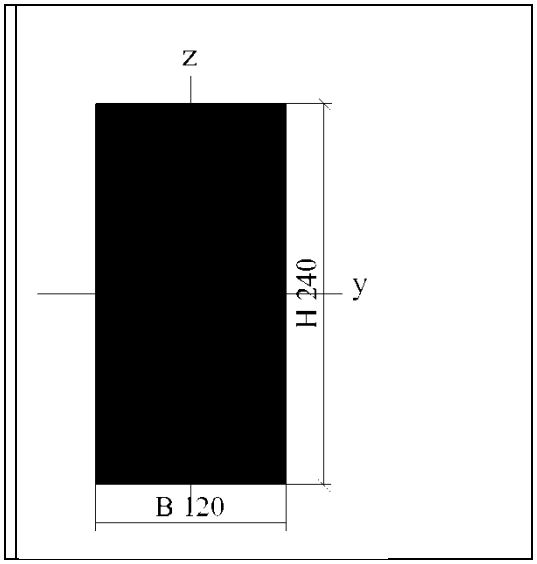
Unity check (6.33) = 0,48 -
Unity check (6.35) = 0,23 + 0,22 = 0,45 -

My,crit Parameters		
G0,05	587,5	MPa
LTB length L	5,000	m
Lef/L	0,90	
Effective length Lef	4,500	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek:

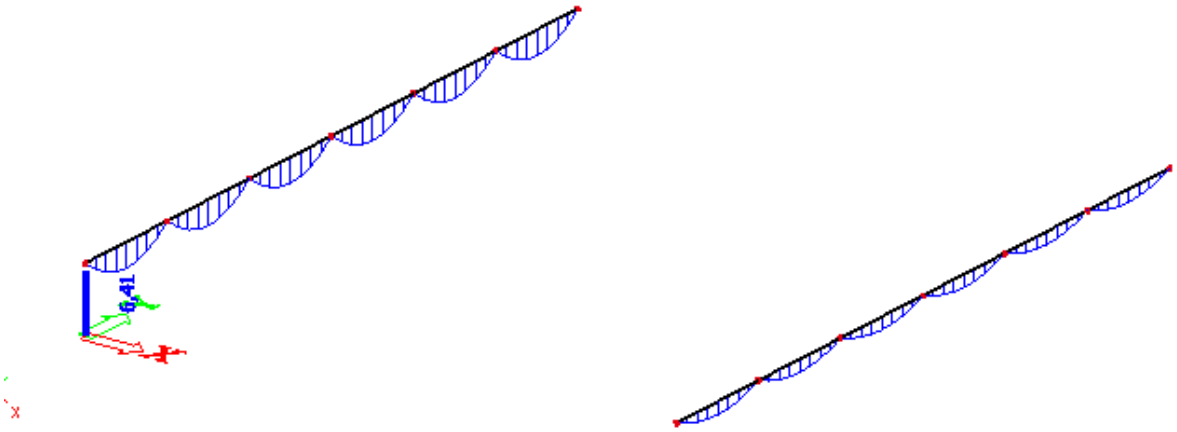
Name	krovna podr
Type	RECT
Detailed	120; 240
Item material	GL24h
Fabrication	timber
Use 2D FEM analysis	✓



A [m_2]	2,8800e-02	
A y, z [m_2]	2,4000e-02	2,4000e-02
I y, z [m_4]	1,3824e-04	3,4560e-05
I w [m_6], t [m_4]	6,0039e-08	9,4694e-05
Wel y, z [m_3]	1,1520e-03	5,7600e-04
Wpl y, z [m_3]	1,4080e-03	7,0400e-04
d y, z [mm]	0	0
c YUCS, ZUCS [mm]	60	120
α [deg]	0,00	
A L, D [m_2/m]	7,2000e-01	7,2000e-01
Mply +, - [Nm]	3,38e+04	3,38e+04
Mplz +, - [Nm]	1,69e+04	1,69e+04

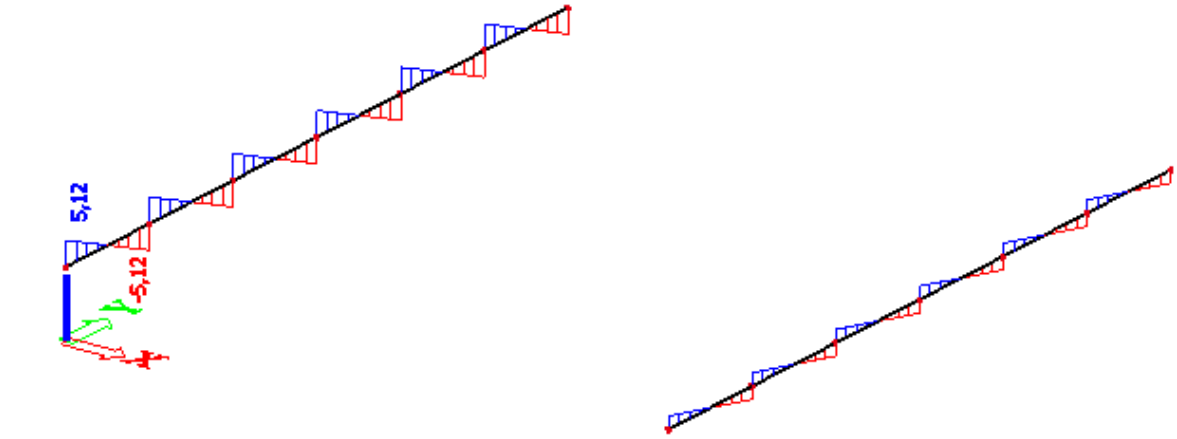
4.5 Dimenzioniranje bočne podrožnice (poz. BP1 i BP2)

Moment savijanja (My)



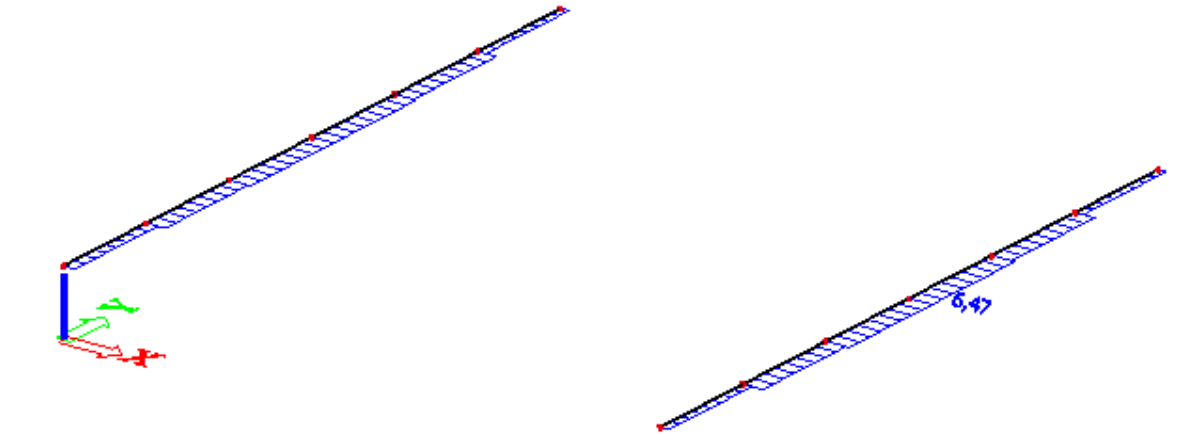
Dijagram momenata savijanja (My)

Poprečna sila (Vz)



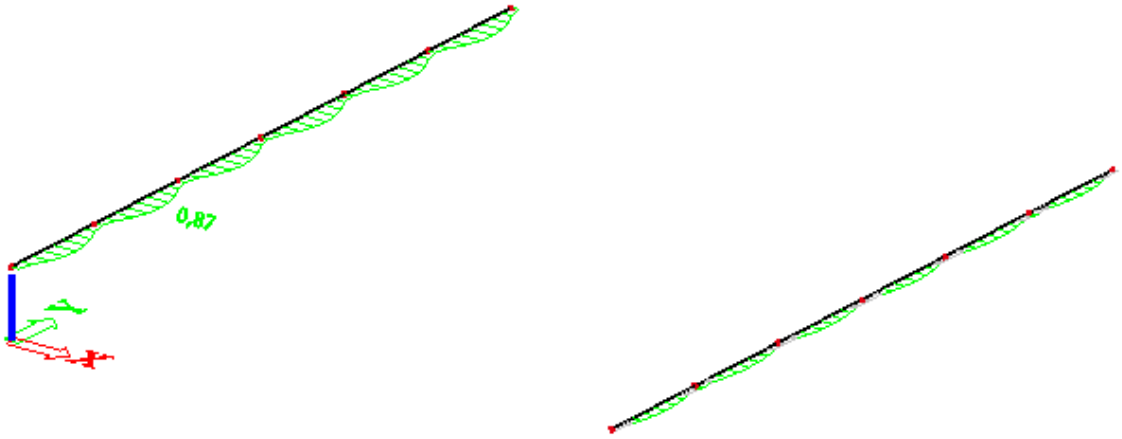
Dijagram poprečnih sila(Vz)

Uzdužna sila (N)



Dijagram uzužnih sila (N)

Iskoristivost:



Prikaz iskoristivosti

Timber ULS check

Linear calculation, Extreme : Cross-section
Selection : All
Class : All ULS
Cross-section : bocna podr - RECT (120; 180)

EN 1995-1-1 Code Check

Beam B64	**5,000 m**	**bocna podr - RECT (120; 180)**	**GL24h**	**All ULS**	**0,87 -**

Combination key
All ULS / 1.35*tezina + 1.35*stalno + 1.50*vjetar p

Basic data	
Partial safety factor γM for Glued laminated timber	1,25

Material data		
Bending (fm,k)	24,0	MPa
Tension (ft,0,k)	16,5	MPa
Tension (ft,90,k)	0,4	MPa
Compression (fc,0,k)	24,0	MPa
Compression (fc,90,k)	2,7	MPa
Shear (fv,k)	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 2,500 m.

Internal forces		
NEd	2,49	kN
Vy,Ed	0,00	kN
Vz,Ed	0,04	kN
TEd	0,00	kNm
My,Ed	0,03	kNm
Mz,Ed	6,41	kNm

Modification factor	
Service Class	1
Load duration	Short term
Modification factor kmod	0,90

..:: SECTION CHECK ::..

Tension parallel to the grain
According to EN 1995-1-1 article 6.1.2 and formula (6.1)

σt,0,d	0,1	MPa
kh	1,10	
ft,0,d	13,1	MPa
Unity check	0,01	-

Bending
According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

σm,y,d	0,0	MPa
kh,y	1,10	
fm,y,d	19,0	MPa
σm,z,d	14,8	MPa
kh,z	1,00	
fm,z,d	17,3	MPa
km	0,70	

Unity check (6.11) = 0,00 + 0,60 = 0,60 -
Unity check (6.12) = 0,00 + 0,86 = 0,86 -

Shear
According to EN 1995-1-1 article 6.1.7 and formula (6.13)

kcr	0,67	
τy,d	0,0	MPa
τz,d	0,0	MPa
fv,d	1,9	MPa
Unity check τy	0,00	-
Unity check τz	0,00	-
Unity check Interaction	0,00	-

Note: The interaction equation has been added as a NCCI.

Torsion
According to EN 1995-1-1 article 6.1.8 and formula (6.14)

τtor,d	0,0	MPa
kshape	1,23	
fv,d	1,9	MPa
Unity check	0,00	-
Unity check Interaction Shear	0,00	-

Note: The interaction equation has been added as a NCCI.

Combined Bending and Axial Tension
According to EN 1995-1-1 article 6.2.3 and formula (6.17),(6.18)

ft,0,d	13,1	MPa
fm,y,d	19,0	MPa
fm,z,d	17,3	MPa
km	0,70	

Unity check (6.17) = 0,01 + 0,00 + 0,60 = 0,61 -
Unity check (6.18) = 0,01 + 0,00 + 0,86 = 0,87 -

The member satisfies the section check.

..:: STABILITY CHECK ::..

Beams subjected to bending or combined bending and compression
According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

LTB Parameters		
Elastic critical moment My,crit	58,61	kNm
Critical bending stress σm,crit	90,5	MPa
Relative slenderness λrel,m	0,52	-
Reduction factor kcrit	1,00	-

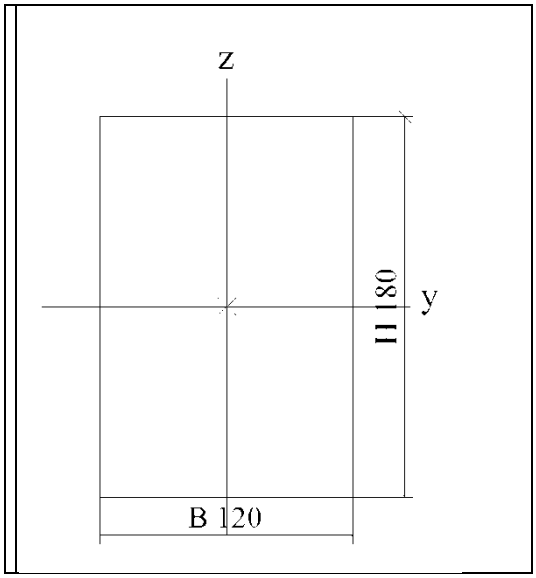
Unity check (6.33) = 0,00 -

My,crit Parameters		
G0,05	587,5	MPa
LTB length L	5,000	m
Lef/L	1,00	
Effective length Lef	5,000	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek:

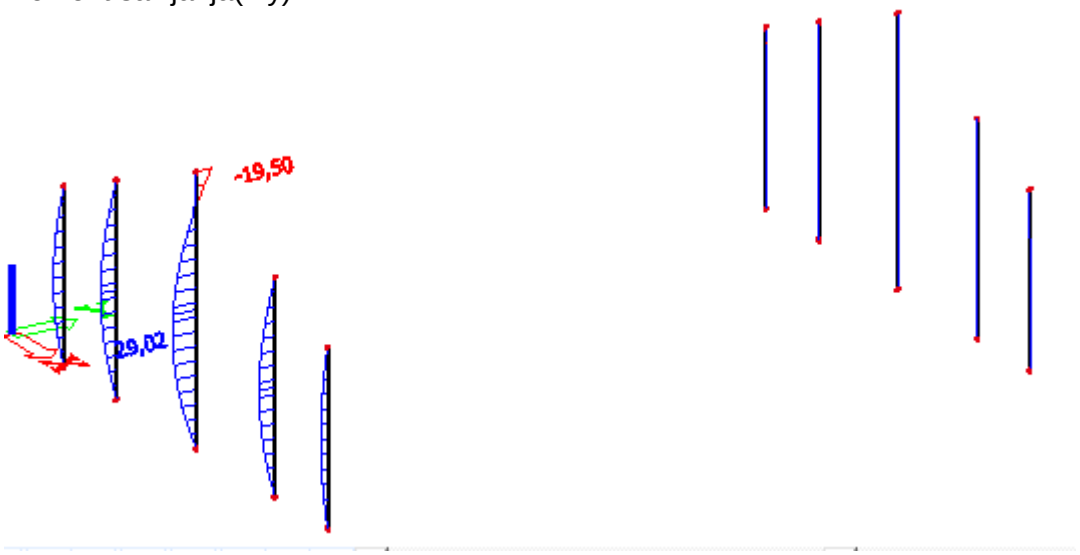
Name	bocna podr
Type	RECT
Detailed	120; 180
Item material	GL24h
Fabrication	timber
Use 2D FEM analysis	✓



