

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 nacрте. 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 characteristic details and make shop drawings. The hall has floor plan dimensions of 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**

KANDIDAT: Nikica Kraljević

BROJ INDEKSA: 4347

KATEDRA: Katedra za metalne i drvene konstrukcije

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 $\alpha = 22^\circ$. Konstrukcija je zamišljena kao okvirni sustav od 7 jednakih okvira razmaknutih za 5,0 m. Statički 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 G124h. 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 djelovanja na konstrukciju napravljena je u skladu sa EUROCODE 1.

1.6 Antikorozivna zaštita

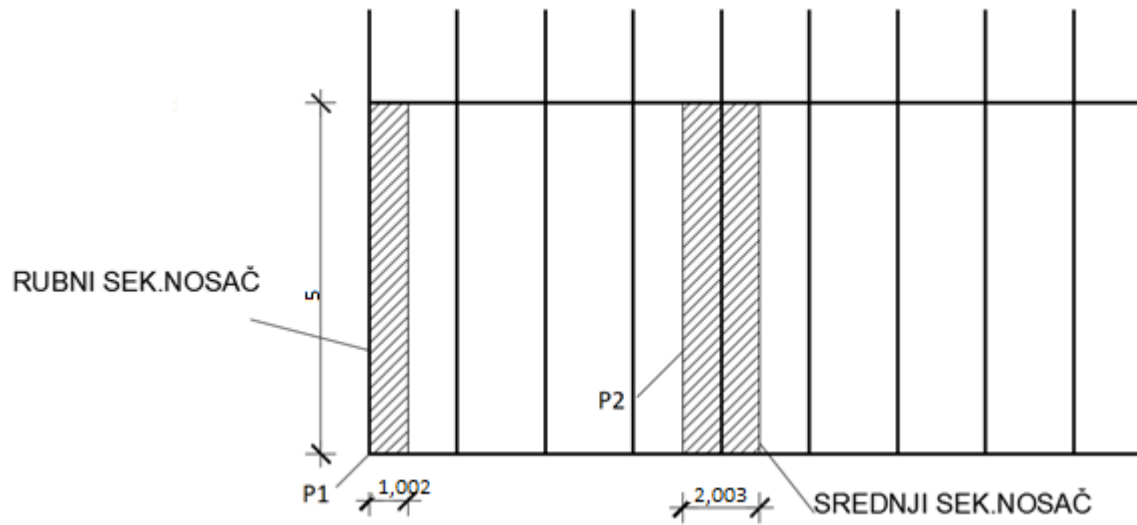
Svi dijelovi spojnih sredstava izrađeni od čelika moraju biti zaštićeni od korozije prema odredbama "Pravilnika o tehničkim mjerama i uvjetima za zaštitu čeličnih konstrukcije od korozije". Odabrana je zaštita vrućim pocinčavanjem i zaštitnim premazom. Ukupna debljina zaštitnog sloja je 200 µm.

1.7 Protupožarna zaštita

Kako bi se spriječilo prerano zagrijavanje nosivih elemenata konstrukcije prilikom požara, svi takvi elementi moraju se zaštititi 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 $g = 0,25 \text{ kN/m}^2$

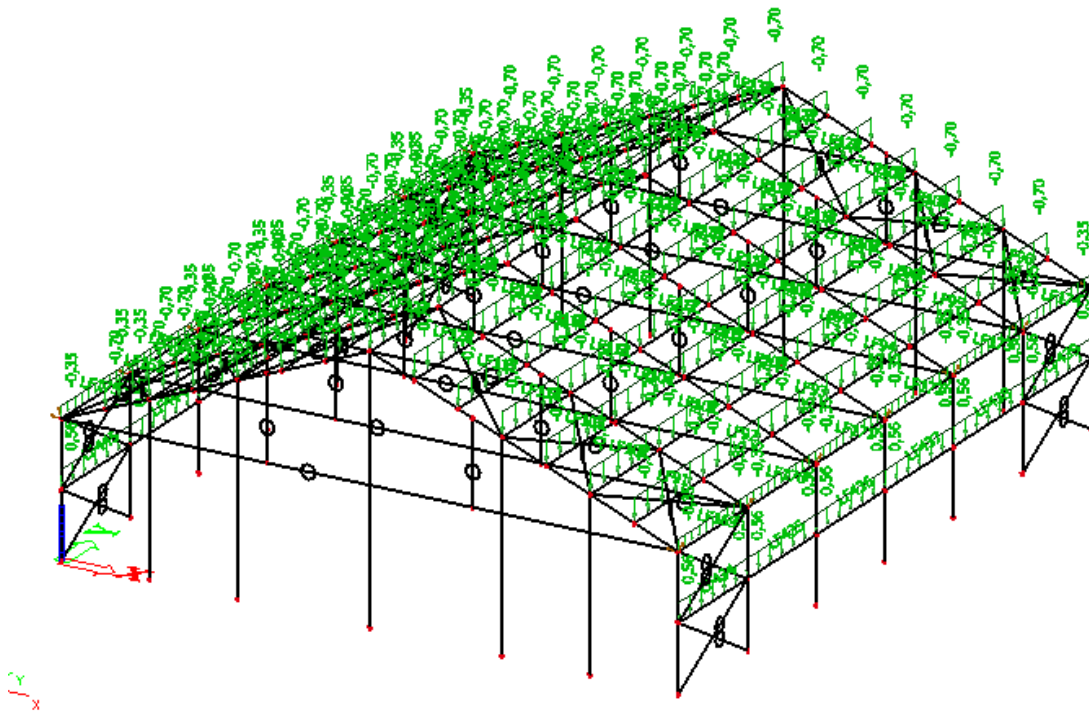
- instalacije $g = 0,1 \text{ kN/m}^2$

- vlastita težina –dodana u sklopu računalnog programa

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

| DODATNO STALNO OPTEREĆENJE NA KROV Δg | | | | |
|---|--------------------|---------------------------------|-------|-------------------|
| NOSAČ | UTJECAJNA POVRŠINA | Δg (kN/m ²) | 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/m ²) | 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 $0^\circ \leq \alpha \leq 30^\circ \Rightarrow \mu_1 = 0,8$

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

zona Zagreba, područje 3. (kontinentalna Hrvatska), nadmorska visina do 100 m

$\Rightarrow s_k = 1,00 kN/m^2$



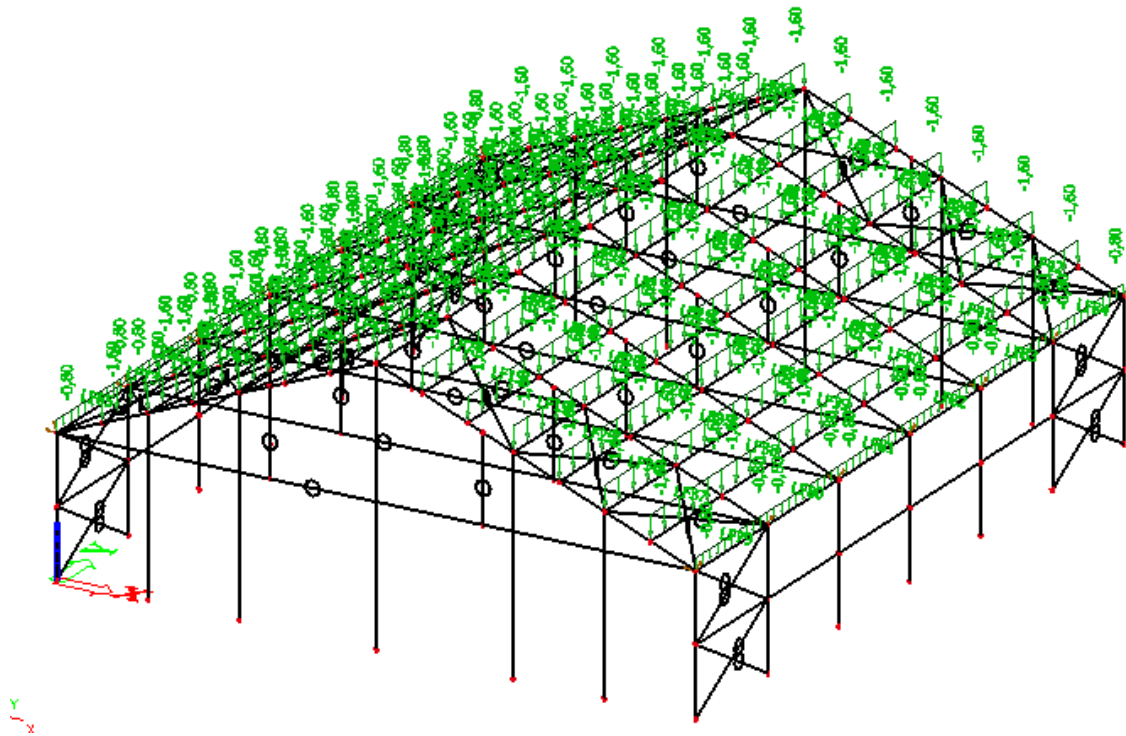
Slika 2.1.. Karta područja za opterećenja snijegom

- C_e - koef. izloženosti $\Rightarrow C_e = 1,0$

- C_t - toplinski koef. $\Rightarrow C_t = 1,0$

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

| OPTEREĆENJE SNIJEGOM S | | | | |
|------------------------|--------------------|------------------------|-------|----------|
| NOSAČ | UTJECAJNA POVRŠINA | S (kN/m ²) | 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/m²]
- pritisak vjetra na unutarnje površine: $w_i = q_p * c_e(z_i) * c_{pi}$ [kN/m²]

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

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

gdje je:

v_b – osnovna brzina vjetra

ρ – gustoća zraka ($\rho = 1,25 \text{ kg/m}^3$)

Osnovna brzina vjetra v_b , dana je izrazom:

$$v_b = C_{dir} \cdot C_{season} \cdot v_{b0}$$

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:

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

očitano za Zagreb

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

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

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

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

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:

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

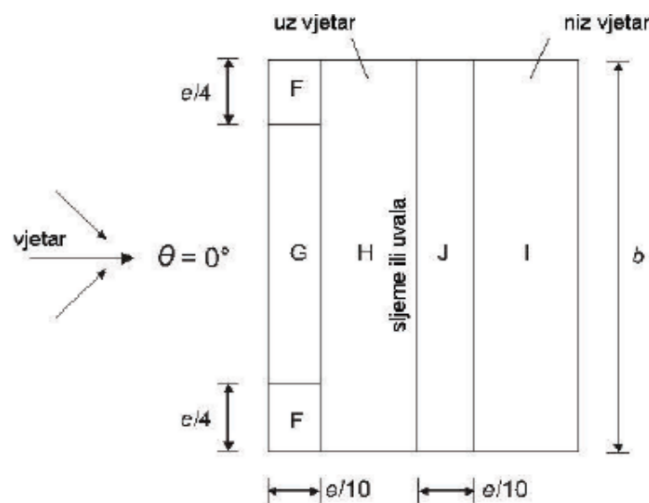
Intezitet turbulencije:

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

Pritisak brzine vjetra pri udaru:

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

Određivanje pritiska na halu za područja dvostrešnog krova $\Theta=0$



Rezultirajuće djelovanje vjetra za dvostrešni krov

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

Koeficijenti vanjskog pritiska na halu s krovom nagiba $\alpha = 22^\circ$ za područja dvostrešnog krova $\Theta=0$ dobiveni su interpolacijom između vrijednosti za 15° i 30° .