A [m2]	2,1600e-02	
A y, z [m2]	1,8000e-02	1,8000e-02
I y, z [m4]	5,8320e-05	2,5920e-05
I w [m6], t [m4]	1,1144e-08	6,0795e-05
Wel y, z [m3]	6,4800e-04	4,3200e-04
Wpl y, z [m3]	7,9200e-04	5,2800e-04
d y, z [mm]	0	0
c YUCS, ZUCS [mm]	60	90
α [deg]	0,00	
A L, D [m2/m]	6,0000e-01	6,0000e-01
Mply +, - [Nm]	1,90e+04	1,90e+04
Mplz +, - [Nm]	1,27e+04	1,27e+04

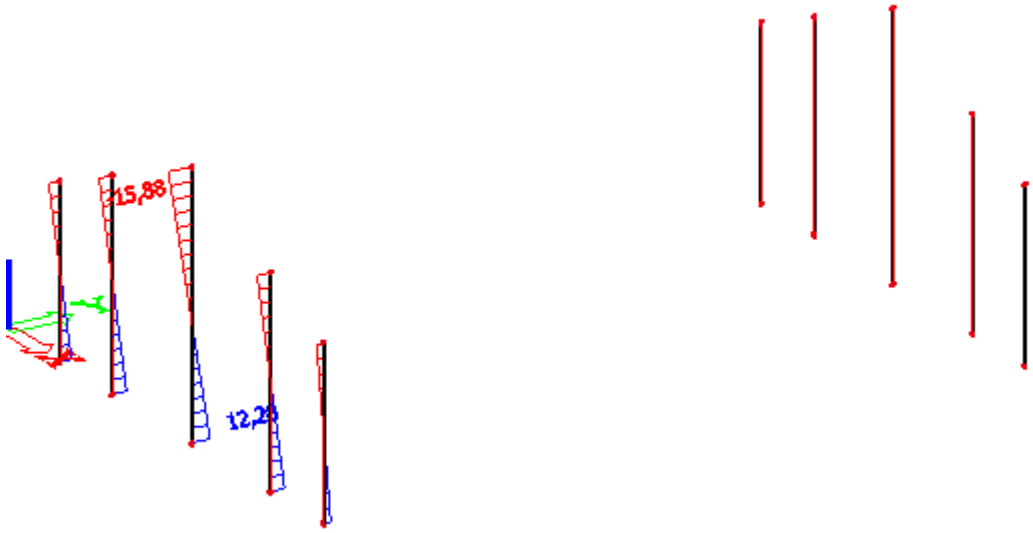
4.6 Dimenzioniranje zabata (poz. ZS1, ZS2 i ZS3)

Moment savijanja(My)



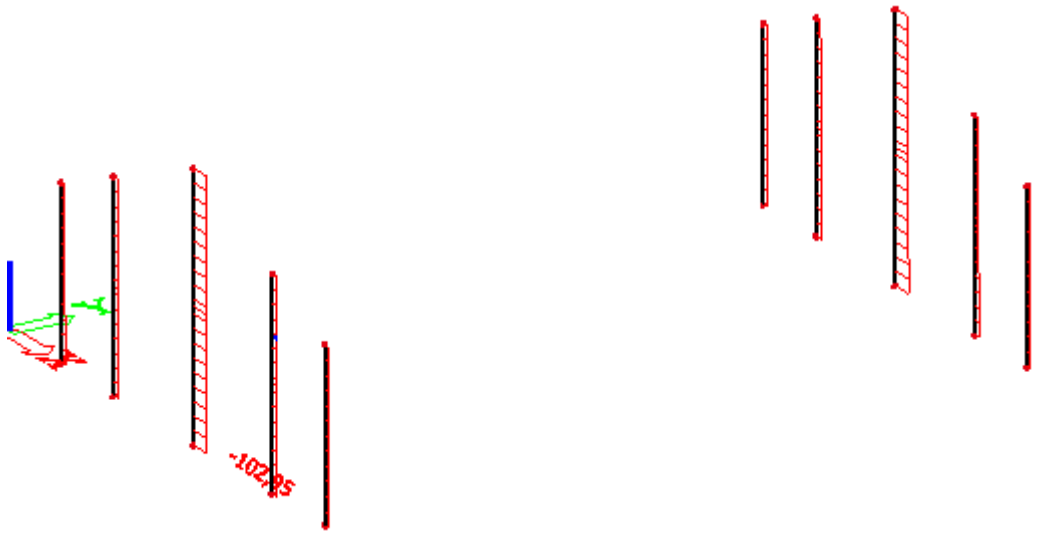
Dijagram momenta savijanja (My)

Poprečna sila (Vz)



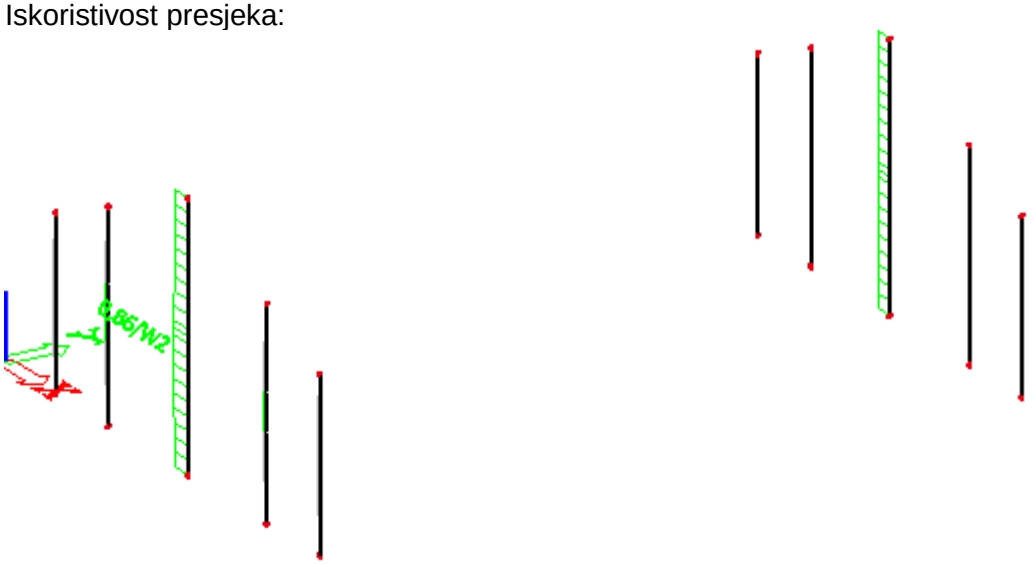
Dijagram poprečnih sila (Vz)

Uzdužna sila(N)



Dijagram uzudžnih sila (N)

Iskoristivost presjeka:



Prikaz iskoristivosti presjeka

Timber ULS check

Linear calculation, Extreme : Cross-section
Selection : All
Class : All ULS
Cross-section : zabat - RECT (220; 600)

EN 1995-1-1 Code Check

Beam B156	**10,850 m**	**zabat - RECT (220; 600)**	**GL24h**	**All ULS**	**0,86 -**

Combination key
All ULS / 1.35*tezina + 1.35*stalno + 1.35*snijeg + 1.35*vjetar p

Basic data	
Partial safety factor γM for Glued laminated timber	1,25

Material data		
Bending (fm,k)	24,0	MPa
Tension (ft,0,k)	16,5	MPa
Tension (ft,90,k)	0,4	MPa
Compression (fc,0,k)	24,0	MPa
Compression (fc,90,k)	2,7	MPa
Shear (fv,k)	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 4,568 m.

Internal forces		
NEd	-99,92	kN
Vy,Ed	0,30	kN
Vz,Ed	0,05	kN
TEd	0,00	kNm
My,Ed	0,21	kNm
Mz,Ed	13,04	kNm

Modification factor	
Service Class	1
Load duration	Short term
Modification factor kmod	0,90

..:: SECTION CHECK ::..

Compression parallel to the grain
According to EN 1995-1-1 article 6.1.4 and formula (6.2)

σc,0,d	0,8	MPa
fc,0,d	17,3	MPa
Unity check	0,04	-

Bending
According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

σm,y,d	0,0	MPa
kh,y	1,00	
fm,y,d	17,3	MPa
σm,z,d	2,7	MPa
kh,z	1,00	
fm,z,d	17,3	MPa
km	0,70	

Unity check (6.11) = 0,00 + 0,11 = 0,11 -
Unity check (6.12) = 0,00 + 0,16 = 0,16 -

Shear
According to EN 1995-1-1 article 6.1.7 and formula (6.13)

kcr	0,67	
τy,d	0,0	MPa
τz,d	0,0	MPa
fv,d	1,9	MPa
Unity check τy	0,00	-
Unity check τz	0,00	-
Unity check Interaction	0,00	-

Note: The interaction equation has been added as a NCCI.

Combined Bending and Axial Compression
According to EN 1995-1-1 article 6.2.4 and formula (6.19),(6.20)

fc,0,d	17,3	MPa
fm,y,d	17,3	MPa
fm,z,d	17,3	MPa
km	0,70	

Unity check (6.19) = 0,00 + 0,00 + 0,11 = 0,11 -
Unity check (6.20) = 0,00 + 0,00 + 0,16 = 0,16 -

The member satisfies the section check.

..:: STABILITY CHECK ::..

Columns subjected to compression or combined compression and bending
According to EN 1995-1-1 article 6.3.2 and formula (6.23),(6.24)

Buckling parameters	yy	zz	
Sway type	sway	non-sway	
System length L	10,850	10,850	m
Buckling factor k	4,05	0,83	
Buckling length Lcr	43,919	9,037	m
Slenderness λ	253,57	142,30	-
Relative slenderness λ	4,08	2,29	-
Limit slenderness	0,30	0,30	-
Imperfection βc	0,10	0,10	-
Reduction factor kc	0,06	0,18	-

Unity check (6.23) = 0,75 + 0,00 + 0,11 = 0,86 -
Unity check (6.24) = 0,24 + 0,00 + 0,16 = 0,40 -

Warning: The slenderness 253,57 is larger than the limit value 200,00!

Beams subjected to bending or combined bending and compression
According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

LTB Parameters		
Elastic critical moment My,crit	634,57	kNm
Critical bending stress σm,crit	48,1	MPa
Relative slenderness λrel,m	0,71	-
Reduction factor kcrit	1,00	-

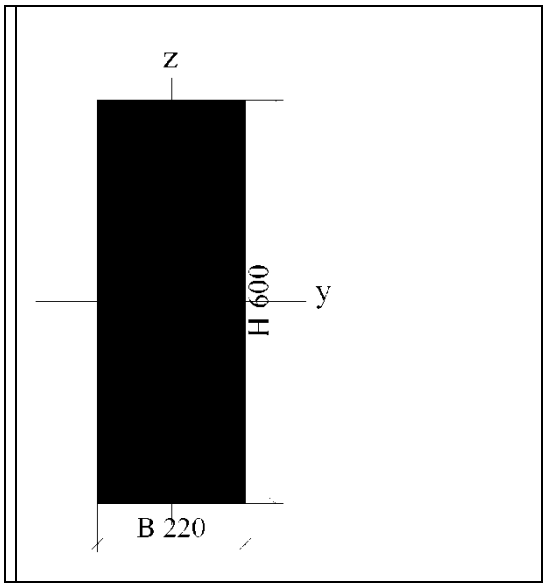
Unity check (6.33) = 0,00 -
Unity check (6.35) = 0,00 + 0,24 = 0,24 -

My,crit Parameters		
G0,05	587,5	MPa
LTB length L	10,850	m
Lef/L	1,00	
Effective length Lef	10,850	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek

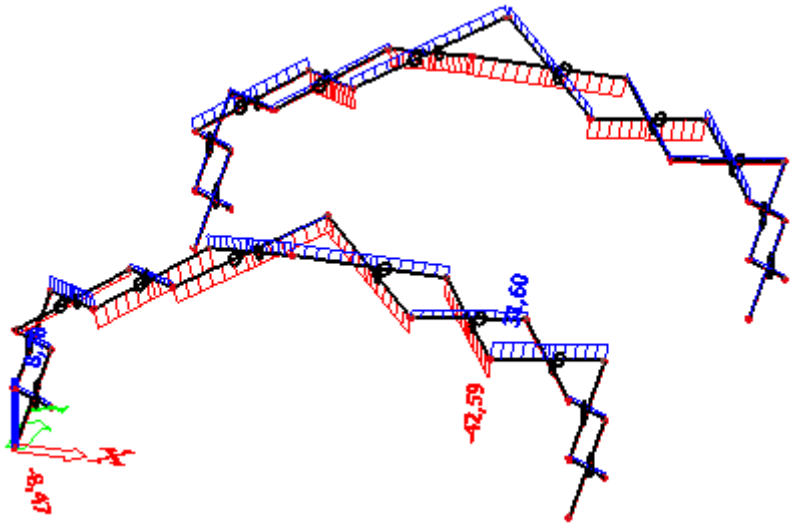
Name	zabat
Type	RECT
Detailed	220; 600
Item material	GL24h
Fabrication	timber
Use 2D FEM analysis	✓



A [m_2]	1,3200e-01	
A y, z [m_2]	1,1000e-01	1,1000e-01
I y, z [m_4]	3,9600e-03	5,3240e-04
I w [m_6], t [m_4]	9,1206e-06	1,6336e-03
Wel y, z [m_3]	1,3200e-02	4,8400e-03
Wpl y, z [m_3]	1,6133e-02	5,9156e-03
d y, z [mm]	0	0
c YUCS, ZUCS [mm]	110	300
α [deg]	0,00	
A L, D [m_2/m]	1,6400e+00	1,6400e+00
Mply +, - [Nm]	3,87e+05	3,87e+05
Mplz +, - [Nm]	1,42e+05	1,42e+05

4.7 Dimenzioniranje spregova – S235 (poz. KS1, KS2, BS1 i BS2)

Uzdužna sila:



Dijagram uzdužnih sila (N)

$odabrano\ \emptyset 15$

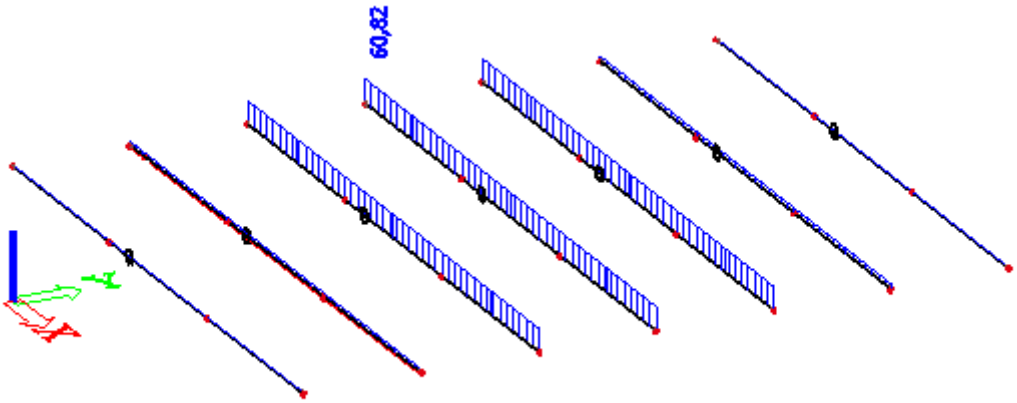
A=1,767·10^{-4} m^2

$$\frac{A \cdot f_y}{\gamma_{M_0}} = \frac{1{,}767 \cdot 23{,}5}{1{,}0} = 41{,}52\ kN$$

$41{,}52\ kN > 31{,}60\ kN$ - presjek zadovoljava

4.8 Dimenzioniranje zatege – S235 (poz. Z)

Uzdužna sila:



Dijagram uzdužnih sila (N)

$odabrano\ \emptyset 20$

A=3,142·10^{-4} m^2

$$\frac{A \cdot f_y}{\gamma_{M_0}} = \frac{3{,}142 \cdot 23{,}5}{1{,}0} = 73{,}84\ kN$$

$73{,}84\ kN > 60{,}82\ kN$ - presjek zadovoljava

5. SPOJEVI

5.1 SPOJ STUPA I GREDE (trnovi)

Rezne sile: $M_{Ed} = 316{,}96\ \text{kNm}$, $V_{Ed} = 56{,}68\ \text{kN}$, $N_{Ed} = 157{,}63\ \text{kN}$ (tlak)

Kvaliteta materijala:

Čelik: S355 → $f_{uk} = 490\ \text{MPa}$

Drvo: LLD GL24h → ρ_k = 380 kg/m^3 → γ_M = 1,25

Uporabna klasa 2. → kratkotrajno opterećenje→ k_{mod} = 0,90

α=90° -kut unosa opterećenja

$d_{odabrano} = 20\ \text{mm}$ –promjer trna

Minimalni razmaci trnova:

$a_1 = (3 + 2|\cos\alpha|)d = (3 + 2|\cos 90|)20 = 60\ \text{mm}$

$a_2 = 3d = 3 \cdot 20 = 60\ \text{mm}$

$a_3 = \max(7d; 80\ \text{mm}) = \max(7 \cdot 20; 80\ \text{mm}) = 140\ \text{mm}$

$a_4 = \max\left((2 + 2\sin\alpha)d; 3d\right) = \max\left((2 + 2\sin 90) \cdot 20; 3 \cdot 20\right) = 80\ \text{mm}$

$r_v = 270$ mm – radijus vanjske kružnice

$r_u = 210$ mm – radijus unutarnje kružnice

Potreban broj trnova:

$$n_v = \frac{2r\pi}{a_1; a_2} = \frac{2 \cdot 270\pi}{60} \rightarrow 28\ \text{komada}$$

$$n_v = \frac{2r\pi}{a_1; a_2} = \frac{2 \cdot 210\pi}{60} \rightarrow 21\ \text{komada}$$

Posmična otpornst jednog trna je najmanja od slijedećih vrijednosti:

$$R_d = \min\left\{\begin{array}{c} f_{h,\alpha,d} \cdot t_1 \cdot d \\ 0.5 \cdot (f_{h,\alpha,d} \cdot t_2 \cdot d) \\ 1.05 \cdot \frac{f_{h,\alpha,d} \cdot t_1 \cdot d}{2+\beta} \cdot \left[\sqrt{2\beta(1+\beta) + \frac{4\beta(2+\beta) \cdot M_{y,Rd}}{f_{h,\alpha,d} \cdot t_1^2 \cdot d}} - \beta\right] \\ 1.15 \cdot \sqrt{\frac{2\beta}{1+\beta}} \cdot \sqrt{2 \cdot M_{y,RD} \cdot f_{h,\alpha,d} \cdot d} \end{array}\right\}$$

β=1.0 –za spojene elemente iste kvalitete drva

t_1-širina grede

t_2-širina stupa

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0{,}3 \cdot f_{uk} \cdot d^{2,6} = 0{,}3 \cdot 490 \cdot 20^{2,6} = 354\,810\ \text{Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{354\,810}{1{,}1} = 322\,554\ \text{Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$f_{h,0,k}$= 0,082·(1-0,01·d)· ρ_k =0,082·(1-0,01·20)· 380 = 24,93 N/mm^2

$k_{90} = 0{,}9 + 0{,}015 \cdot d = 0{,}9 + 0{,}015 \cdot 20 = 1{,}2$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

α=45°-najopterećeniji trn

$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2\alpha + \cos^2\alpha} = \frac{24{,}93}{1{,}2 \cdot \sin^2 45 + \cos^2 45} = 22{,}66\ N/mm^2$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0{,}90 \cdot \frac{22{,}66}{1{,}25} = 16{,}32\ N/mm^2$

<u>Proračunska otpornost jednog trna:</u>

$f_{h,\alpha,d} \cdot t_1 \cdot d = 16{,}32 \cdot 200 \cdot 20 = 65\ 280$ N

$0.5 \cdot (f_{h,\alpha,d} \cdot t_2 \cdot d) = 0{,}5 \cdot (16{,}32 \cdot 400 \cdot 20) = 65\ 280$ N

$$1.05 \cdot \frac{f_{h,\alpha,d} \cdot t_1 \cdot d}{2+\beta} \cdot \left[\sqrt{2\beta(1+\beta) + \frac{4\beta(2+\beta) \cdot M_{y,Rd}}{f_{h,\alpha,d} \cdot t_1^2 \cdot d}} - \beta\right] =$$

$$= 1{,}05 \cdot \frac{16{,}32 \cdot 200 \cdot 20}{2+1} \cdot \left[\sqrt{2(1+1) + \frac{4(2+1) \cdot 322\ 554}{16{,}32 \cdot 200^2 \cdot 20}} - 1\right] = 24\ 918 \text{ N}$$

$$1.15 \cdot \sqrt{\frac{2\beta}{1+\beta}} \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} = 1.15 \cdot \sqrt{\frac{2}{1+1}} \cdot \sqrt{2 \cdot 322\ 554 \cdot 16{,}32 \cdot 20} =$$

= 17 687 N

min R_d= 17 687 N

ΣR_d=2·minR_d= 2·17 687 = 35 374 N = 35,37 kN

<u>Doprinos jednog trna u prihvaćanju unutrašnjih sila montažne veze:</u>

Budući da su trnovi raspoređeni u 2 kružnice, trnovi prihvaćaju silu od momenta savijanja u omjeru radijusa kružnica:

$$\frac{r_u}{r_v} = \frac{210}{270} = \frac{7}{9} \rightarrow M_{d,v} = \frac{9}{16} M_{Ed}\ ;\ M_{d,u} = \frac{7}{16} M_{Ed}$$

-od momenta savijanja:

$$F_{Md,v} = \frac{\frac{9}{16} M_{Ed}}{r \cdot n} = \frac{\frac{9}{16} \cdot 316{,}96}{0{,}27 \cdot 28} = 23{,}6 \text{ kN}$$

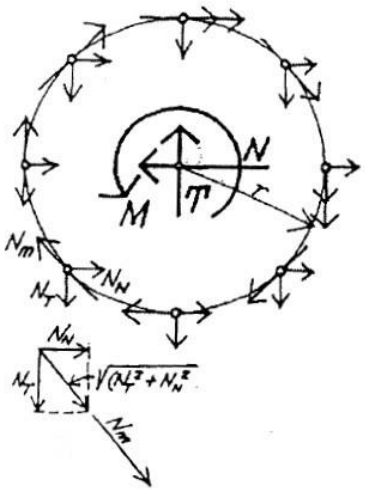
$$F_{Md,u} = \frac{\frac{7}{16} M_{Ed}}{r \cdot n} = \frac{\frac{7}{16} \cdot 316{,}96}{0{,}21 \cdot 21} = 31{,}4 \text{ kN}$$

-od poprečne sile:

$$F_{Vd} = \frac{V_{Ed}}{n} = \frac{56{,}68}{49} = 1{,}16 \text{ kN}$$

-od uzdužne sile:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{157,63}{49} = 3,21 \text{ kN}$$



<u>Proračunska vrijednost sile koju preuzima 1 trn:</u>

$$F_d = F_M + \sqrt{F_N^2 + F_V^2}$$

$$F_{d,v} = 23,6 + \sqrt{3,21^2 + 1,16^2} = 27,01 \text{ kN}$$

$$F_{d,u} = 31,4 + \sqrt{3,21^2 + 1,16^2} = 34,8 \text{ kN}$$

R_d= 35,37 kN > $F_d = 34,8$ kN

$$\eta = \frac{34,8}{35,37} = 0,98$$

5.2 MONTAŽNI SPOJ DVIJU GREDA-ZGLOB (trn,pločice i vijci)

Rezne sile: $V_{Ed} = 44{,}70\ \text{kN}$, $N_{Ed} = 116{,}31\ \text{kN}$

Kvaliteta materijala:

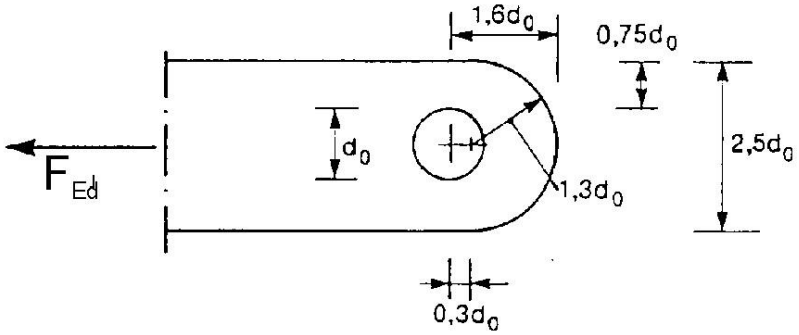
Čelik: S355 → $f_{uk} = 490\ \text{MPa}$

Drvo: LLD GL24h → ρ_k = 380 kg/m^3 → γ_M = 1,25

Uporabna klasa 2. → kratkotrajno opterećenje→ k_{mod} = 0,90

5.2.1Proračun trna i debljine pločica (P1) na zglobu

$d_{odabrano}$ =26 mm –promjer trna



Dimenzije pločice odabiru se prema preporukama sa slike.

Geometrijski uvjeti:

1. $t \geq 0{,}7 \cdot \sqrt{\frac{F_{Ed} \cdot \gamma_{M0}}{f_y}} = 0{,}7 \cdot \sqrt{\frac{116310 \cdot 1.0}{355}} = 12{,}67\ \text{mm}$
2. $d_0 \leq 2{,}5\ t$

   $27\ \text{mm} \leq 2{,}5 \cdot 14 = 35\ \text{mm}$

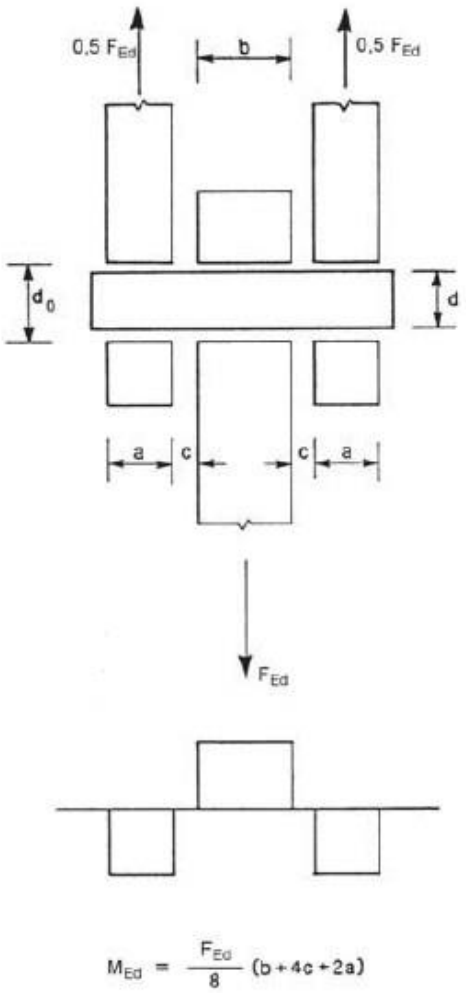
→Uvjeti zadovoljeni→odabrana debljina pločice t= 14 mm

Otpornost trna savijanje:

$$M_{b,Rd} = \frac{1{,}5 \cdot W_{el} \cdot f_{yp}}{\gamma_{M0}} = \frac{1{,}5 \cdot 1689 \cdot 355}{1{,}0} = 899\ 393\ \text{Nmm}$$

$$M_{Ed} = \frac{F_{Ed}}{8} \cdot (b + 4c + 2a) = \frac{116\ 310}{8} \cdot (14 + 12 + 28) = 785\ 093\ \text{Nmm}$$

Napomena: Moment savijanja izračunat je prema shemi sa slike.



$M_{b,Rd} = 0{,}89\ \text{kNm} > M_{Ed} = 0{,}79\ \text{kNm}$

→Uvjet zadovoljen

Posmična otpornost trna:

$$F_{V,Rd} = \frac{0{,}6 \cdot A \cdot f_{up}}{\gamma_{M2}} = \frac{0{,}6 \cdot 530{,}9 \cdot 490}{1{,}25} = 124\,867\ \text{N} = 124{,}87\ \text{kN}$$

$F_{V,Ed} = 44{,}70\ \text{kN}$

$F_{V,Rd} > F_{V,Ed}$ → Uvjet zadovoljen

Interakcija M+V:

$$\left(\frac{M_{Ed}}{M_{Rd}}\right)^2 + \left(\frac{F_{V,Ed}}{F_{V,Rd}}\right)^2 \leq 1$$

$$\left(\frac{0{,}79}{0{,}89}\right)^2 + \left(\frac{44{,}70}{124{,}87}\right)^2 \leq 1$$

$0{,}92 \leq 1$

Pritisak po omotaču rupe:

$$F_{b,Rd} = \frac{1{,}5 \cdot t \cdot d \cdot f_y}{\gamma_{M0}} = \frac{1{,}5 \cdot 14 \cdot 26 \cdot 355}{1{,}0} = 193\,830\ \text{N} = 193{,}83\ \text{kN}$$

$$F_{b,Ed} = 116{,}31\ \text{kN}$$

$F_{b,Rd} > F_{b,Ed}$ → Uvjet zadovoljen

Debljina pločice P2 i P3 je 26 mm.