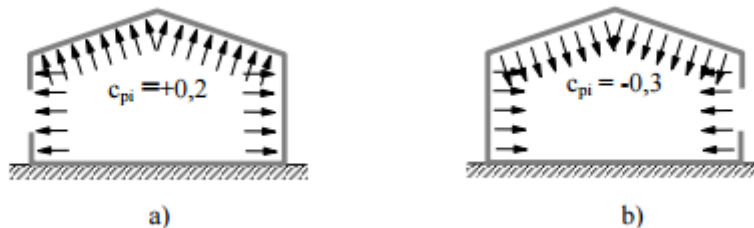
| Nagib α | Područje za smjer vjetra $\theta = 0^\circ$ | | | | | | | | | |
|----------------|---|------------|-------------|------------|-------------|------------|-------------|------------|-------------|------------|
| | F | | G | | H | | I | | J | |
| | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ | $c_{pe,10}$ | $c_{pe,1}$ |
| -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 | |
| | | | | | | | -0,5 | | -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 $\theta = 0^\circ$ tlak se naglo mijerja između pozitivnih i negativnih vrijednosti na strani uz vjetar oko kuta $\alpha = -5^\circ$ do $+45^\circ$, stoga su navedene i pozitivne i negativne vrijednosti. Za takva krovove treba uzeti u obzir slučaj gdje su najmanje vrijednosti u svih područja F, G i H kombinirane s najvećim ili najmanjim vrijednostima područja I i J. Nije dopušteno mješanje 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 $\alpha = -5^\circ$ i $\alpha = +5^\circ$ 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 ($\theta=0$)

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



Koeficijenti unutarnjeg tlaka

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

| Područje | $q_p(\text{kN/m}^2)$ | c_{pe} | $W_{e1}(\text{kN/m}^2)$ |
|----------|----------------------|----------|-------------------------|
| 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 | $q_p(\text{kN/m}^2)$ | c_{pi} | $W_{e2}(\text{kN/m}^2)$ |
|----------|----------------------|----------|-------------------------|
| 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/m²]

| Područje | q_p (kN/m ²) | c_{pi} | W_{i1} (kN/m ²) |
|----------|----------------------------|----------|-------------------------------|
| 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/m ²) | c_{pi} | W_{i2} (kN/m ²) |
|----------|----------------------------|----------|-------------------------------|
| 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/m ²) | | | | |
|--|---------------------------|---------------------------|---------------------------|---------------------------|
| Područje | Vjetar 1= $W_{e1}+W_{i1}$ | Vjetar 2= $W_{e1}+W_{i2}$ | Vjetar 3= $W_{e2}+W_{i1}$ | Vjetar 4= $W_{e2}+W_{i2}$ |
| 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:

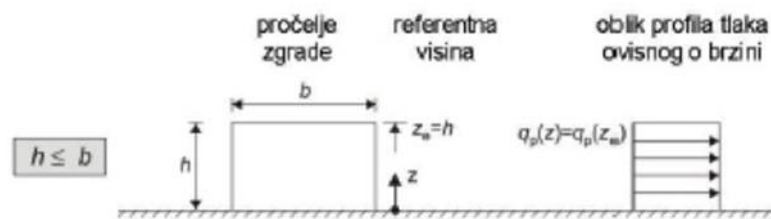
| REZULTIRAJUĆE DJELOVANJE ZA VJETAR 1 (odižući) | | | |
|--|---------------------|------------|---------------------|
| PODROŽNICA | OPTEREĆENJE (kN/m') | PODROŽNICA | OPTEREĆENJE (kN/m') |
| 1 | -0,22 | 9 | -0,30 |
| 2 | -0,37 | 10 | -0,50 |
| 3 | -0,28 | 11 | -0,36 |
| 4 | -0,28 | 12 | -0,36 |
| 5 | -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

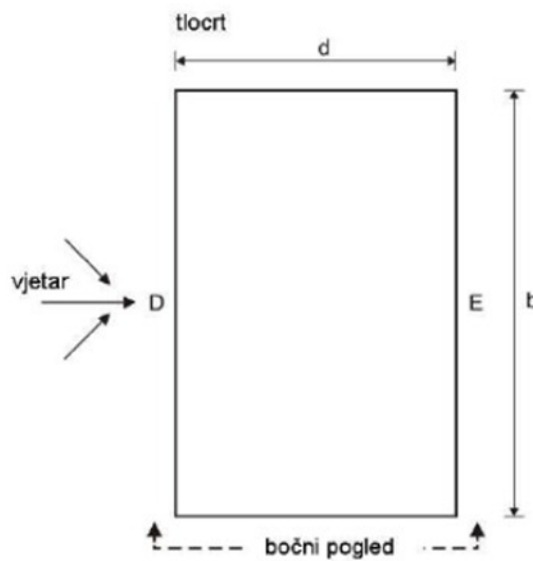
| REZULTIRAJUĆE DJELOVANJE ZA VJETAR 4 (pritiskajući) | | | |
|---|---------------------|------------|---------------------|
| PODROŽNICA | OPTEREĆENJE (kN/m') | PODROŽNICA | OPTEREĆENJE (kN/m') |
| 1 | 0,22 | 9 | 0,09 |
| 2 | 0,41 | 10 | 0,18 |
| 3 | 0,36 | 11 | 0,18 |
| 4 | 0,36 | 12 | 0,18 |
| 5 | 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 odgovarajuća raspodjela tlaka



Djelovanje vjetra na vertikalne zidove

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

| Područje | $q_p(\text{kN/m}^2)$ | c_{pe} | $W_e(\text{kN/m}^2)$ |
|----------|----------------------|----------|----------------------|
| D | 0,306 | 0,733 | 0,224 |
| E | 0,306 | -0,367 | -0,112 |

Pritisak vjetra na vanjske površine

| Područje | $q_p(\text{kN/m}^2)$ | c_{pi} | $W_{i1}(\text{kN/m}^2)$ |
|----------|----------------------|----------|-------------------------|
| D | 0,306 | 0,20 | 0,061 |
| E | 0,306 | 0,20 | 0,061 |

| Područje | $q_p(\text{kN/m}^2)$ | c_{pi} | $W_{i2}(\text{kN/m}^2)$ |
|----------|----------------------|----------|-------------------------|
| D | 0,306 | -0,30 | -0,092 |
| E | 0,306 | -0,30 | -0,092 |

Pritisak vjetra na unutarnje površine

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

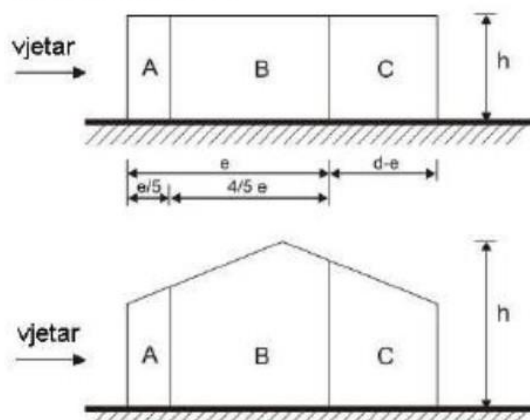
Prikaz rezultirajućeg djelovanja vjetra ($V(\text{kN/m}^2)$)

| 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 ($\text{kN/m}'$)

Djelovanje vjetra na zabatni zid :

bočni pogled za $e < d$



Prikaz područja djelovanja za zabatne zidove

| Područje | $q_p(\text{kN/m}^2)$ | c_{pe} | $W_e(\text{kN/m}^2)$ |
|----------|----------------------|----------|----------------------|
| 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 | $q_p(\text{kN/m}^2)$ | c_{pi} | $W_{i1}(\text{kN/m}^2)$ |
|----------|----------------------|----------|-------------------------|
| A | 0,306 | 0,2 | 0,061 |
| B | 0,306 | 0,2 | 0,061 |
| C | 0,306 | 0,2 | 0,061 |
| Područje | $q_p(\text{kN/m}^2)$ | c_{pi} | $W_{i2}(\text{kN/m}^2)$ |
| A | 0,306 | -0,3 | -0,092 |
| B | 0,306 | -0,3 | -0,092 |
| C | 0,306 | -0,3 | -0,092 |

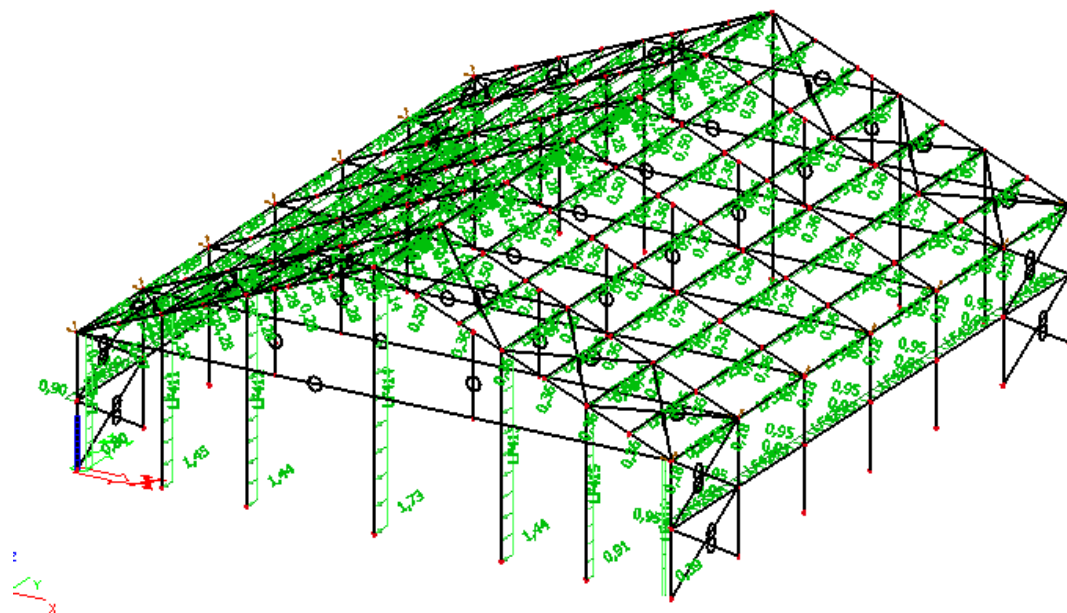
Prikaz djelovanja na unutarnje površine

| REZULTIRAJUĆE DJELOVANJE VJETRA(kN/m^2) | | | | |
|--|-----------|--------------|-----------|--------------|
| 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 |

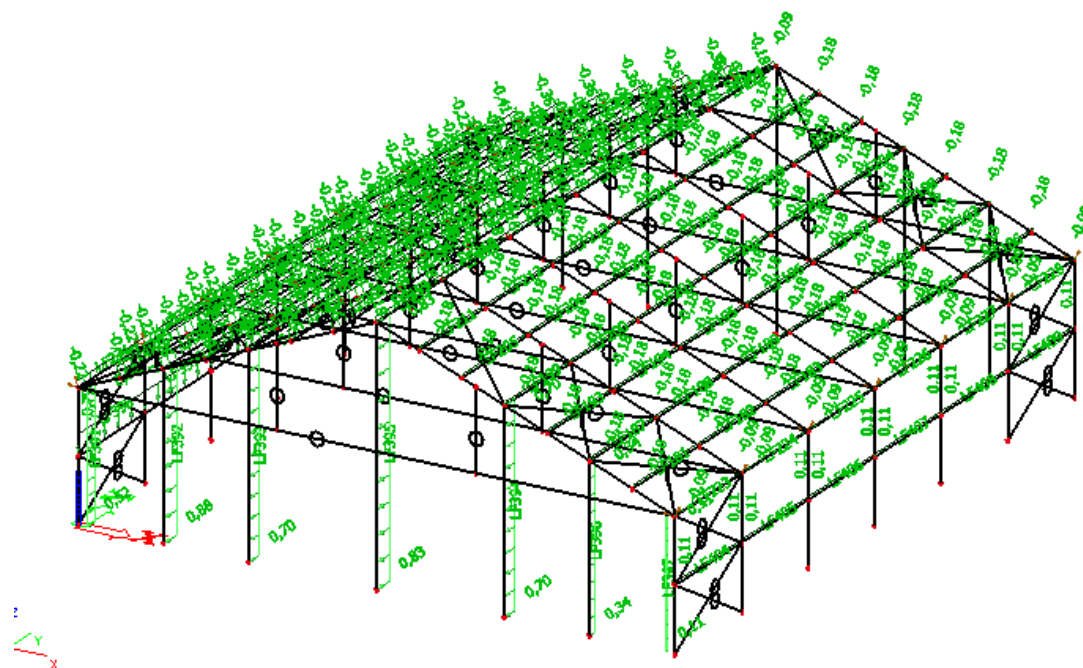
Prikaz rezultirajućeg djelovanja vjetra

| REZULTIRAJUĆE DJELOVANJE VJETRA NA STUPOVE | | | |
|--|-------|---------------------|-------|
| ODIŽUĆI VJETAR ($\text{kN/m}'$) | | 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 odizujućim 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

| | | |
|-----|--------------------------------|---------------------|
| CO1 | Name | CO1 |
| CO2 | Description | |
| CO3 | Type | Envelope - ultimate |
| CO4 | Contents of combination | |
| | tezina [-] | 1,35 |
| | stalno [-] | 1,35 |
| | snijeg [-] | 1,50 |

| | | |
|-----|--------------------------------|---------------------|
| CO1 | Name | CO2 |
| CO2 | Description | |
| CO3 | Type | Envelope - ultimate |
| CO4 | Contents of combination | |
| | tezina [-] | 1,35 |
| | stalno [-] | 1,35 |
| | vjetar p [-] | 1,50 |

| | | |
|-----|--------------------------------|---------------------|
| CO1 | Name | CO3 |
| CO2 | Description | |
| CO3 | Type | Envelope - ultimate |
| CO4 | Contents of combination | |
| | tezina [-] | 1,00 |
| | stalno [-] | 1,00 |
| | vjetar o [-] | 1,50 |

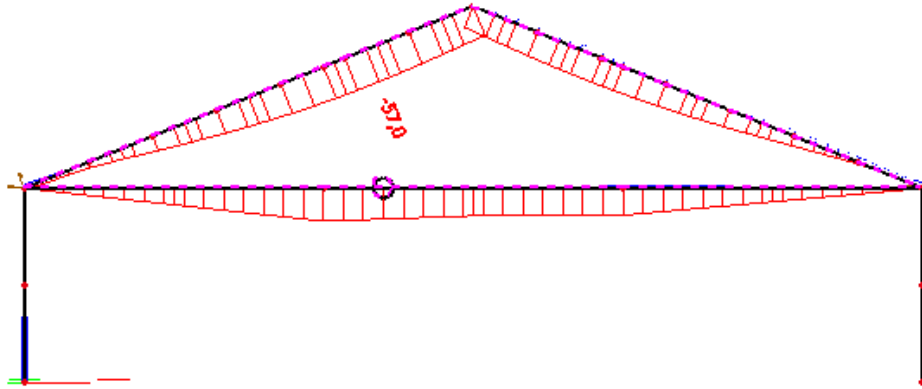
| | | |
|-----|--------------------------------|---------------------|
| CO1 | Name | CO4 |
| CO2 | Description | |
| CO3 | Type | Envelope - ultimate |
| CO4 | Contents of combination | |
| | tezina [-] | 1,35 |
| | stalno [-] | 1,35 |
| | snijeg [-] | 1,35 |
| | vjetar p [-] | 1,35 |

4. Dimenzioniranje elemenata konstrukcije

4.1 Pomaci konstrukcije

Progibi se provjeravaju na krajnje granično stanje.

Vertikalni pomak konstrukcije



Vertikalni pomak

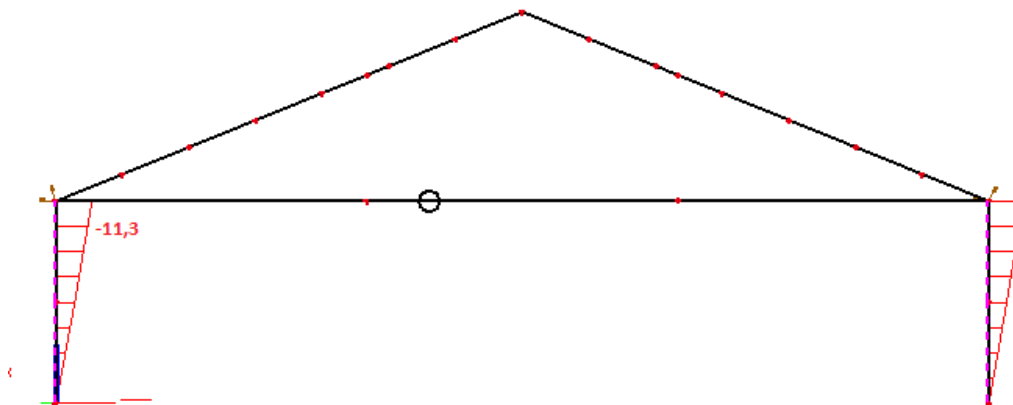
Vertikalni pomak: $u_z = 57,0 \text{ mm}$

Dopušteni vertikalni pomak:

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

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

Horizontalni pomak konstrukcije



Horizontalni pomak (opterećenje)

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

Dopušteni horizontalni pomak :

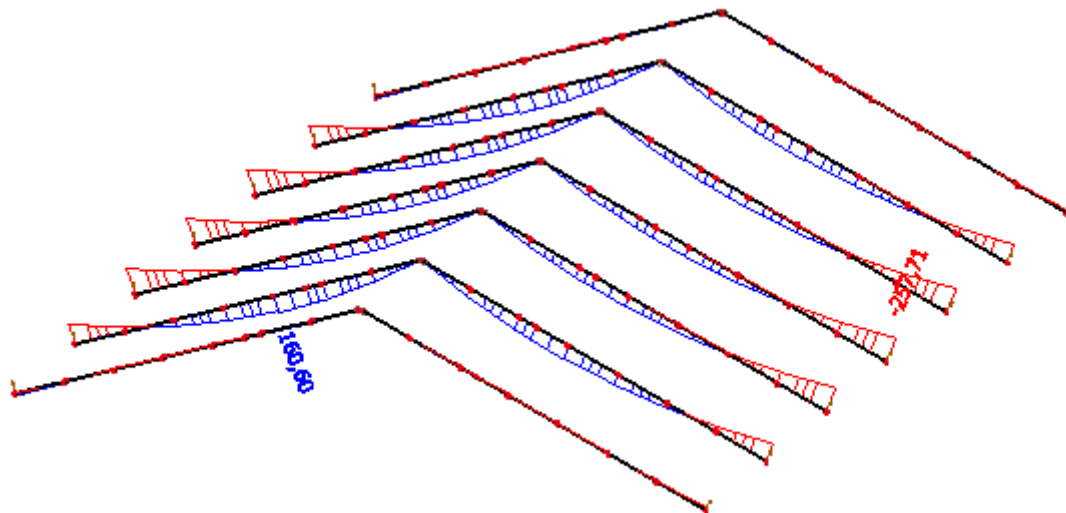
$$u_{dop} = \frac{h}{200} = \frac{5,6 \cdot 1000}{200} = 28,0 \text{ mm}$$