Naprezanja na drvenoj gredi preko pločice P2:

$$f_{b,Ed} \leq k_{mod} \cdot \frac{f_{c,90,k}}{\gamma_M}$$

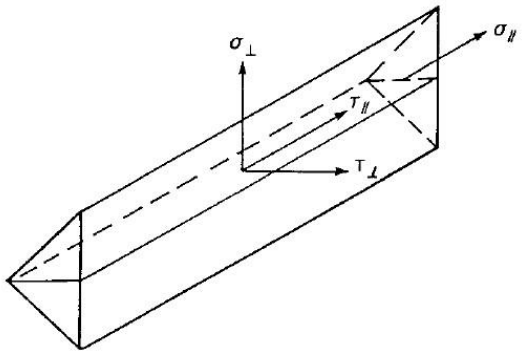
$$f_{b,Ed} = \frac{N_{Ed}}{h \cdot b_{PL}} = \frac{116\,310}{460 \cdot 26} = 11{,}18\ \text{Mpa} < 0{,}90 \cdot \frac{26{,}5}{1{,}25} = 19{,}08\ \text{Mpa}$$

→ Uvjet zadovoljen

5.2.2 Proračun vara između pločica P1 i P2 direktnom metodom

a=7 mm –debljina vara

L=75 mm –duljina vara



1.uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{116\,310}{7 \cdot 75} = 221{,}54\ \text{MPa} < 0{,}9 \cdot \frac{f_u}{\gamma_{M2}} = 0{,}9 \cdot \frac{490}{1{,}25} = 352{,}80\ \text{MPa}$$

→Uvjet zadovoljen

$$\tau_{\parallel} = \frac{V_{Ed} \cdot S}{I \cdot b} = \frac{44\,700 \cdot 4\,921{,}88}{246\,093{,}80 \cdot 7} = 127{,}71\ \text{Mpa}$$

$$I = \frac{b \cdot h^3}{12} = \frac{7 \cdot 75^3}{12} = 246\,093{,}80\ \text{mm}^4 - \text{moment tromosti}$$

$$S = \frac{75}{2} \cdot 7 \cdot \frac{75}{4} = 4\,921{,}88\ \text{mm}^3 - \text{statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{116\,310 \cdot 459{,}38}{2\,143{,}80 \cdot 75} = 332{,}31\ \text{Mpa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{75 \cdot 7^3}{12} = 2\,143{,}80\ \text{mm}^4 - \text{moment tromosti}$$

$$S = 75 \cdot 3{,}5 \cdot 1{,}75 = 459{,}38\ \text{mm}^3 - \text{statički moment površine}$$

2.uvjet:

$$\frac{\left[\sigma_{\perp}^2 + 3\left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)\right]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{\left[\sigma_{\perp}^2 + 3\left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)\right]^{0.5}}{2} = \frac{\left[221{,}54^2 + 3\left(332{,}31^2 + 127{,}71^2\right)\right]^{0.5}}{2} = 327{,}60 \text{ Mpa}$$

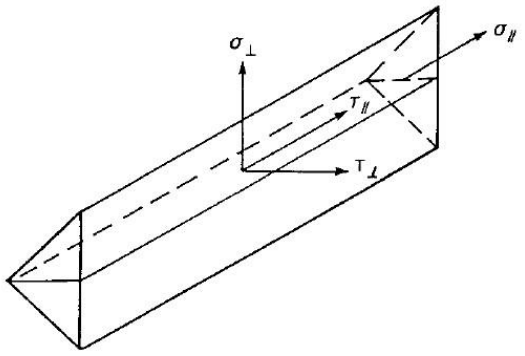
$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0{,}9 \cdot 1{,}25} = 435{,}55 \text{ MPa}$$

327,60 Mpa < 435.55 Mpa →Uvjet zadovoljen

5.2.3 Proračun vara između pločica P2 i P3 direktnom metodom

a=4 mm –debljina vara

L=320 mm –duljina vara



1.uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{116\,310}{4 \cdot 320} = 115{,}39 \text{ MPa} < 0{,}9 \cdot \frac{f_u}{\gamma_{M2}} = 0{,}9 \cdot \frac{490}{1{,}25} = 352{,}80 \text{ MPa}$$

→Uvjet zadovoljen

$$\tau_{\parallel} = \frac{V_{Ed} \cdot S}{I \cdot b} = \frac{20\,680 \cdot 51\,200}{19\,114\,667 \cdot 4} = 13{,}85 \text{ Mpa}$$

$$I = \frac{b \cdot h^3}{12} = \frac{4 \cdot 320^3}{12} = 19\,114\,667 \text{ mm}^4 - \text{moment tromosti}$$

$$S = \frac{320}{2} \cdot 4 \cdot \frac{320}{4} = 51\,200 \text{ mm}^3 - \text{statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{147\,700 \cdot 640}{1\,706{,}67 \cdot 320} = 173{,}09 \text{ Mpa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{320 \cdot 4^3}{12} = 1\,706{,}67 \text{ mm}^4 - \text{moment tromosti}$$

$$S = 320 \cdot 2 \cdot 1 = 640 \text{ mm}^3 - \text{statički moment površine}$$

2.uvjet:

$$\frac{\left[\sigma_{\perp}^2 + 3\left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)\right]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{\left[\sigma_{\perp}^2 + 3\left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)\right]^{0.5}}{4} = \frac{\left[115{,}39^{\,2} + 3\left(173{,}09^2 + 13{,}85^2\right)\right]^{0.5}}{4} = 80{,}53 \text{ Mpa}$$

$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0{,}9 \cdot 1{,}25} = 435{,}55 \text{ MPa}$$

80,53 Mpa < 435,55 Mpa →Uvjet zadovoljen

5.2.4 Spoj grede s pločicama P10 vijcima M20

Spoj je dvorezan s debelim pločama kao vanjskim elementima ($t_{PL} > d_{spajala}$)

a = 4d = 4·20 = 80 mm – minimalni razmak vijaka u smjeru okomitom na vlakanca grede

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0{,}3 \cdot f_{uk} \cdot d^{2,6} = 0{,}3 \cdot 490 \cdot 20^{2,6} = 354\,810 \text{ Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{354\,810}{1{,}1} = 322\,555 \text{ Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$f_{h,0,k}$= 0,082·(1-0,01·d)· ρ_k =0,082·(1-0,01·20)· 380 = 24,93 N/mm^2

$k_{90} = 0{,}9 + 0{,}015 \cdot d = 0{,}9 + 0{,}015 \cdot 20 = 1{,}20$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

α=90°

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2\alpha + \cos^2\alpha} = \frac{24{,}93}{1.2 \cdot \sin^2 90 + \cos^2 90} = 20{,}78 \text{ N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0{,}90 \cdot \frac{20{,}78}{1{,}25} = 14{,}96 \text{ N/mm}^2$$

Proračunska otpornost jednog vijka:

$$R_d = \min \begin{Bmatrix} 0{,}5 \cdot (f_{h,\alpha,d} \cdot t_2 \cdot d) = 0{,}5 \cdot (14{,}96 \cdot 200 \cdot 20) = 29\,920 \text{ N} \\ 2{,}3 \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} + \frac{F_{ax}}{4} = 2{,}3 \cdot \sqrt{2 \cdot 322\,555 \cdot 14{,}96 \cdot 20} + \frac{F_{ax}}{4} = \\ = 31\,954 + \frac{F_{ax}}{4} = 31\,954 + \frac{31\,954}{4} = 39\,943 \text{ N} \end{Bmatrix}$$

$$R_d = 29{,}92 \text{ kN}$$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

-od poprečne sile:

$$F_{Vd} = \frac{V_{Ed}}{n} = \frac{44{,}70}{6} = 7{,}45 \text{ kN}$$

-od uzdužne sile:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{116,31}{6} = 19,38 \text{ kN}$$

Proračunska vrijednost sile koju preuzima 1 vijak:

$$F_d = \sqrt{F_N^2 + F_V^2}$$

$$F_d = \sqrt{19,38^2 + 7,45^2} = 20,77 \text{ kN}$$

$$R_d = 29,92 \text{ kN} < F_d = 20,77 \text{ kN}$$

→Uvjet zadovoljen

$$\eta = \frac{20,77}{29,92} = 0,69$$

5.3 VLAČNI NASTAVAK GREDE (pločice i vijci)

Rezne sile: $V_{Ed} = 76{,}66,\ N_{Ed} = 155{,}89\ \text{kN}$

Kvaliteta materijala:

Vijci : kv.5.8; $f_{yk} = 400\ \text{MPa}$; $f_{uk} = 500\ \text{MPa}$

Drvo: LLD GL24h → ρ_k = 380 kg/m^3 → γ_M = 1,25

Uporabna klasa 2. → kratko opterećenje→ k_{mod} = 0,90

Spoj je dvorezan s čeličnim pločicama kao vanjskim elementima .

d = 20mm

a = 4d = 4·20 = 80 mm – minimalni razmak vijaka u smjeru okomitom na vlakanca grede

t_{min}= 0.3d = 6mm

Odabrane dimenzije pločice P14: 480/240/10mm

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0{,}3 \cdot f_{uk} \cdot d^{2,6} = 0{,}3 \cdot 490 \cdot 20^{2,6} = 354\,810\ \text{Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{354\,810}{1{,}1} = 322\,555\ \text{Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$f_{h,0,k}$= 0,082·(1-0,01·d)· ρ_k =0,082·(1-0,01·20)· 380 = 24,93 N/mm^2

$$k_{90} = 0{,}9 + 0{,}015 \cdot d = 0{,}9 + 0{,}015 \cdot 20 = 1{,}20$$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

α=90°

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2\alpha + \cos^2\alpha} = \frac{24{,}93}{1.2 \cdot \sin^2 90 + \cos^2 90} = 20{,}78\ \text{N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0{,}90 \cdot \frac{20{,}78}{1{,}25} = 14{,}96\ \text{N/mm}^2$$

Proračunska otpornost jednog vijka:

$$R_d = \min \left\{ \begin{array}{c} 0{,}5 \cdot (f_{h,\alpha,d} \cdot t \quad \cdot d) = 0{,}5 \cdot (14{,}96 \cdot 200 \cdot 20) = 29\,920\ \text{N} \\ 2{,}3 \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} + \frac{F_{ax}}{4} = 2{,}3 \cdot \sqrt{2 \cdot 322\,555 \cdot 14{,}96 \cdot 20} + \frac{F_{ax}}{4} = \\ = 31\,954 + \frac{F_{ax}}{4} = 31\,954 + \frac{31\,954}{4} = 39\,943\ \text{N} \end{array} \right\}$$

$$R_d = 29{,}92\ \text{kN}$$

$$odabrano\ n = 8$$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

-od uzdužne sile:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{155,89}{8} = 19,48 \text{ kN}$$

-od poprečne sile:

$$F_{Vd} = \frac{V_{Ed}}{n} = \frac{76,66}{8} = 9,58 \text{ kN}$$

Proračunska vrijednost sile koju preuzima 1 vijak:

$$F_d = \sqrt{F_N^2 + F_V^2}$$

$$F_d = \sqrt{19,48^2 + 9,58^2} = 21,71 \text{ kN}$$

$R_d = 29,92 \text{ kN} < F_d = 21,71 \text{ kN}$

→Uvjet zadovoljen

$$\eta = \frac{21,71}{29,92} = 0,73$$

5.4 SPOJ STUP – ZATEGA

Rezne sile: $N_{Ed} = 60{,}82\ \text{kN}$

Kvaliteta materijala:

Vijci : kv.5.8; $f_{yk} = 400\ \text{MPa}$; $f_{uk} = 500\ \text{MPa}$

Drvo: LLD GL24h → ρ_k = 380 kg/m^3 → γ_M = 1,25

Uporabna klasa 2. → kratko opterećenje→ k_{mod} = 0,90

5.4.1 Proračun vijaka i pločica na stupu:

Spoj je dvorezan s čeličnim pločicama kao vanjskim elementima .

d = 20mm

a = 4d = 4·20 = 80 mm – minimalni razmak vijaka u smjeru okomitom na vlakanca

Odabrane dimenzije pločice: 320/320/8mm

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0{,}3 \cdot f_{uk} \cdot d^{2,6} = 0{,}3 \cdot 490 \cdot 20^{2,6} = 354\,810\ \text{Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{354\,810}{1{,}1} = 322\,555\ \text{Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$f_{h,0,k}$= 0,082·(1-0,01·d)· ρ_k =0,082·(1-0,01·20)· 380 = 24,93 N/mm^2

$$k_{90} = 0{,}9 + 0{,}015 \cdot d = 0{,}9 + 0{,}015 \cdot 20 = 1{,}20$$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

α=90°

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2\alpha + \cos^2\alpha} = \frac{24{,}93}{1.2 \cdot \sin^2 90 + \cos^2 90} = 20{,}78\ \text{N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0{,}90 \cdot \frac{20{,}78}{1{,}25} = 14{,}96\ \text{N/mm}^2$$

Proračunska otpornost jednog vijka:

$$R_d = \min \left\{ \begin{array}{c} 0{,}5 \cdot (f_{h,\alpha,d} \cdot t \quad \cdot d) = 0{,}5 \cdot (14{,}96 \cdot 200 \cdot 20) = 29\,920\ \text{N} \\ 2{,}3 \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} + \frac{F_{ax}}{4} = 2{,}3 \cdot \sqrt{2 \cdot 322\,555 \cdot 14{,}96 \cdot 20} + \frac{F_{ax}}{4} = \\ = 31\,954 + \frac{F_{ax}}{4} = 31\,954 + \frac{31\,954}{4} = 39\,943\ \text{N} \end{array} \right\}$$

$$R_d = 29{,}92\ \text{kN}$$

$$odabrano\ n = 6$$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{60{,}82}{6} = 10{,}14 \text{ kN}$$

$$R_d = 29{,}92 \text{ kN} \geq F_d = 10{,}14 \text{ kN}$$

→Uvjet zadovoljen

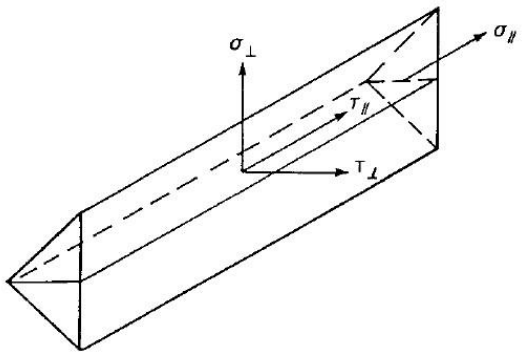
$$\eta = \frac{10{,}14}{29{,}92} = 0{,}34$$

5.4.2 Proračun vara između pločica P11 i P12 direktnom metodom

Dimenzije pločice P12: 320/184/10mm

a=4 mm –debljina vara

L=100 mm –duljina vara



1.uvjet:

$$\sigma_\perp = \frac{N_{Ed}}{A} = \frac{60\,820}{4 \cdot 100} = 152{,}05 \text{ MPa} < 0{,}9 \cdot \frac{f_u}{\gamma_{M2}} = 0{,}9 \cdot \frac{490}{1{,}25} = 352{,}80 \text{ MPa}$$

→Uvjet zadovoljen

$$I = \frac{b \cdot h^3}{12} = \frac{4 \cdot 100^3}{12} = 333\,333 \text{ mm}^4 - \text{moment tromosti}$$

$$S = \frac{100}{2} \cdot 4 \cdot \frac{100}{4} = 5\,000 \text{ mm}^3 - \text{statički moment površine}$$

$$\tau_\perp = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{60\,820 \cdot 300}{533{,}33 \cdot 100} = 342{,}11 \text{ Mpa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{100 \cdot 4^3}{12} = 533{,}33 \text{ mm}^4 - \text{moment tromosti}$$

$$S = 100 \cdot 2 \cdot 1.5 = 300 \text{ mm}^3 - \text{statički moment površine}$$

2.uvjet:

$$\frac{\left[\sigma_\perp^2 + 3\left(\tau_\perp^2 + \tau_\parallel^2\right)\right]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{\left[\sigma_\perp^2 + 3\left(\tau_\perp^2 + \tau_\parallel^2\right)\right]^{0.5}}{2} = \frac{\left[152{,}05^2 + 3\left(342{,}11^2\right)\right]^{0.5}}{2} = 305{,}87 \text{ Mpa}$$

$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0{,}9 \cdot 1{,}25} = 435{,}55 \text{ MPa}$$

305,87Mpa < 435,55 Mpa →Uvjet zadovoljen

Napomena: istim se varom spaja i pločica P13 sa zategom.