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

4.2 Dimenzioniranje grede (poz. G1 i G2)

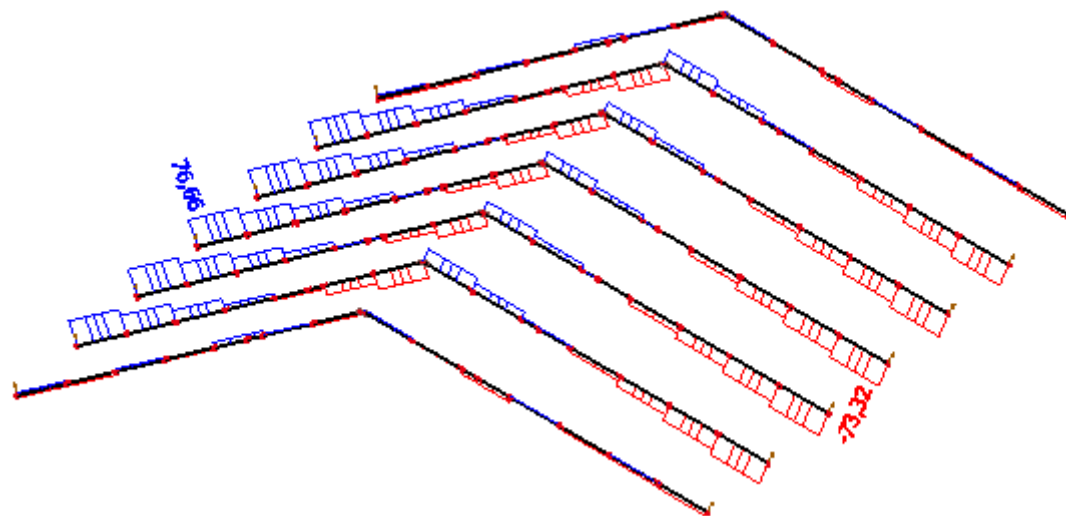
Dimenzioniranje konstrukcijskih elemenata provedeno je softverom Scia Enginner 2014 pomoću modula Timber.

Moment savijanja u gredi (My)



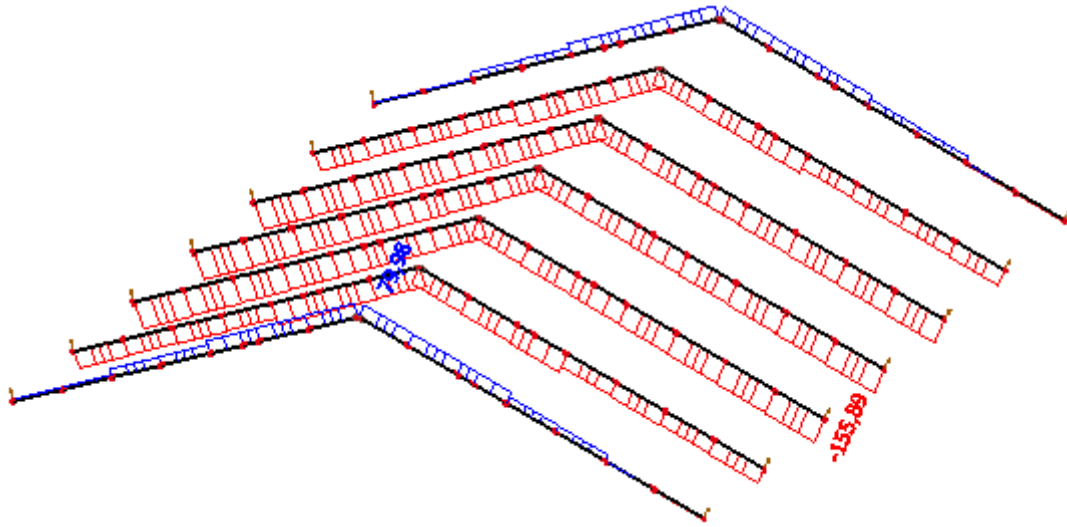
Dijagram momenata savijanja (My)

Poprečne sile u gredi (Vz)



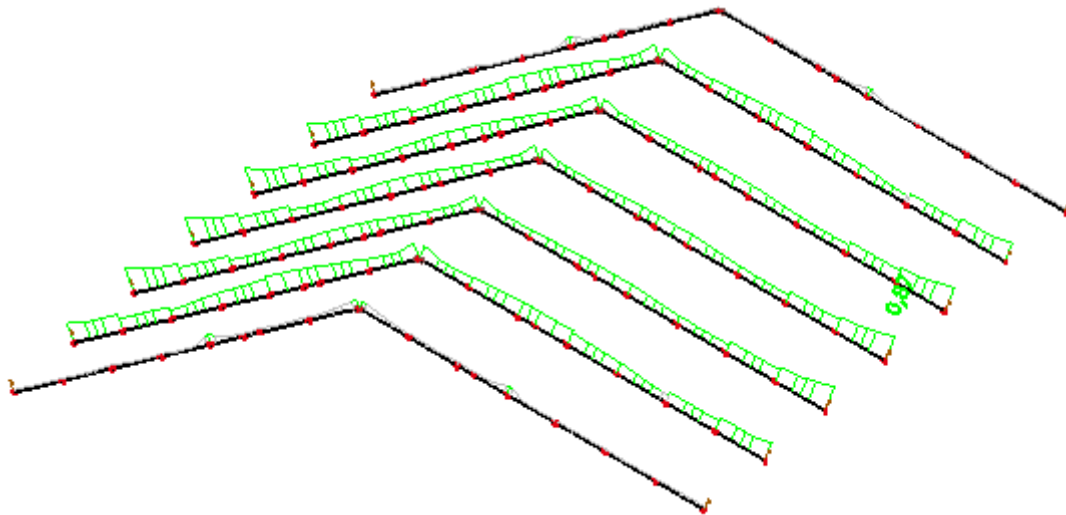
Dijagram poprečnih sila (Vz)

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 γ_M 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 k_{mod} | 0,90 |

...: SECTION CHECK ...:

Compression parallel to the grain

According to EN 1995-1-1 article 6.1.4 and formula (6.2)

| | | |
|------------------|------|-----|
| $\sigma_{c,0,d}$ | 1,0 | MPa |
| $f_{c,0,d}$ | 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)

| | | |
|-------------------|----------|-----------------|
| $F_{c,90,d}$ | 73,32 | kN |
| l | 760 | mm |
| l _{ef} | 790 | mm |
| b | 200 | mm |
| A _{ef} | 158000 | mm ² |
| $\sigma_{c,90,d}$ | 0,5 | MPa |
| Support condition | Discrete | |
| h | 760 | mm |
| kc,90 | 1,00 | - |
| $f_{c,90,d}$ | 1,9 | MPa |
| Unity check | 0,24 | - |

Bending

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

| | | |
|------------------|------|-----|
| $\sigma_{m,y,d}$ | 13,4 | MPa |
| kh,y | 1,00 | |
| $f_{m,y,d}$ | 17,3 | MPa |
| $\sigma_{m,z,d}$ | 0,0 | MPa |
| kh,z | 1,00 | |
| $f_{m,z,d}$ | 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 | |
| $\tau_{y,d}$ | 0,0 | MPa |
| $\tau_{z,d}$ | 1,1 | MPa |
| $f_{v,d}$ | 1,9 | MPa |
| Unity check τ_y | 0,00 | - |
| Unity check τ_z | 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)

| | | |
|-------------------------------|------|-----|
| $\tau_{tor,d}$ | 0,0 | MPa |
| kshape | 1,57 | |
| $f_{v,d}$ | 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)

| | | |
|-------------|------|-----|
| $f_{c,0,d}$ | 17,3 | MPa |
| $f_{m,y,d}$ | 17,3 | MPa |
| $f_{m,z,d}$ | 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 L_{cr} | 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 β_c | 0,10 | 0,10 | - |
| Reduction factor k_c | 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 $M_{y,crit}$ | 3785,37 | kNm |
| Critical bending stress $\sigma_{m,crit}$ | 196,6 | MPa |
| Relative slenderness $\lambda_{rel,m}$ | 0,35 | - |
| Reduction factor k_{crit} | 1,00 | - |

Unity check (6.33) = 0,77 -

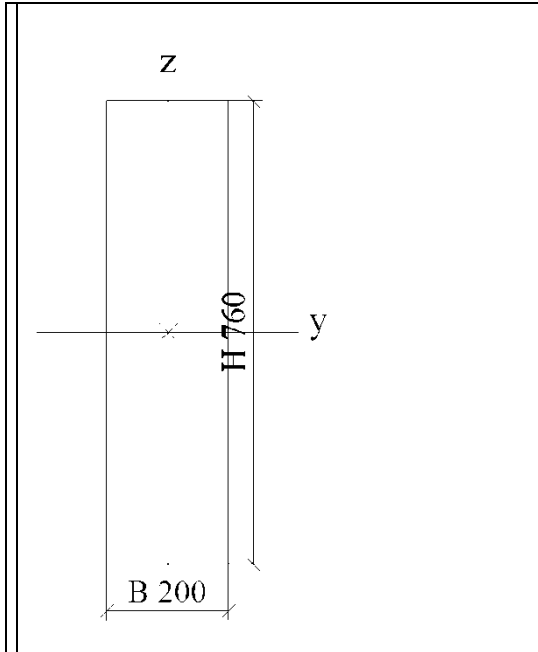
Unity check (6.35) = 0,60 + 0,06 = 0,66 -

| | | |
|---|--------|-----|
| $M_{y,crit}$ Parameters | | |
| $G_{0,05}$ | 587,5 | MPa |
| LTB length L | 2,003 | m |
| L_{ef}/L | 0,90 | |
| Effective length L_{ef} | 1,802 | m |
| Load position | normal | |

The member satisfies the stability check.

Poprečni presjek nosača:

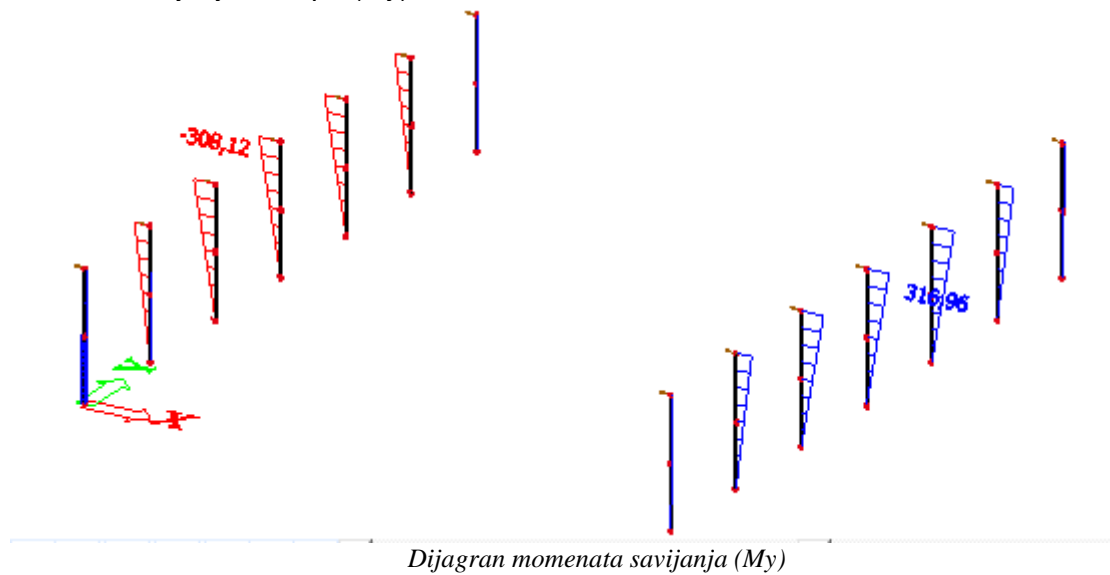
| | |
|---------------------|----------|
| Name | greda |
| Type | RECT |
| Detailed | 200; 760 |
| Item material | GL24h |
| Fabrication | timber |
| Use 2D FEM analysis | ✓ |



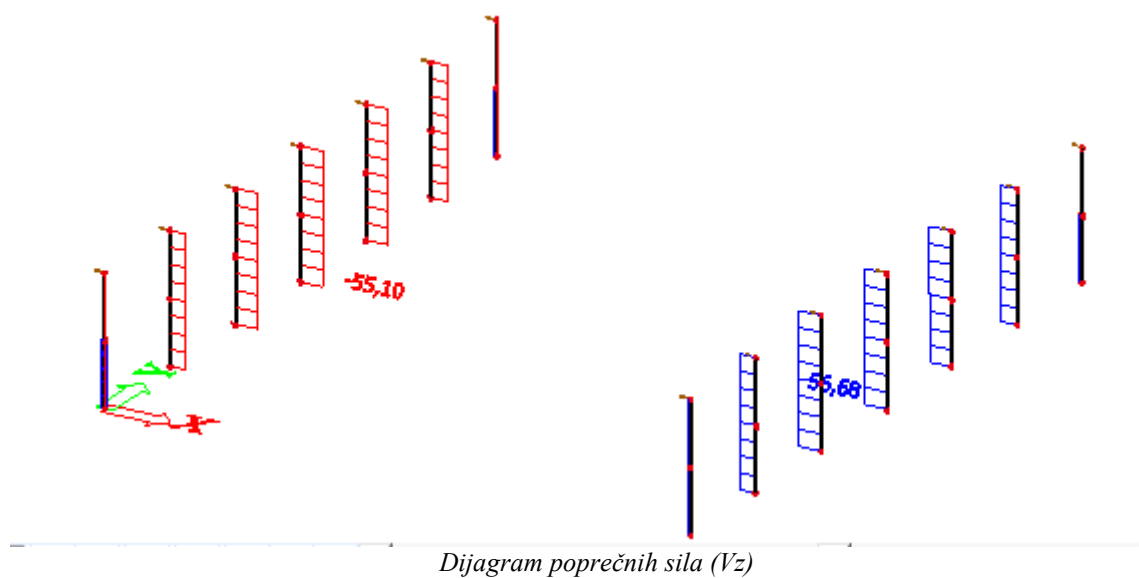
| | | |
|---|------------|------------|
| A [m ²] | 1,5200e-01 | |
| A _{y, z} [m ²] | 1,2667e-01 | 1,2667e-01 |
| I _{y, z} [m ⁴] | 7,3163e-03 | 5,0667e-04 |
| I _w [m ⁶], t [m ⁴] | 1,7996e-05 | 1,6857e-03 |
| W _{el y, z} [m ³] | 1,9253e-02 | 5,0667e-03 |
| W _{pl y, z} [m ³] | 2,3532e-02 | 6,1926e-03 |
| 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 |
| M _{ply +, -} [Nm] | 5,65e+05 | 5,65e+05 |
| M _{plz +, -} [Nm] | 1,49e+05 | 1,49e+05 |

4.3 Dimenzioniranje stupa (poz. S)

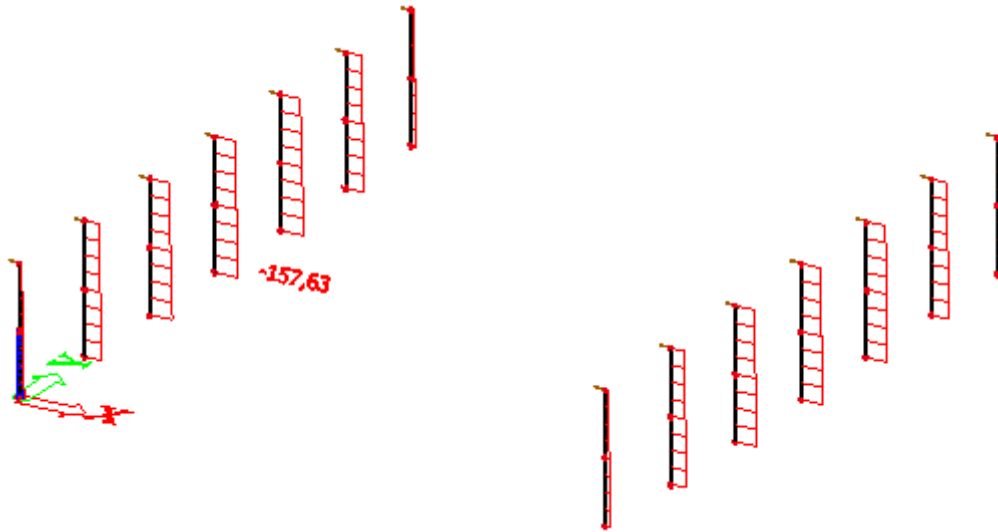
Moment savijanja u stupu (My)



Poprečna sila (Vz)

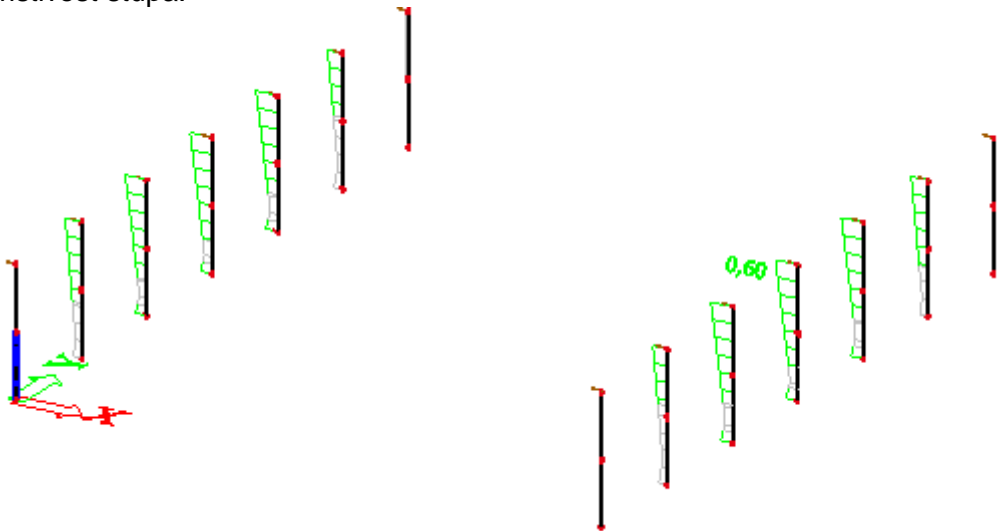


Uzdužna sila (N)



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 γ_M 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 k_{mod} | 0,90 |

...: SECTION CHECK ...:

Compression parallel to the grain

According to EN 1995-1-1 article 6.1.4 and formula (6.2)

| | | |
|------------------|------|-----|
| $\sigma_{c,0,d}$ | 0,4 | MPa |
| $f_{c,0,d}$ | 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)

| | | |
|-------------------|----------|-----------------|
| $F_{c,90,d}$ | 56,52 | kN |
| l | 760 | mm |
| l _{ef} | 790 | mm |
| b | 400 | mm |
| A _{ef} | 316000 | mm ² |
| $\sigma_{c,90,d}$ | 0,2 | MPa |
| Support condition | Discrete | |
| h | 760 | mm |
| $k_{c,90}$ | 1,00 | - |
| $f_{c,90,d}$ | 1,9 | MPa |
| Unity check | 0,09 | - |