5.4.3 Proračun vijaka na spoju pločica P12 i P13 (spoj čelik – čelik)

Odabrano: d = 16mm, n = 2

Preporučeni razmaci vijaka za odabrani promjer i debljinu lima t = 10 mm:

$e_1 = 40\ \text{mm}$ → udaljenost od kraja lima

$p_1 = p_2 = 55\ \text{mm}$ → međusobna udaljenost vijaka

$e_2 = 30\ \text{mm}$ → udaljenost od ruba lima

Odabrane dimenzije pločice: 285/70/10mm

Otpornost vijka na posmik: $F_{t,Rk} = \alpha \cdot f_{uk} \cdot A_S = 0{,}6 \cdot 500 \cdot 157 = 47{,}1\ kN$

$$F_{t,Rd} = \frac{47{,}1}{1{,}25} = 37{,}68\ kN$$

<u>Doprinos jednog vijka u prihvaćanju unutrašnjih sila:</u>

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{60{,}82}{2} = 30{,}41\ \text{kN}$$

$F_{t,Rd} = 37{,}68\ \text{kN} \geq F_d = 30{,}41\ \text{kN}$

→Uvjet zadovoljen

$$\eta = \frac{30{,}41}{37{,}68} = 0{,}81$$

5.5 SPOJ STUP-TEMELJ

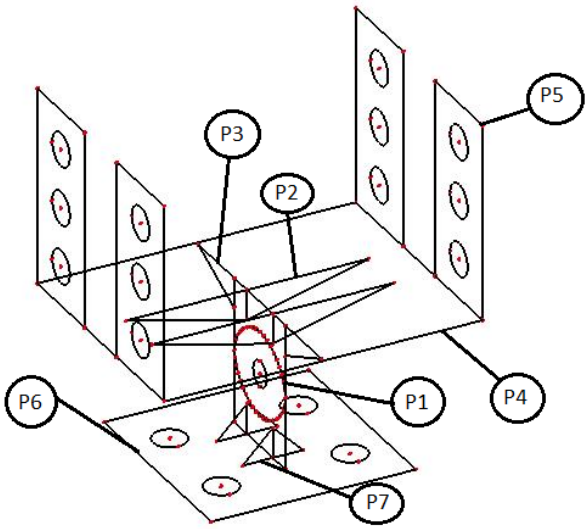
Rezne sile: $V_{Ed} = 56{,}68\ \text{kN}$, $N_{Ed} = 157{,}63\ \text{kN}$

Kvaliteta materijala:

Trnovi i vijci : kv.5.8; $f_{yk} = 400\ \text{MPa}$; $f_{uk} = 500\ \text{MPa}$

Drvo: LLD GL24h → ρ_k = 380 kg/m^3 → γ_M = 1,25

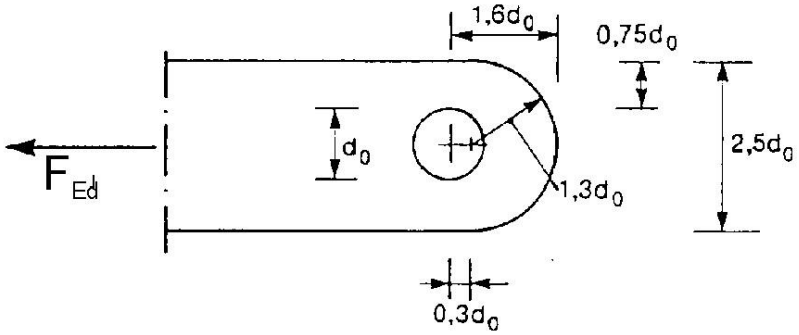
Uporabna klasa 2. → kratko opterećenje→ k_{mod} = 0,90



Prikaz modela s oznakama pločica

5.5.1 Proračun trna i debljine pločica P1 na zglobu

$d_{odabrano}$ =32 mm –promjer trna



Preporučene dimenzije za P1 prema Eurokodu 3

Dimenzije pločice odabiru se prema preporukama sa slike 6.1.2.

Geometrijski uvjeti:

1. $t \geq 0{,}7 \cdot \sqrt{\frac{F_{Ed} \cdot \gamma_{M0}}{f_y}} = 0{,}7 \cdot \sqrt{\frac{157\,630 \cdot 1.0}{355}} = 14{,}75\ \text{mm}$
2. $d_0 \leq 2{,}5\ t$

   $33\ \text{mm} \leq 2{,}5 \cdot 18 = 45\ \text{mm}$

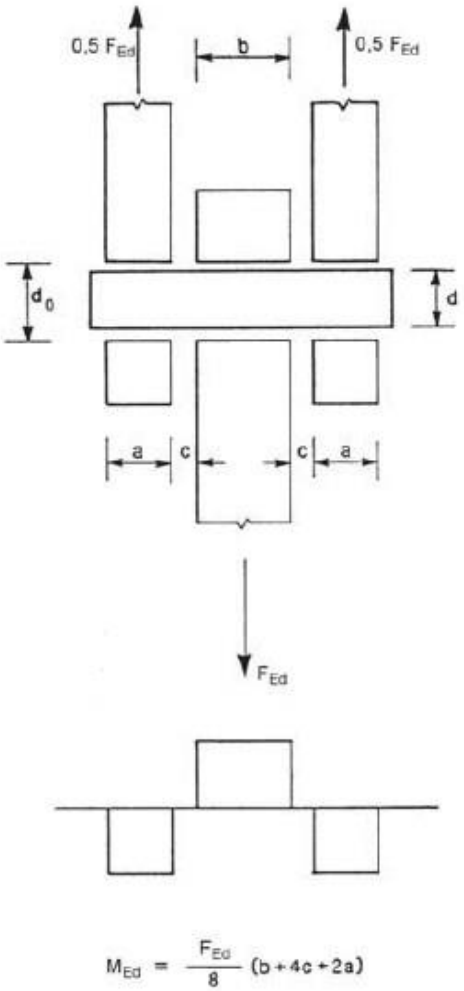
→Uvjeti zadovoljeni→odabrana debljina pločice t=18 mm

Otpornost trna savijanje:

$$M_{b,Rd} = \frac{1{,}5 \cdot W_{el} \cdot f_y}{\gamma_{M0}} = \frac{1{,}5 \cdot 3149{,}60 \cdot 400}{1.0} = 1\,889\,760 \text{ Nmm}$$

$$M_{Ed} = \frac{F_{Ed}}{8} \cdot (b + 4c + 2a) = \frac{157\,630}{8} \cdot (18 + 20 + 36) = 1\,458\,078 \text{ Nmm}$$

Napomena: Moment savijanja izračunat je prema shemi sa slike



Moment savijanja u spajalu

$M_{b,Rd} = 1{,}89 \text{ kNm} > M_{Ed} = 1{,}46 \text{ kNm}$

→Uvjet zadovoljen

Posmična otpornost trna:

$$F_{V,Rd} = \frac{0{,}6 \cdot A \cdot f_{up}}{\gamma_{M2}} = \frac{0{,}6 \cdot 804 \cdot 490}{1{,}25} = 189\,100 \text{ N} = 189{,}10 \text{ kN}$$

$F_{V,Ed} = 56{,}68 \text{ kN}$

$F_{V,Rd} > F_{V,Ed}$ → Uvjet zadovoljen

Interakcija M+V:

$$\left(\frac{M_{Ed}}{M_{Rd}}\right)^2 + \left(\frac{F_{V,Ed}}{F_{V,Rd}}\right)^2 \leq 1$$

$$\left(\frac{1,46}{1,89}\right)^2 + \left(\frac{56,68}{189,10}\right)^2 \leq 1$$

$$0,69 \leq 1$$

Pritisak po omotaču rupe:

$$F_{b,Rd} = \frac{1,5 \cdot t \cdot d \cdot f_y}{\gamma_{M0}} = \frac{1,5 \cdot 18 \cdot 32 \cdot 355}{1,0} = 306\,720\ \text{N} = 306,72\ \text{kN}$$

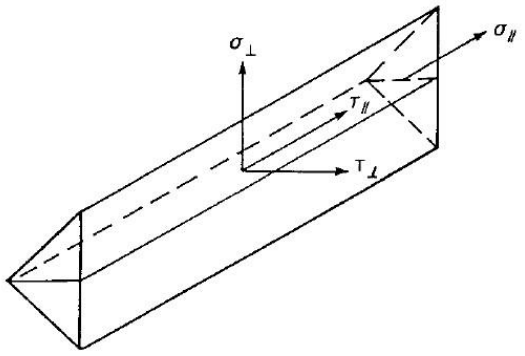
$$F_{b,Ed} = 157,63\ \text{kN}$$

$F_{b,Rd} > F_{b,Ed}$ → Uvjet zadovoljen

5.5.2 Proračun vara između pločica P1 i P4 direktnom metodom

a=7 mm –debljina vara

L=130 mm –duljina vara



1.uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{157\,630}{7 \cdot 130} = 173,22\ \text{MPa} < 0,9 \cdot \frac{f_u}{\gamma_{M2}} = 0,9 \cdot \frac{490}{1,25} = 352,80\ \text{MPa}$$

→Uvjet zadovoljen

$$\tau_{\parallel} = \frac{V_{Ed} \cdot S}{I \cdot b} = \frac{56\,680 \cdot 14\,788}{1\,281\,583 \cdot 7} = 93,43\ \text{Mpa}$$

$$I = \frac{b \cdot h^3}{12} = \frac{7 \cdot 130^3}{12} = 1\,281\,583\ \text{mm}^4 - \text{moment tromosti}$$

$$S = \frac{130}{2} \cdot 7 \cdot \frac{130}{4} = 14\,788\ \text{mm}^3 - \text{statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{157\,630 \cdot 796,30}{3\,716 \cdot 130} = 259,83\ \text{Mpa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{130 \cdot 7^3}{12} = 3\,716\ \text{mm}^4 - \text{moment tromosti}$$

$$S = 130 \cdot 3.5 \cdot 1.75 = 796.30\ \text{mm}^3 - \text{statički moment površine}$$

2.uvjet:

$$\frac{\left[\sigma_{\perp}^2 + 3\left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)\right]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{\left[\sigma_{\perp}^2 + 3\left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)\right]^{0.5}}{2} = \frac{\left[173{,}22^2 + 3\left(259{,}83^2 + 93{,}43^2\right)\right]^{0.5}}{2} = 254{,}33 \text{ Mpa}$$

$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0{,}9 \cdot 1{,}25} = 435{,}55 \text{ MPa}$$

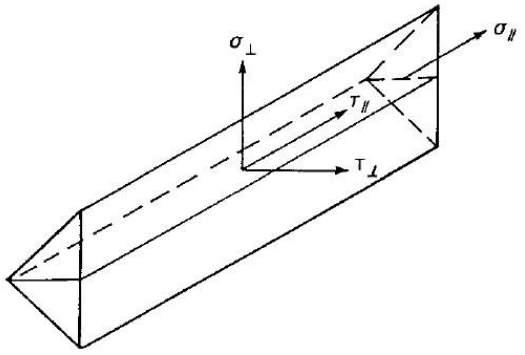
254,33 Mpa < 435,55 Mpa →Uvjet zadovoljen

Napomena:isti var se nalazi između pločica P1 i P5.

5.5.3 Proračun vara između pločica P3 i P4 direktnom metodom

a=6 mm –debljina vara

L=120 mm –duljina vara



1.uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{157\,630}{6 \cdot 120} = 218{,}93 \text{ MPa} < 0{,}9 \cdot \frac{f_u}{\gamma_{M2}} = 0{,}9 \cdot \frac{490}{1{,}25} = 352{,}80 \text{ MPa}$$

→Uvjet zadovoljen

$$\tau_{\parallel} = \frac{V_{Ed} \cdot S}{I \cdot b} = \frac{56\,680 \cdot 10\,800}{864\,000 \cdot 6} = 118{,}08 \text{ Mpa}$$

$$I = \frac{b \cdot h^3}{12} = \frac{6 \cdot 120^3}{12} = 864\,000 \text{ mm}^4 - \text{moment tromosti}$$

$$S = \frac{120}{2} \cdot 6 \cdot \frac{120}{4} = 10\,800 \text{ mm}^3 - \text{statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{157\,630 \cdot 540}{2\,160 \cdot 120} = 328{,}40 \text{ Mpa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{120 \cdot 6^3}{12} = 2\,160 \text{ mm}^4 - \text{moment tromosti}$$

$$S = 120 \cdot 3 \cdot 1.5 = 540 \text{ mm}^3 - \text{statički moment površine}$$

2.uvjet:

$$\frac{\left[\sigma_{\perp}^2 + 3\left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)\right]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{\left[\sigma_{\perp}^2 + 3\left(\tau_{\perp}^2 + \tau_{\parallel}^2\right)\right]^{0.5}}{2} = \frac{\left[218{,}93^2 + 3\left(328{,}4^2 + 118{,}08^2\right)\right]^{0.5}}{2} = 321{,}44 \text{ Mpa}$$

$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0{,}9 \cdot 1{,}25} = 435{,}55 \text{ MPa}$$

321,44 Mpa < 435,55 Mpa →Uvjet zadovoljen

5.5.4 Spoj stupa s pločicama P5 vijcima d = 20 mm

Spoj je dvorezan s debelim pločama kao vanjskim elementima ($t_{PL} > d_{spajala}$)

a = 4d = 4·20 = 80 mm – minimalni razmak trnova u smjeru okomitom na vlakanca grede.

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0{,}3 \cdot f_{uk} \cdot d^{2,6} = 0{,}3 \cdot 500 \cdot 20^{2,6} = 362\,051 \text{ Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{362\,051}{1{,}1} = 329\,137 \text{ Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$f_{h,0,k}$= 0,082·(1-0,01·d)· ρ_k =0,082·(1-0,01·20)· 380 = 24,93 N/mm^2

$$k_{90} = 0{,}9 + 0{,}015 \cdot d = 0{,}9 + 0{,}015 \cdot 20 = 1{,}20$$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

α=90°

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2\alpha + \cos^2\alpha} = \frac{24{,}93}{1.2 \cdot \sin^2 90 + \cos^2 90} = 20{,}78 \text{ N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0{,}90 \cdot \frac{20{,}78}{1{,}25} = 14{,}96 \text{ N/mm}^2$$

Proračunska otpornost jednog vijka:

$$R_d = \min \left\{ \begin{array}{c} 0{,}5 \cdot (f_{h,\alpha,d} \cdot t_2 \cdot d) = 0{,}5 \cdot (14{,}96 \cdot 200 \cdot 20) = 29\,920 \text{ N} \\ 2{,}3 \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} + \frac{F_{ax}}{4} = 2{,}3 \cdot \sqrt{2 \cdot 329\,137 \cdot 14{,}96 \cdot 20} + \frac{F_{ax}}{4} = \\ = 32\,278 + \frac{F_{ax}}{4} = 32\,278 + \frac{32\,278}{4} = 40\,348 \text{ N} \end{array} \right\}$$

$$R_d = 29{,}92 \text{ kN}$$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

-od poprečne sile:

$$F_{Vd} = \frac{V_{Ed}}{n} = \frac{56,68}{8} = 7,09 \text{ Kn}$$

-od uzdužne sile:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{157,63}{8} = 19,7 \text{ kN}$$

Proračunska vrijednost sile koju preuzima 1 vijak:

$$F_d = \sqrt{F_N^2 + F_V^2}$$

$$F_d = \sqrt{7,09^2 + 19,7^2} = 20,93 \text{ kN}$$

$$R_d = 29,92 \text{ kN} > F_d = 20,93 \text{ kN}$$

→Uvjet zadovoljen

$$\eta = \frac{20,93}{29,92} = 0,70$$

Naprezanja na stupu preko pločice P5:

$$f_{b,Ed} \leq k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$

$$f_{b,Ed} = \frac{N_{Ed}}{h \cdot b_{PL}} = \frac{157\ 630}{460\ \cdot 20} = 17,13 \text{ Mpa} < 0,90 \cdot \frac{24}{1,25} = 17,28 \text{ Mpa}$$

→ Uvjet zadovoljen

5.5.5 Proračun sidrenih vijaka za spoj s temeljom preko pločice P6

Vijci M20 kv.5.8.

Otpornost na trenje između pločice i podložnog morta:

$$F_{f,Rd} = C_{f,Rd} \cdot N_{c,Ed} = 0,20 \cdot 157,63 = 31,53 \text{ kN}$$

Posmična otpornost sidrenog vijka:

$$F_{vb,Rd} = \min \begin{Bmatrix} F_{1,vb,Rd} = \frac{\alpha_v \cdot f_{ub} \cdot A}{\gamma_{M2}} = \frac{0,5 \cdot 500 \cdot 314}{1,25} = 62,80 \text{ kN} \\ F_{2,vb,Rd} = \frac{\alpha_v \cdot f_{ub} \cdot A}{\gamma_{M2}} = \frac{0,32 \cdot 500 \cdot 314}{1,25} = 40,19 \text{ kN} \end{Bmatrix}$$

$$\alpha_b = 0,44 - 0,0003 \cdot f_{yb} = 0,44 - 0,0003 \cdot 400 = 0,32$$

Posmična otpornost čelične pločice:

$$F_{V,Rd} = F_{f,Rd} + n \cdot F_{vb,Rd} = 31,53 + 4 \cdot 40,19 = 192,29 \text{ kN} > F_{V,Ed} = 56,68 \text{ kN}$$

→ Uvjet zadovoljen

Računska čvrstoća prionjljivosti vijka:

$f_{b,d} = 2{,}25 \cdot \eta_1 \cdot \eta_2 \cdot f_{ct,d} = 2{,}25 \cdot 1 \cdot 1 \cdot 1 = 2{,}25\ \text{MPa}$

$f_{ct,d} - \text{vlačna čvrstoća betona}$

$$f_{ct,d} = \alpha_{CT} \cdot \frac{f_{ctk,05}}{\gamma_c} = 1 \cdot \frac{1{,}50}{1{,}5} = 1{,}50\ \text{MPa}$$

Duljina sidrenja vijaka:

$$l_{b,rqd} = \frac{d}{4} \cdot \frac{\sigma_{Ed}}{f_{bd}} = \frac{20}{4} \cdot \frac{131{,}57}{2{,}25} = 292\ \text{mm}$$

$$l_{b,odabrano} = 300\ \text{mm}$$

Naprezanje u 1 vijku:

$$\sigma_{Ed} = \frac{N_{Ed}}{A} = \frac{157\,630}{4 \cdot 314} = 125{,}50\ \text{Mpa}$$

Usvojene dimenzije pločice P6: 320x320x40 mm

$$f_{b,Ed} \leq \frac{f_{ck}}{\gamma_C}$$

$$f_{b,Ed} = \frac{N_{Ed}}{h \cdot b_{PL}} = \frac{157\,630}{320\ \cdot 40} = 12{,}32\ \text{Mpa} < \frac{20}{1{,}5} = 13{,}33\ \text{Mpa}$$

→ Uvjet zadovoljen

Debljine pločica

PLOČICA	t_{PL}(mm)
P1	18
P2	10
P3	18
P4	26
P5	20
P6	40
P7	10

6. PRORAČUN TEMELJA

Proračun dimenzija temelja samca.
Dimenzije temelja:1500x1500x1000 mm
Dopušteno naprezanje σ=500 Mpa

N_{sd} =157,63 kN (tlak)

h=100 cm

$$a = \sqrt{\frac{P}{\sigma}} = \sqrt{\frac{157,63}{500}} = 0,56m \Rightarrow$$ odabrano a=1,50 m

Težina temelja:

$$N_t = 1,5 \cdot 1,5 \cdot 1,0 \cdot 25 = 56,25\ [kN]$$

$$N_{Ed} = N'_{Ed} + N_t = 157,63 + 56,25 = 213,88\ kN\ (tlak)$$

Naprezanje ispod temelja:

$$\sigma_{1,2} \leq \sigma_{dop,tla} = 500\ \left(\frac{kN}{m^2}\right)$$

$$\sigma_{1,2} = \frac{N_{Ed}}{A} \pm \frac{M_{Ed}}{W}$$

$$A = 1,5 \cdot 1,5 = 2,25\ \left(m^2\right);$$

$$W = \frac{b \cdot a^2}{6} = \frac{1,5^3}{6} = 0,56\ \left(m^3\right)$$

$$\sigma_{1,2} = \frac{213,88}{2,25}$$

$$\sigma_1 = 95,06\ kN/m^2 < 500\ kN/m^2$$

$$\sigma_2 = 95,06\ kN/m^2 < 500\ kN/m^2$$

7. NACRTI

7.1 PLAN POZICIJA HALE, M 1:100

7.2 PRESJEK KROZ GLAVNI NOSAČ, M 1:50

7.3 DETALJ „A“: SPOJ STUP-TEMELJ, M 1:10

7.4 DETALJ „B“: SPOJ STUP-GREDA, M 1:10

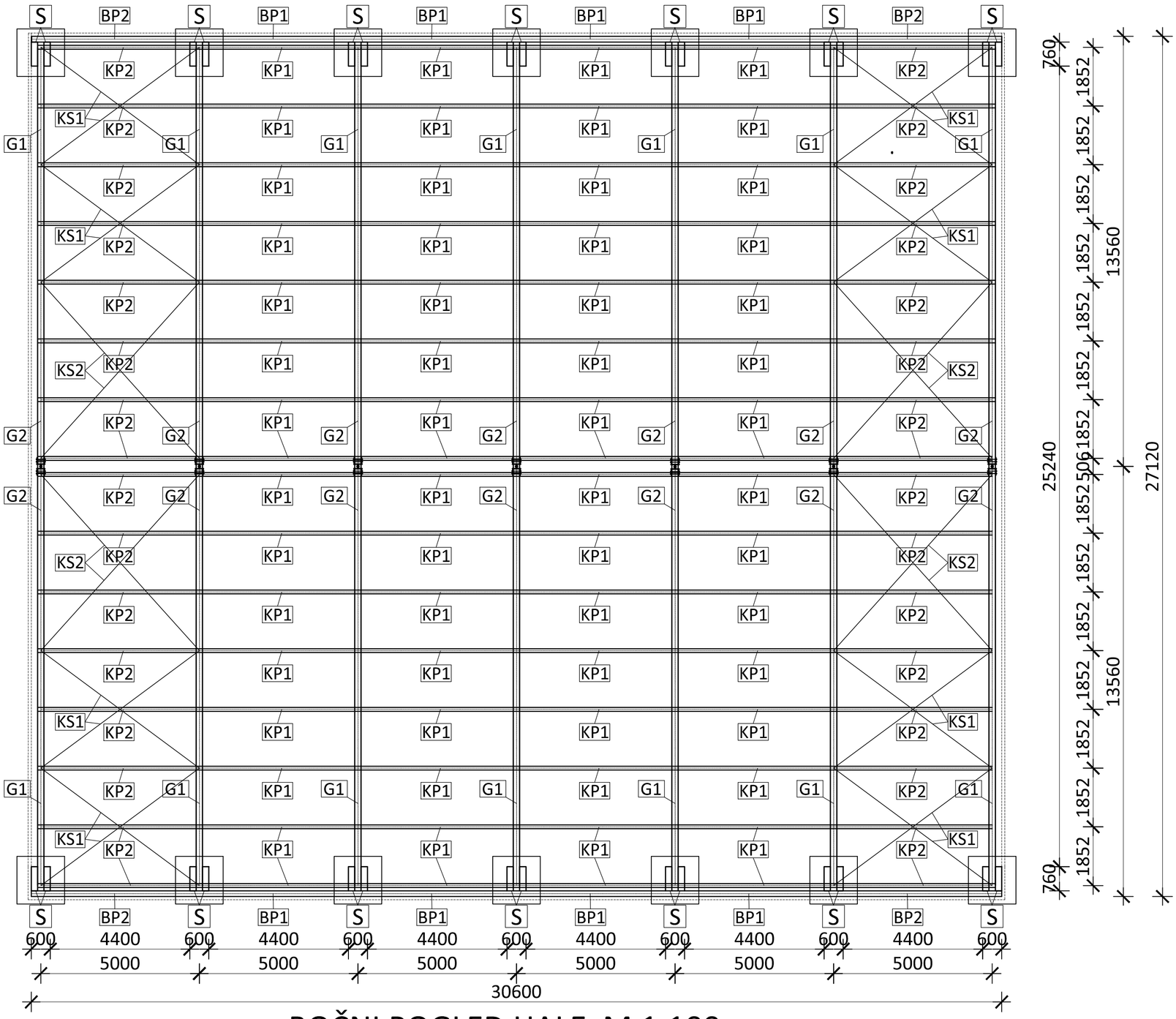
7.5 DETALJ „C“: ZGLOBNI SPOJ DVIJU GREDA, M 1:10

7.6 DETALJ „D“: SPOJ STUP-ZATEGA, M 1:10

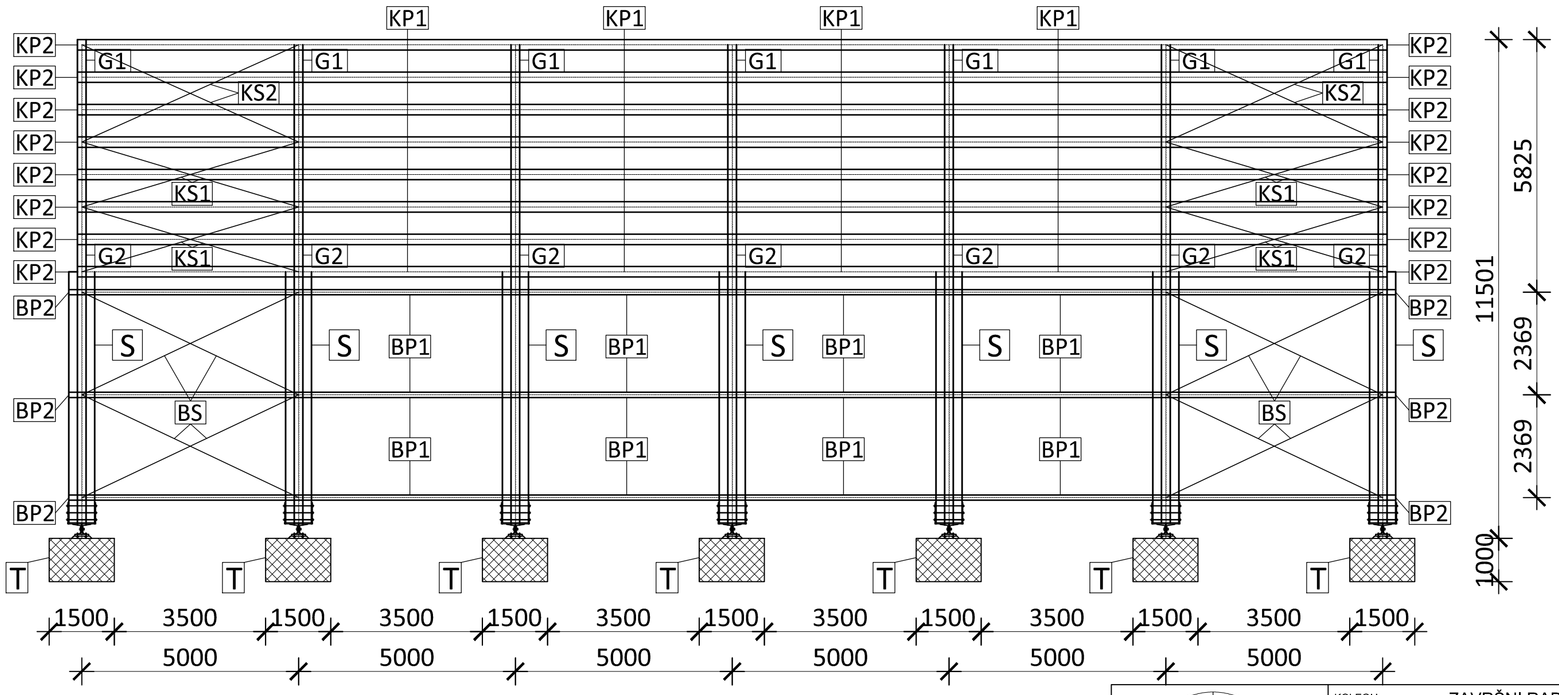
7.7 DETALJ „E“: VLAČNI NASTAVAK GREDE, M 1:10

7.8 ISKAZ MATERIJALA, M 1:50

TLOCRT HALE M 1:100



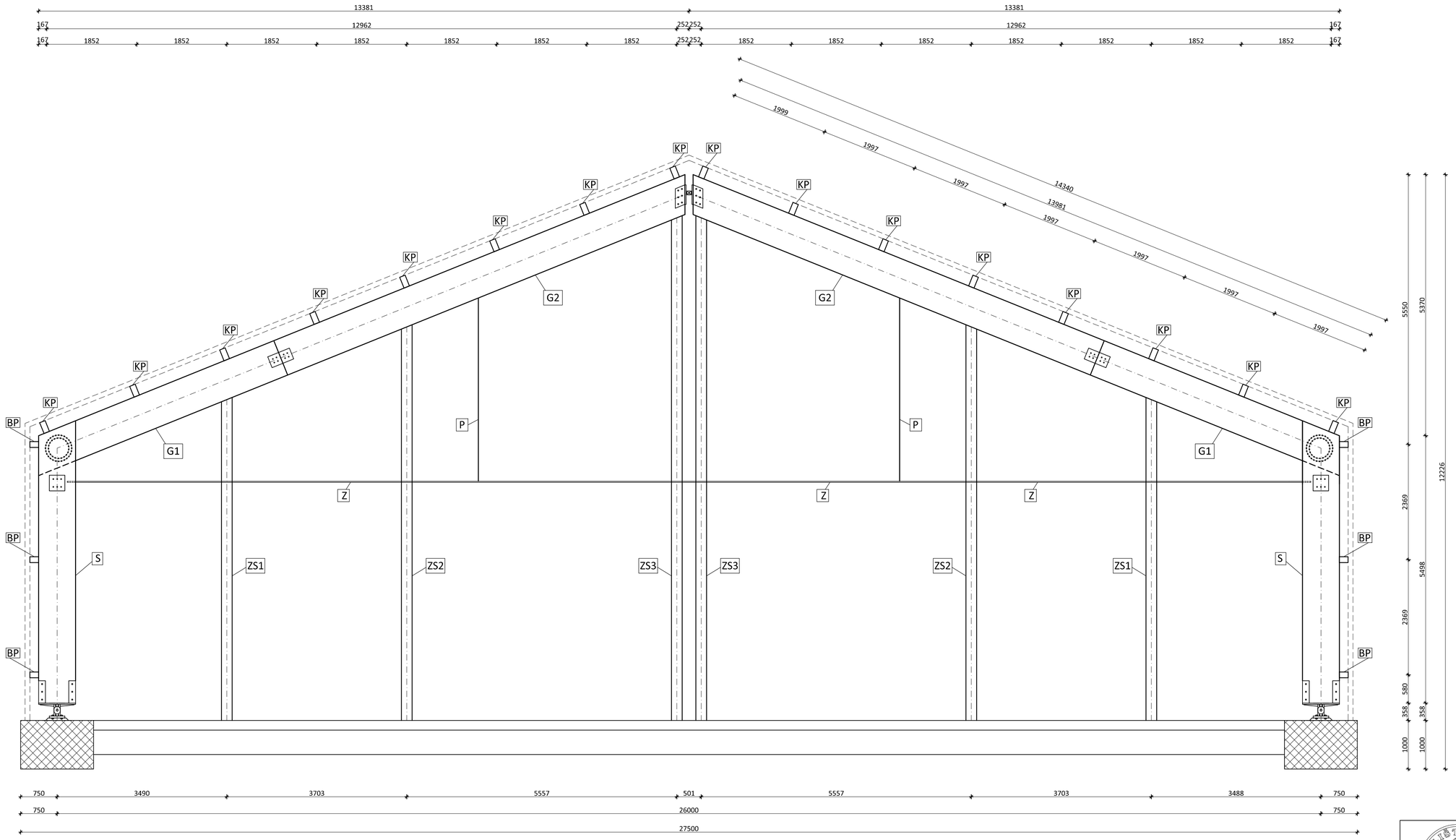
BOČNI POGLED HALE M 1:100



SVEUČILIŠTE U SPLITU
FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
KATEDRA ZA METALNE I DRVENE KONSTRUKCIJE
21000 SPLIT, MATICE HRVATSKE 15