Bending

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

| | | |
|------------------|------|-----|
| $\sigma_{m,y,d}$ | 8,2 | MPa |
| $k_{h,y}$ | 1,00 | |
| $f_{m,y,d}$ | 17,3 | MPa |
| $\sigma_{m,z,d}$ | 0,0 | MPa |
| $k_{h,z}$ | 1,00 | |
| $f_{m,z,d}$ | 17,3 | MPa |
| k_m | 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 | |
| $\tau_{y,d}$ | 0,0 | MPa |
| $\tau_{z,d}$ | 0,4 | MPa |
| $f_{v,d}$ | 1,9 | MPa |
| Unity check τ_y | 0,00 | - |
| Unity check τ_z | 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)

| | | |
|-------------------------------|------|-----|
| $\tau_{tor,d}$ | 0,0 | MPa |
| kshape | 1,00 | |
| $f_{v,d}$ | 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)

| | | |
|-------------|------|-----|
| $f_{c,0,d}$ | 17,3 | MPa |
| $f_{m,y,d}$ | 17,3 | MPa |
| $f_{m,z,d}$ | 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 L_{cr} | 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 β_c | 0,10 | 0,10 | - |
| Reduction factor k_c | 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 $M_{y,crit}$ | 17551,01 | kNm |
| Critical bending stress $\sigma_{m,crit}$ | 455,8 | MPa |
| Relative slenderness $\lambda_{rel,m}$ | 0,23 | - |
| Reduction factor k_{crit} | 1,00 | - |

Unity check (6.33) = 0,48 -

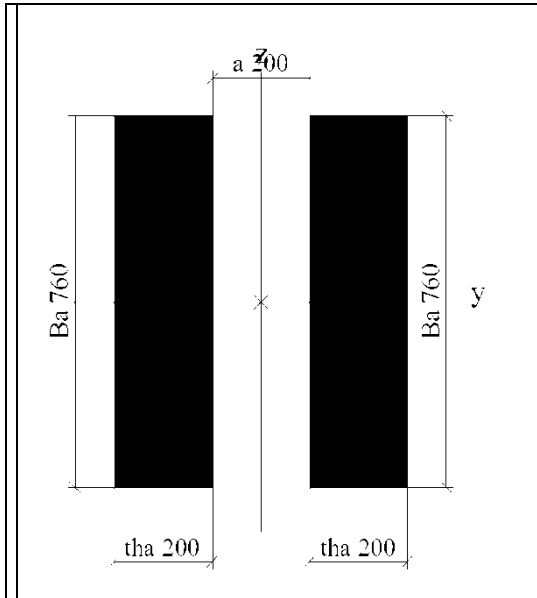
Unity check (6.35) = 0,23 + 0,03 = 0,25 -

| | | |
|---|--------|-----|
| $M_{y,crit}$ Parameters | | |
| $G_{0,05}$ | 587,5 | MPa |
| LTB length L | 2,800 | m |
| L_{ef}/L | 1,00 | |
| Effective length L_{ef} | 2,800 | m |
| Load position | normal | |

The member satisfies the stability check.

Poprečni presjek stupa:

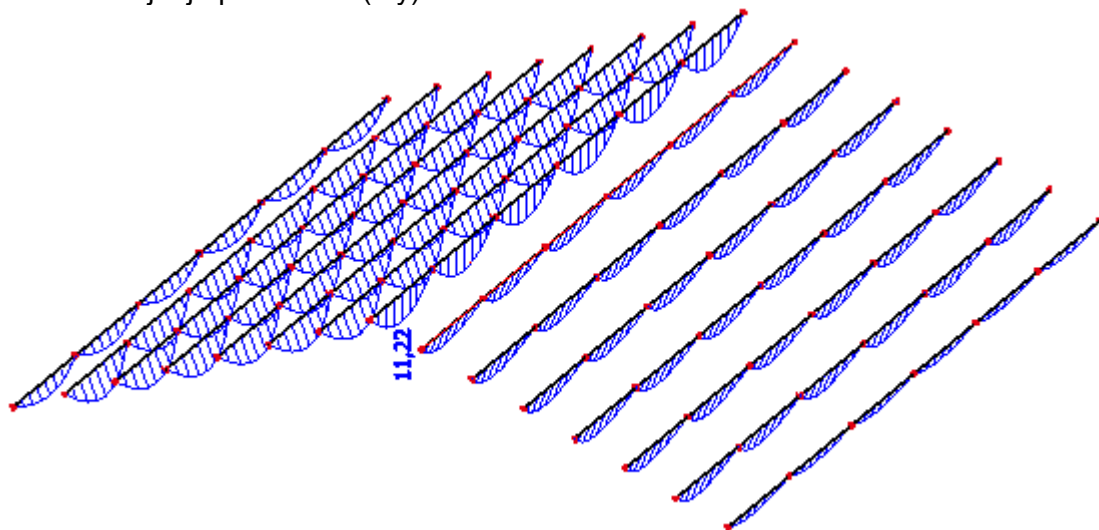
| | |
|---------------------|---------------|
| Name | stup |
| Type | 2 Rect |
| Detailed | 200; 760; 200 |
| Item material | GL24h |
| Fabrication | timber |
| Use 2D FEM analysis | ✓ |



| | | |
|---|------------|------------|
| 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 |
| W _{el y, z} [m ₃] | 3,8507e-02 | 4,3911e-02 |
| W _{pl 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 |
| M _{ply +, -} [Nm] | 1,13e+06 | 1,13e+06 |
| M _{plz +, -} [Nm] | 1,10e+06 | 1,10e+06 |

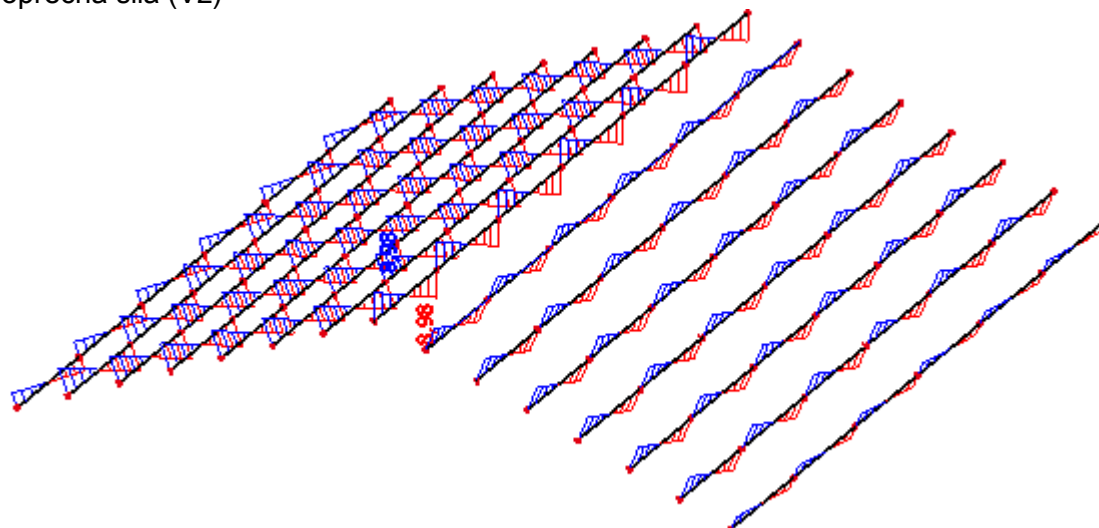
4.4 Dimnezioniranje krovne podrožnice (poz. KP1 i KP2)

Moment savijanja podrožnice(M_y)



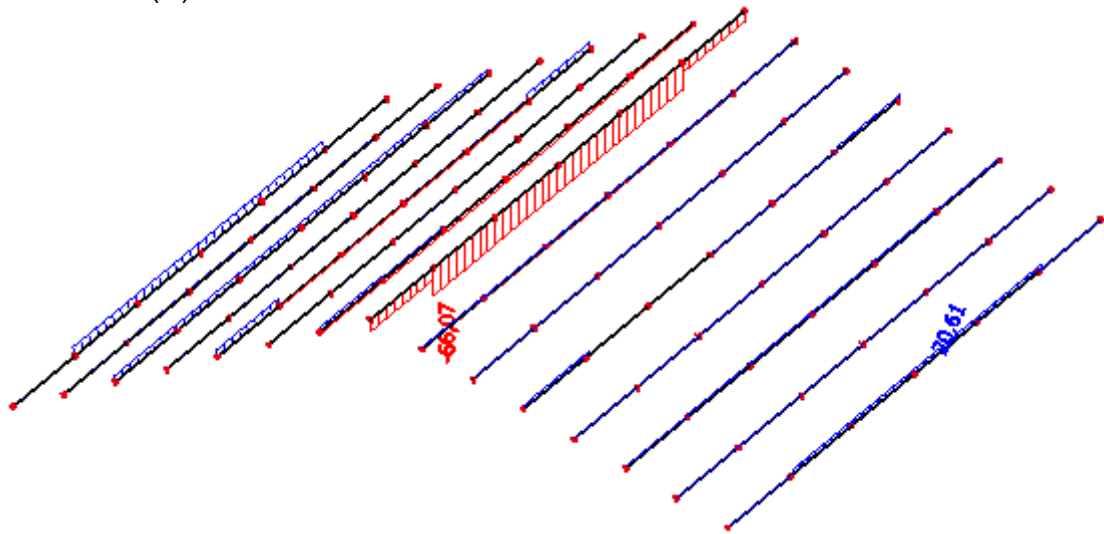
Dijagram momenata savijanja (M_y)

Poprečna sila (V_z)



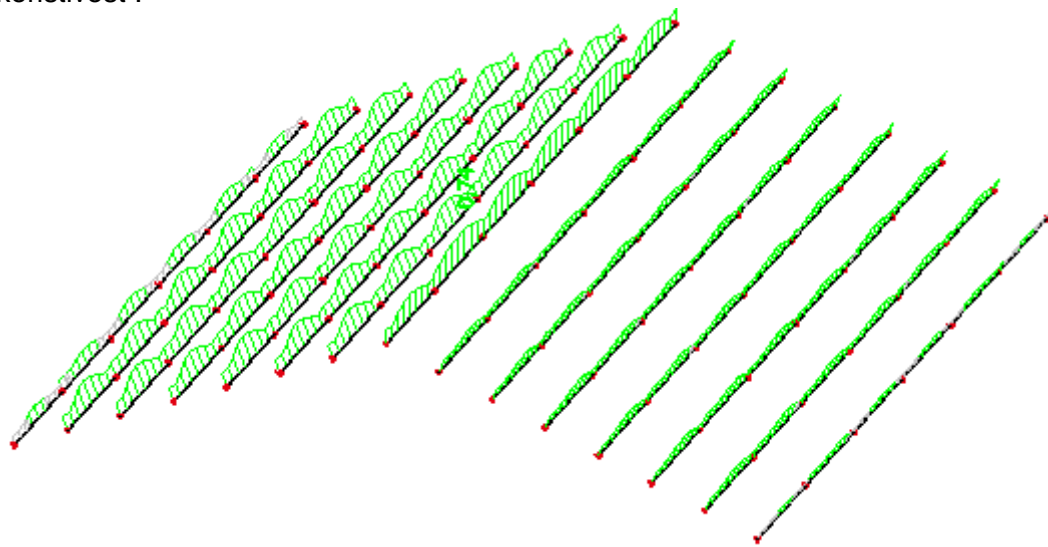
Dijagram poprečnih sila (V_z)

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 γ_M 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 k_{mod} | 0,90 |

...: SECTION CHECK ...:

Compression parallel to the grain

According to EN 1995-1-1 article 6.1.4 and formula (6.2)

| | | |
|------------------|------|-----|
| $\sigma_{c,0,d}$ | 2,3 | MPa |
| $f_{c,0,d}$ | 17,3 | MPa |
| Unity check | 0,13 | - |

Bending

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

| | | |
|------------------|------|-----|
| $\sigma_{m,y,d}$ | 9,1 | MPa |
| kh,y | 1,10 | |
| $f_{m,y,d}$ | 18,9 | MPa |
| $\sigma_{m,z,d}$ | 1,1 | MPa |
| kh,z | 1,00 | |
| $f_{m,z,d}$ | 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 | |
| $\tau_{y,d}$ | 0,1 | MPa |
| $\tau_{z,d}$ | 0,2 | MPa |
| $f_{v,d}$ | 1,9 | MPa |
| Unity check τ_y | 0,04 | - |
| Unity check τ_z | 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)

| | | |
|-------------------------------|------|-----|
| $\tau_{tor,d}$ | 0,9 | MPa |
| kshape | 1,30 | |
| $f_{v,d}$ | 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)

| | | |
|-------------|------|-----|
| $f_{c,0,d}$ | 17,3 | MPa |
| $f_{m,y,d}$ | 18,9 | MPa |
| $f_{m,z,d}$ | 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 L _{cr} | 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 β_c | 0,10 | 0,10 | - |
| Reduction factor k _c | 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 $M_{y,crit}$ | 93,85 | kNm |
| Critical bending stress $\sigma_{m,crit}$ | 81,5 | MPa |
| Relative slenderness $\lambda_{rel,m}$ | 0,54 | - |
| Reduction factor k _{crit} | 1,00 | - |

Unity check (6.33) = 0,48 -

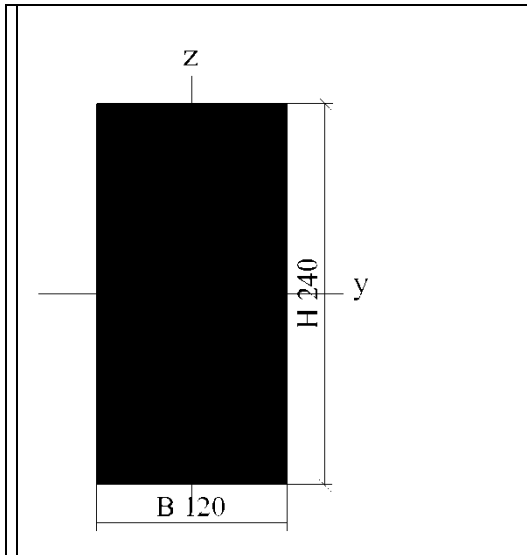
Unity check (6.35) = 0,23 + 0,22 = 0,45 -

| | | |
|---|--------|-----|
| $M_{y,crit}$ Parameters | | |
| G _{0,05} | 587,5 | MPa |
| LTB length L | 5,000 | m |
| L _{ef} /L | 0,90 | |
| Effective length L _{ef} | 4,500 | m |
| Load position | normal | |

The member satisfies the stability check.

Poprečni presjek:

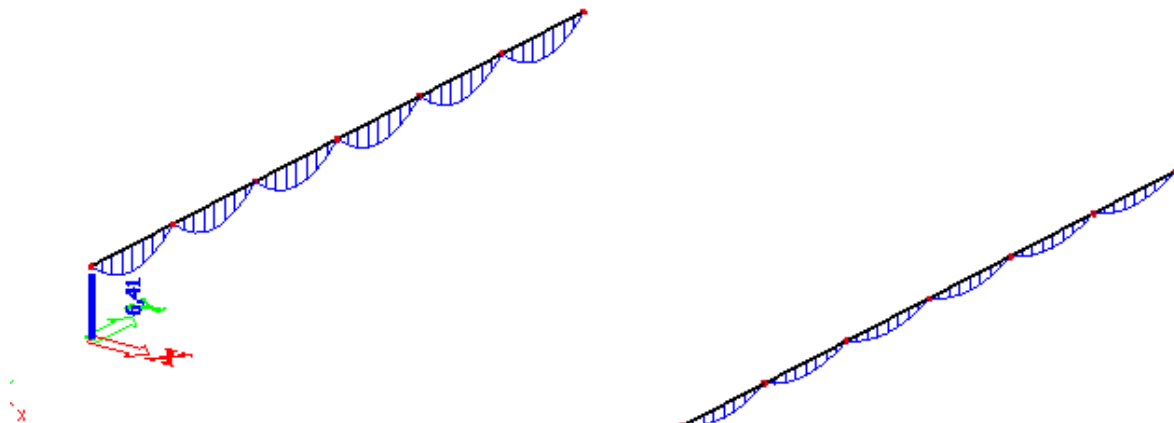
| | |
|----------------------------|-------------|
| Name | krovna podr |
| Type | RECT |
| Detailed | 120; 240 |
| Item material | GL24h |
| Fabrication | timber |
| Use 2D FEM analysis | ✓ |



| | | |
|---|------------|------------|
| A [m²] | 2,8800e-02 | |
| A y, z [m²] | 2,4000e-02 | 2,4000e-02 |
| I y, z [m⁴] | 1,3824e-04 | 3,4560e-05 |
| I w [m⁶], t [m⁴] | 6,0039e-08 | 9,4694e-05 |
| Wel y, z [m³] | 1,1520e-03 | 5,7600e-04 |
| Wpl y, z [m³] | 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 [m²/m] | 7,2000e-01 | 7,2000e-01 |
| Mply +, - [Nm] | 3,38e+04 | 3,38e+04 |
| Mplz +, - [Nm] | 1,69e+04 | 1,69e+04 |

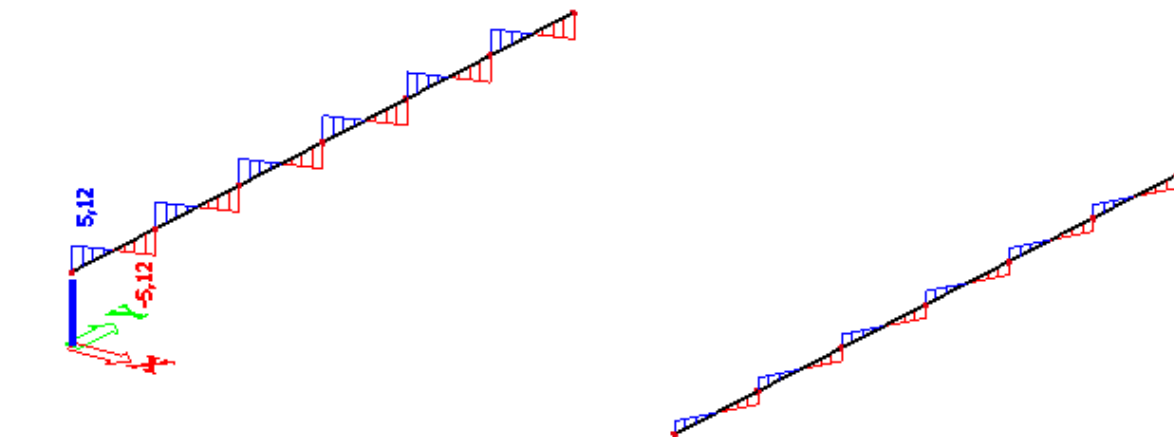
4.5 Dimenzioniranje bočne podrožnice (poz. BP1 i BP2)

Moment savijanja (M_y)