KOLEGIJ:	ZAVRŠNI RAD - ODK
PROGRAM:	KONSTRUKCIJA DRVENE HALE
STUDENT:	NIKICA KRALJEVIĆ, 4347
SADRŽAJ:	PLAN POZICIJA HALE
MJERILO:	1:100
DATUM:	RUJAN 2018.
PRILOG:	1

PRESJEK KROZ GLAVNI NOSAČ
M 1:50

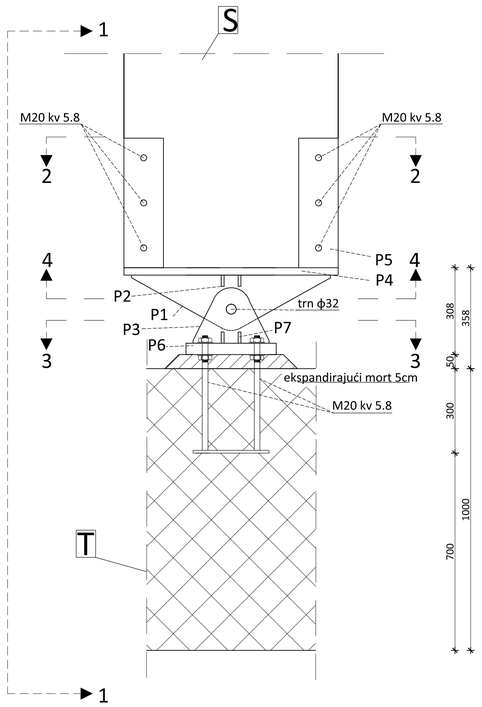


KOLEGIJ:	ZAVRŠNI RAD - ODK
PROGRAM:	KONSTRUKCIJA DRVENE HALE
STUDENT:	NIKICA KRALJEVIĆ, 4347
SADRŽAJ:	PRESJEK KROZ GLAVNI NOSAČ
MJERILO:	1:50
DATUM:	RUJAN 2018.
PRILOG:	2

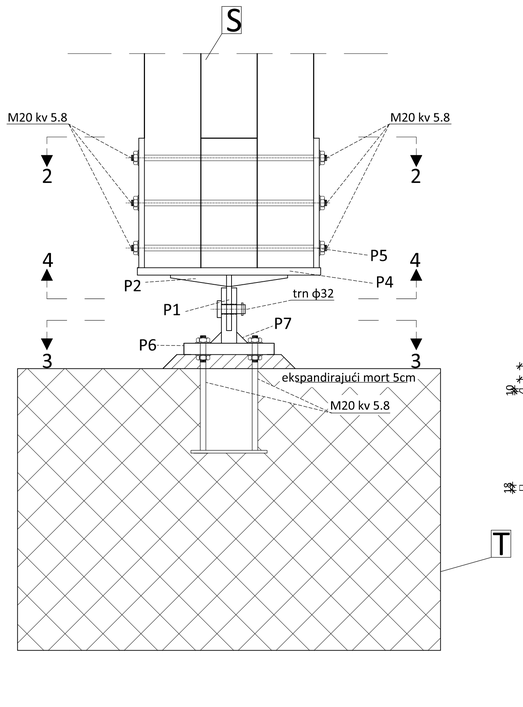
FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
KATEDRA ZA METALNE I DRVENE KONSTRUKCIJE
21000 SPLIT, MATICE HRVATSKE 15

DETALJ "A"
M 1:10

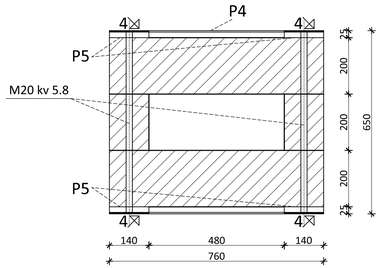
DETALJ "A"



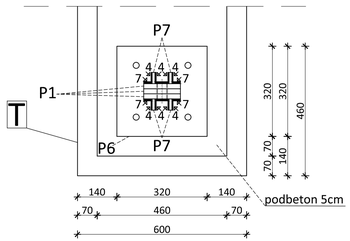
POGLED 1-1



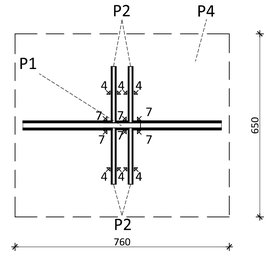
PRESJEK 2-2



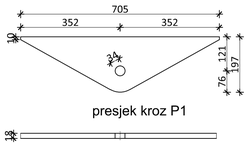
PRESJEK 3-3



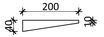
PRESJEK 4-4



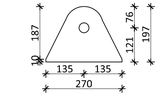
P1 S355 1 kom po spoju



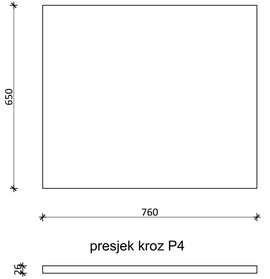
P2 200/40/10 S355
kom. 4 po spoju



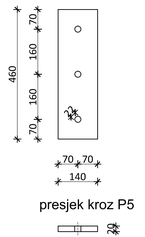
P3 S335 2 kom. po spoju



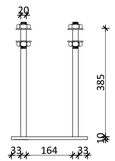
P4 760/620/26 S355
1 kom. po spoju



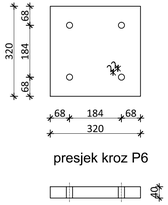
P5 140/460/20 S355
4 kom. po spoju



SIDRENI VIJCI M2O kv.5.8



P6 320/320/40 S355
1 kom. po spoju



P7 30/40/10 S355
kom. 4 po spoju



FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
KATEDRA ZA METALNE I DRVENE KONSTRUKCIJE
21000 SPLIT, MATICE HRVATSKE 15

ZAVRŠNI RAD - ODK

PROGRAM: KONSTRUKCIJA DRVENE HALE

STUDENT: NIKICA KRALJEVIĆ, 4347

SADRŽAJ: DETALJ "A"

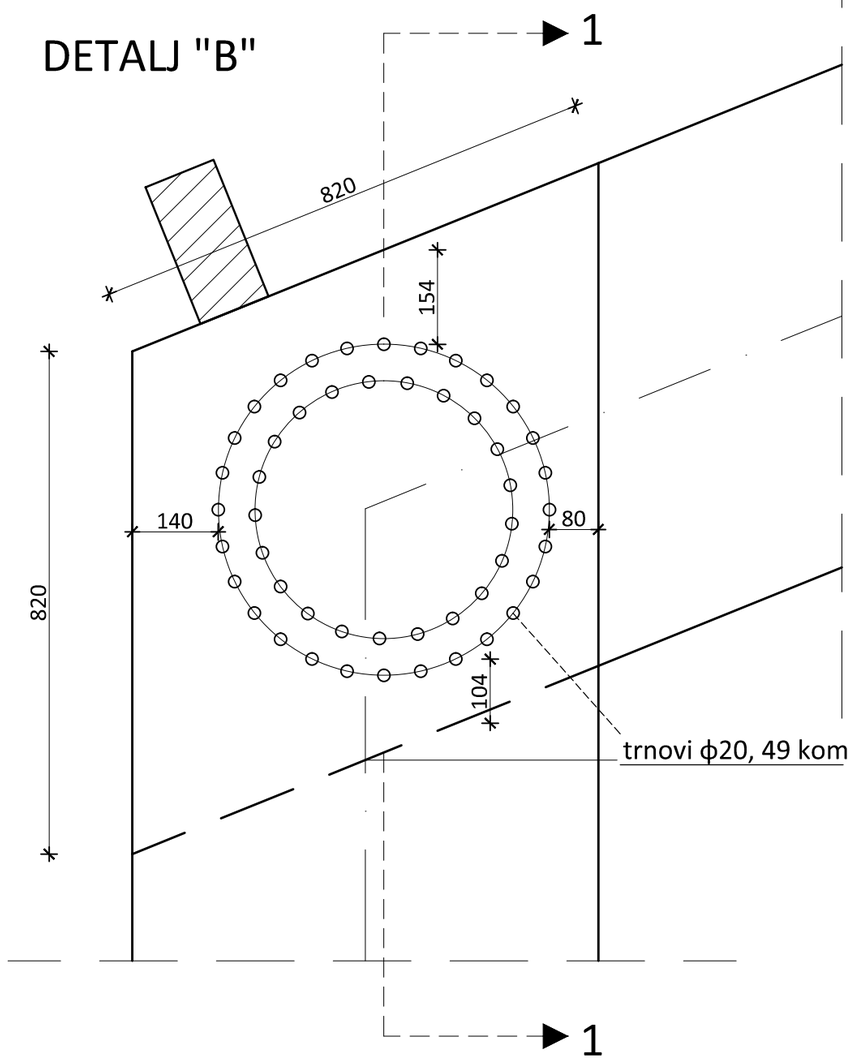
MJERILO: 1:10

RUJAN 2018.

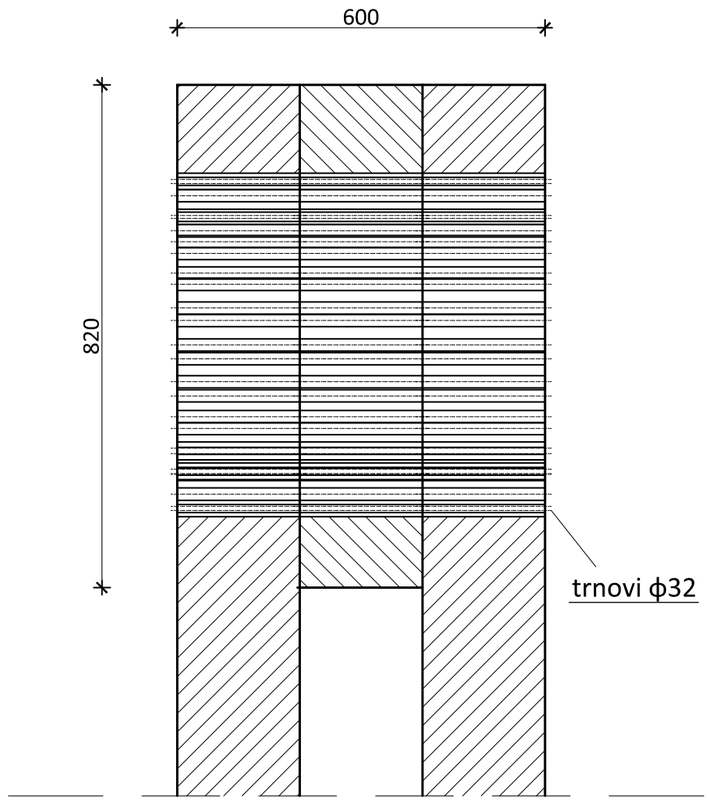
3

DETALJ "B"
M 1:10

DETALJ "B"



POGLED 1-1



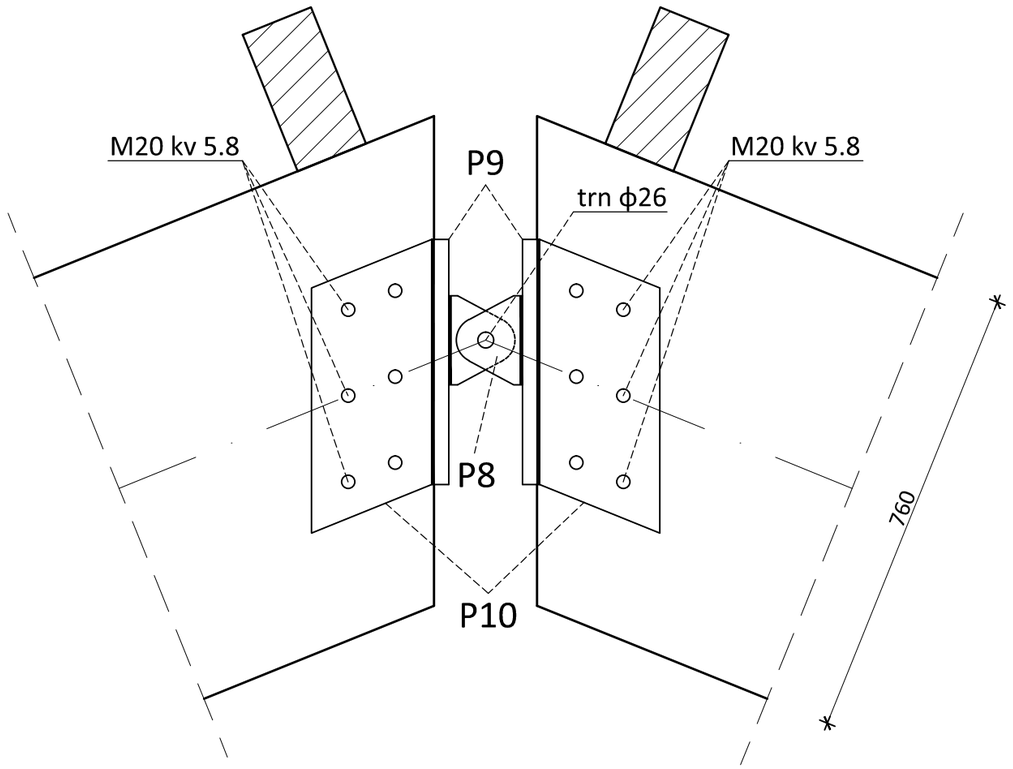
SVEUČILIŠTE U SPLITU

FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
KATEDRA ZA METALNE I DRVENE KONSTRUKCIJE
21000 SPLIT, MATICE HRVATSKE 15

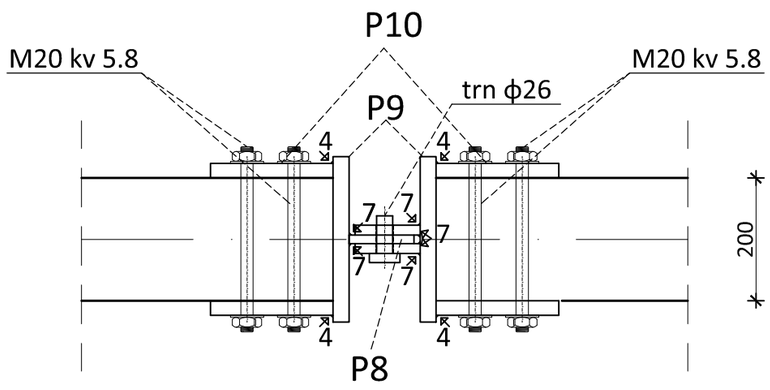
ZAVRŠNI RAD - ODK		
PROGRAM: KONSTRUKCIJA DRVENE HALE		
STUDENT: NIKICA KRALJEVIĆ, 4347		
SADRŽAJ: DETALJ "B"	MJERILO:	1:10
RUJAN 2018.		4

DETALJ "C"
M 1:10

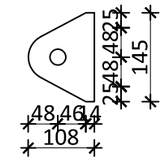
DETALJ "C"



TLOCRT



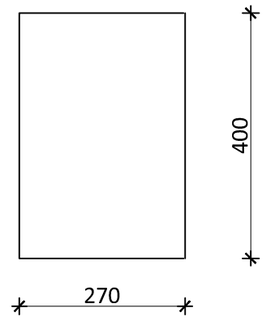
P8 S355 3 kom. po spoju



presjek kroz P8



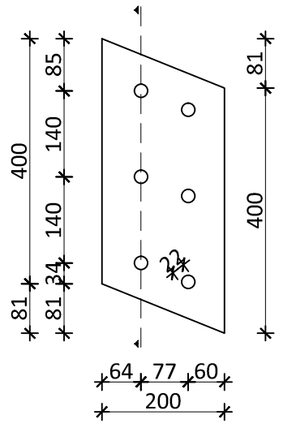
P9 270/400/26 S355
2 kom. po spoju



presjek kroz P9



P10 170/400/26 S355
4 kom. po spoju



presjek kroz P10



FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
KATEDRA ZA METALNE I DRVENE KONSTRUKCIJE
21000 SPLIT, MATICE HRVATSKE 15

ZAVRŠNI RAD - ODK

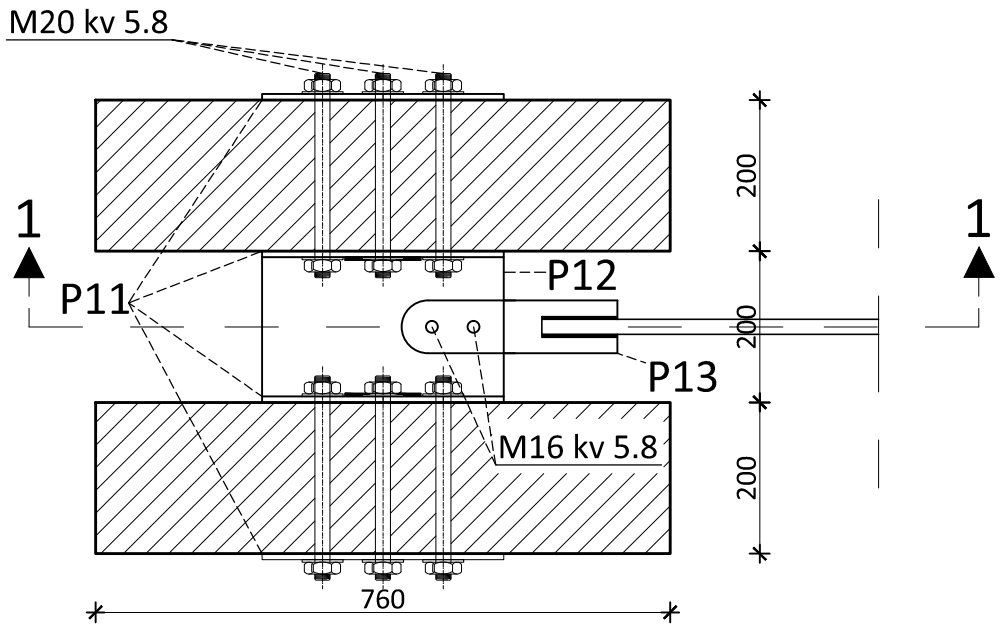
PROGRAM: KONSTRUKCIJA DRVENE HALE

STUDENT: NIKICA KRALJEVIĆ, 4347

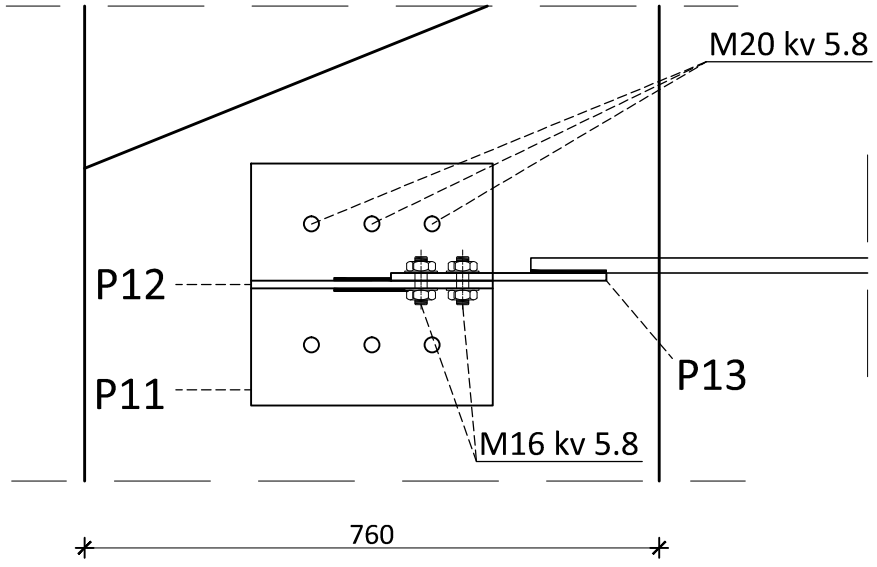
SADRŽAJ: DETALJ "C" | MJERILO: 1:10

RUJAN 2018. | 5

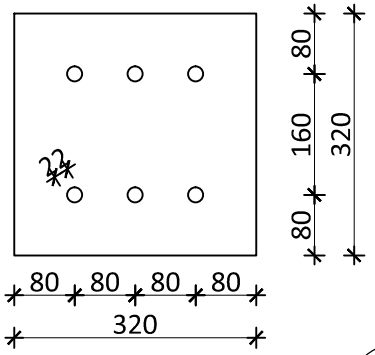
DETALJ "D"



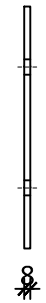
POGLED 1-1



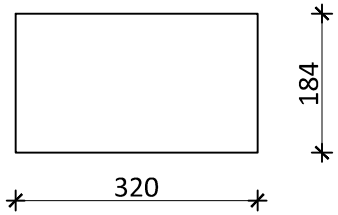
P11 320/320/8 S355
4 kom. po spoju



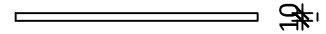
presjek kroz P14



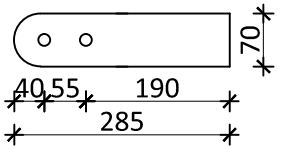
P12 320/184/10 S355
1 kom. po spoju



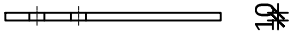
presjek kroz P12



P11 285/70/10 S355
1 kom. po spoju



presjek kroz P11



FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
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ZAVRŠNI RAD - ODK

PROGRAM: KONSTRUKCIJA DRVENE HALE

STUDENT: NIKICA KRALJEVIĆ, 4347

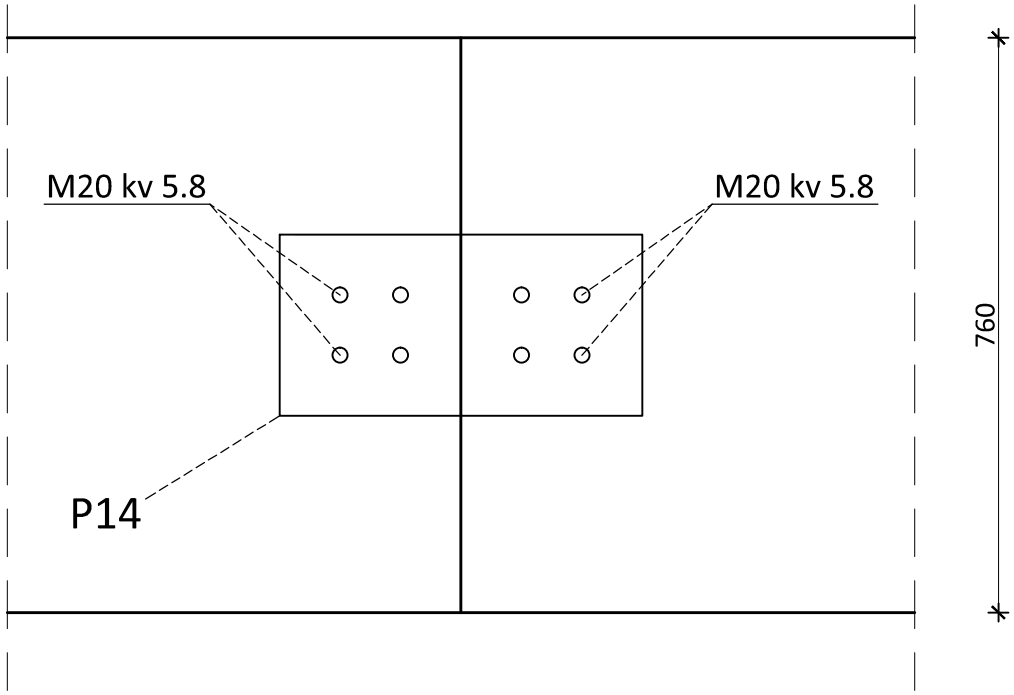
SADRŽAJ: DETALJ "A"

MJERILO: 1:10

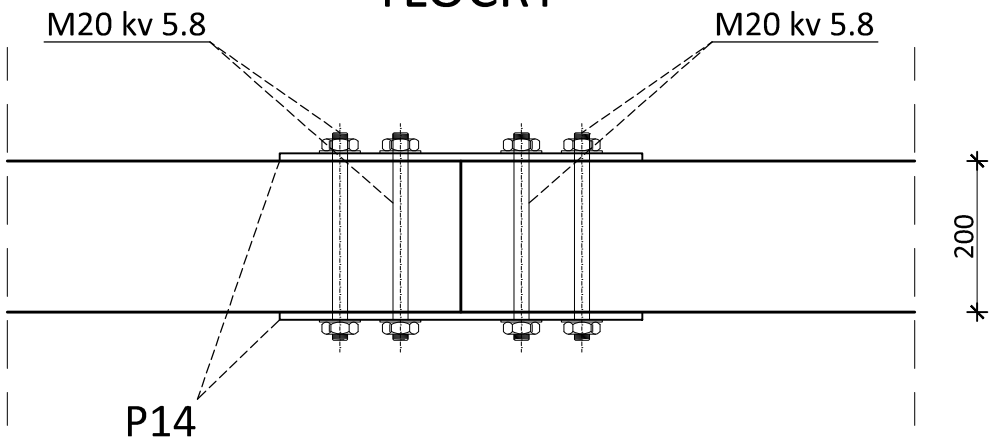
RUJAN 2018.

6

DETALJ "E"

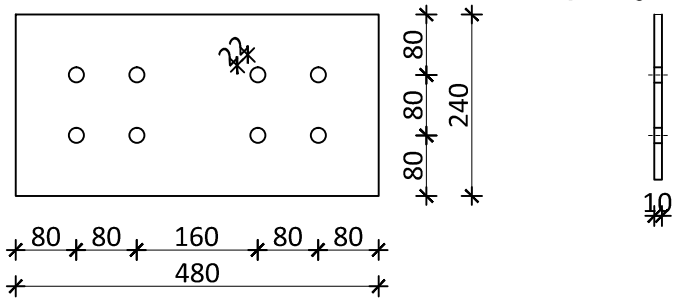


TLOCRT



presjek kroz P14

P14 480/240/10 S355
2 kom. po spoju



SVEUČILIŠTE U SPLITU

FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
KATEDRA ZA METALNE I DRVENE KONSTRUKCIJE
21000 SPLIT, MATICE HRVATSKE 15

ZAVRŠNI RAD - ODK		
PROGRAM: KONSTRUKCIJA DRVENE HALE		
STUDENT: NIKICA KRALJEVIĆ, 4347		
SADRŽAJ: DETALJ "E"		MJERILO: 1:10
RUJAN 2018.		7

ISKAZ MATERIJALA M 1:50

SEKUNDARNI NOSAČI NA KROVU

Poprečni presjek

KP1 — 5000

KP2 — 5100

240 × 240

ZABATNI STUP

Poprečni presjek

ZS1	6555	6644	89	600 × 220
ZS2	8051	8140	89	600 × 220
ZS3	10295	10384	89	600 × 220

SEKUNDARNI BOČNI NOSAČI

Poprečni presjek

BP1 — 5000

BP2 — 5300

180 × 120

DIJAGONALE SPREGOVA

Poprečni presjek

KS1 — 6222

KS2 — 7477

BS — 5533

15

ZATEGA I PRIDRŽANJE

Poprečni presjek

Z — 8526

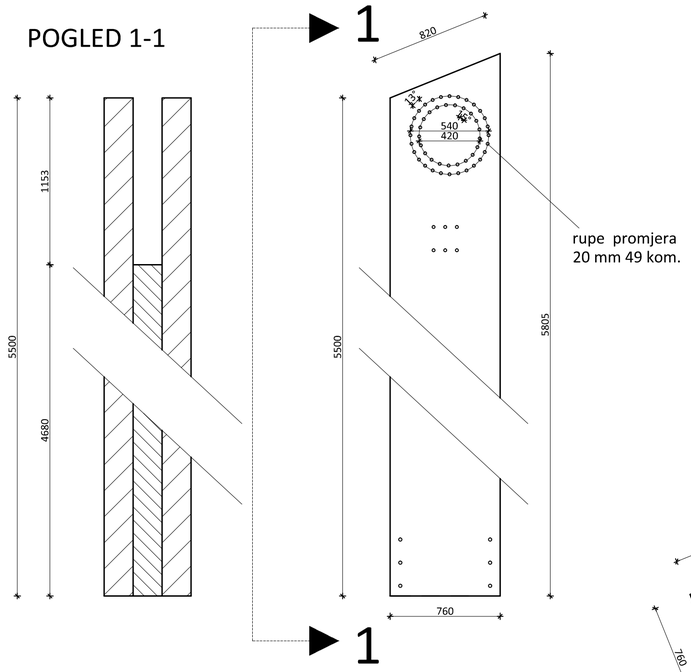
20

P — 3774

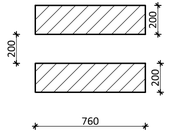
10

S -STUP GLAVNOG OKVIRA M 1:25

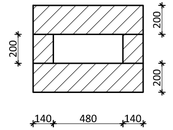
POGLED 1-1



-Poprečni presjek na vrhu stupa:

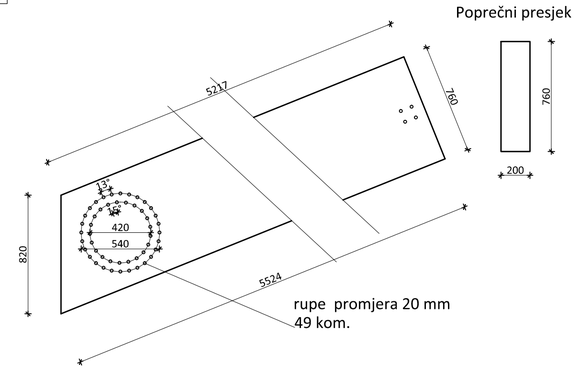


-Poprečni presjek na dnu stupa:



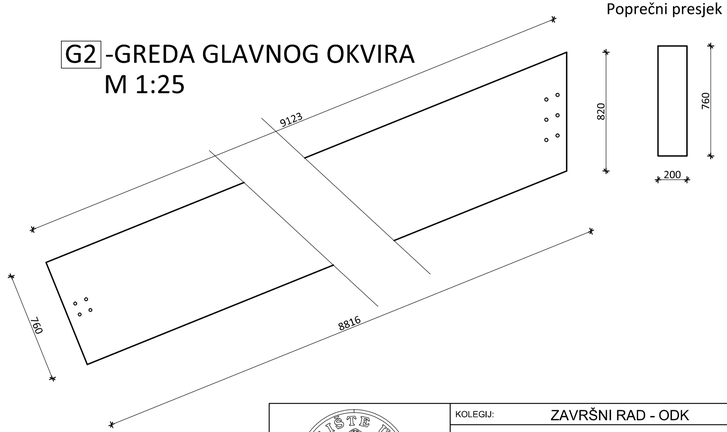
G1 -GREDA GLAVNOG OKVIRA M 1:25

Poprečni presjek



G2 -GREDA GLAVNOG OKVIRA M 1:25

Poprečni presjek



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PROGRAM:	KONSTRUKCIJA DRVENE HALE
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SADRŽAJ:	ISKAZ MATERIJALA
MJERILO:	1:50
DATUM:	RUJAN 2018.
PRILOG:	8

8. LITERATURA

A. Bjelanović, V. Rajčić: DRVENE KONSTRUKCIJE PREMA EUROPSKIM NORMAMA

doc. dr. sc. Neno Torić: ODK-predavanja, vježbe i rješeni zadaci