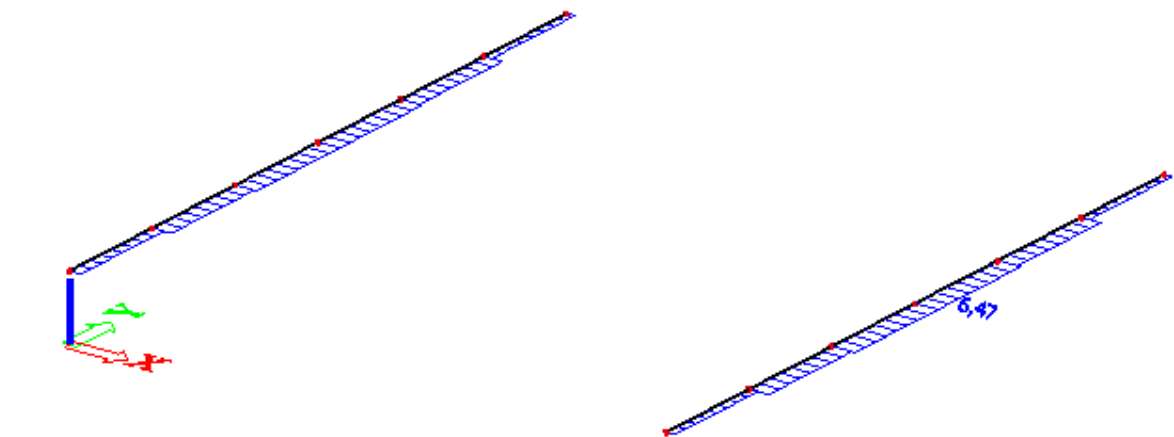
Dijagram momenata savijanja (M_y)

Poprečna sila (V_z)



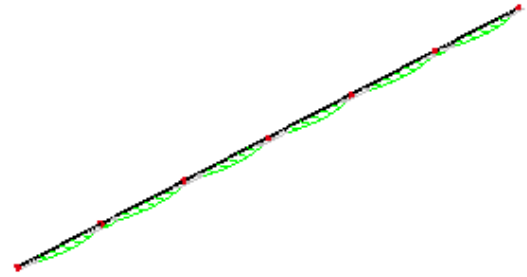
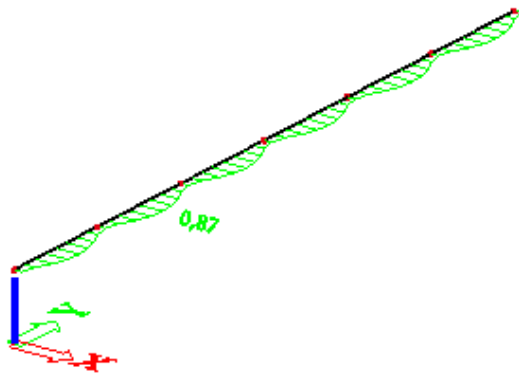
Dijagram poprečnih sila (V_z)

Uzdužna sila (N)



Dijagram uzdužnih 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 γ_M 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 k_{mod} | 0,90 |

...: SECTION CHECK ...:

Tension parallel to the grain

According to EN 1995-1-1 article 6.1.2 and formula (6.1)

| | | |
|------------------|------|-----|
| $\sigma_{t,0,d}$ | 0,1 | MPa |
| kh | 1,10 | |
| $f_{t,0,d}$ | 13,1 | MPa |
| Unity check | 0,01 | - |

Bending

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

| | | |
|------------------|------|-----|
| $\sigma_{m,y,d}$ | 0,0 | MPa |
| kh,y | 1,10 | |
| $f_{m,y,d}$ | 19,0 | MPa |
| $\sigma_{m,z,d}$ | 14,8 | MPa |
| kh,z | 1,00 | |
| $f_{m,z,d}$ | 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 | |
| $\tau_{y,d}$ | 0,0 | MPa |
| $\tau_{z,d}$ | 0,0 | MPa |
| $f_{v,d}$ | 1,9 | MPa |
| Unity check τ_y | 0,00 | - |
| Unity check τ_z | 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)

| | | |
|-------------------------------|------|-----|
| $\tau_{tor,d}$ | 0,0 | MPa |
| kshape | 1,23 | |
| $f_{v,d}$ | 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)

| | | |
|-------------|------|-----|
| $f_{t,0,d}$ | 13,1 | MPa |
| $f_{m,y,d}$ | 19,0 | MPa |
| $f_{m,z,d}$ | 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 $M_{y,crit}$ | 58,61 | kNm |
| Critical bending stress $\sigma_{m,crit}$ | 90,5 | MPa |
| Relative slenderness $\lambda_{rel,m}$ | 0,52 | - |
| Reduction factor k_{crit} | 1,00 | - |

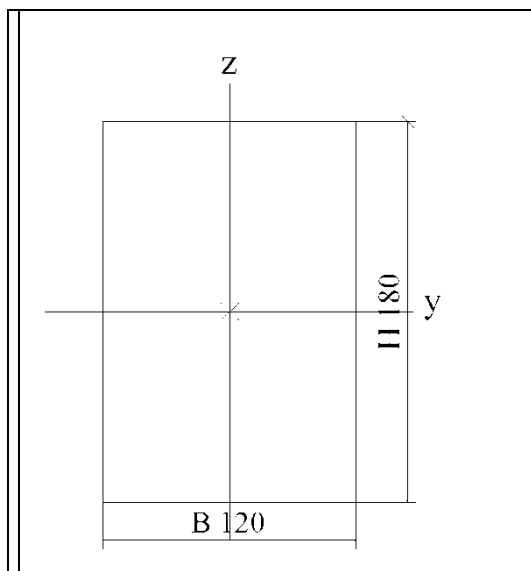
Unity check (6.33) = 0,00 -

| 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:

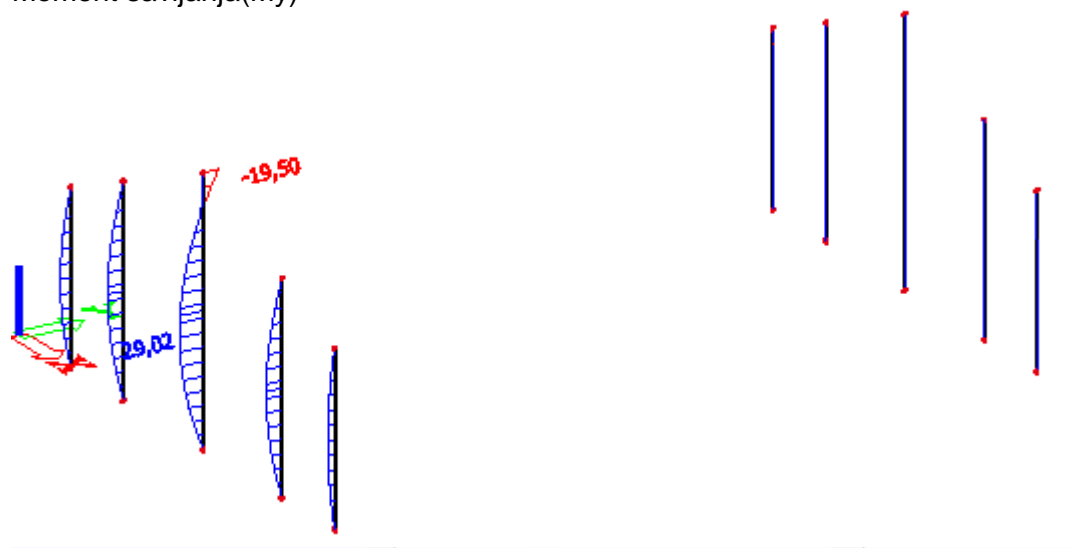
| | |
|---------------------|------------|
| Name | bocna podr |
| Type | RECT |
| Detailed | 120; 180 |
| Item material | GL24h |
| Fabrication | timber |
| Use 2D FEM analysis | ✓ |



| | | |
|---|------------|------------|
| A [m ²] | 2,1600e-02 | |
| A _{y, z} [m ²] | 1,8000e-02 | 1,8000e-02 |
| I _{y, z} [m ⁴] | 5,8320e-05 | 2,5920e-05 |
| I _w [m ⁶], t [m ⁴] | 1,1144e-08 | 6,0795e-05 |
| W _{el y, z} [m ³] | 6,4800e-04 | 4,3200e-04 |
| W _{pl y, z} [m ³] | 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} [m ² /m] | 6,0000e-01 | 6,0000e-01 |
| M _{ply +, -} [Nm] | 1,90e+04 | 1,90e+04 |
| M _{plz +, -} [Nm] | 1,27e+04 | 1,27e+04 |

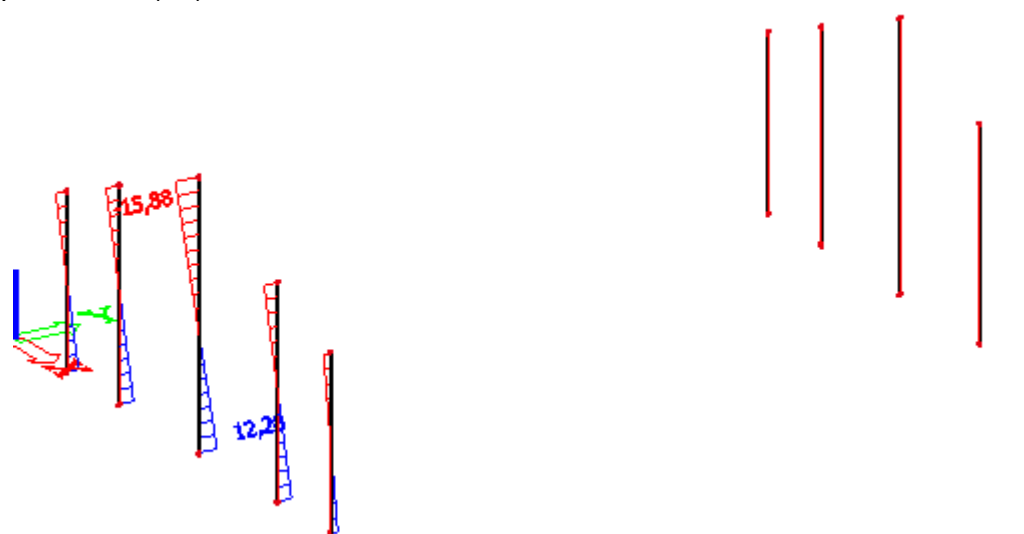
4.6 Dimenzioniranje zabata (poz. ZS1, ZS2 i ZS3)

Moment savijanja (M_y)



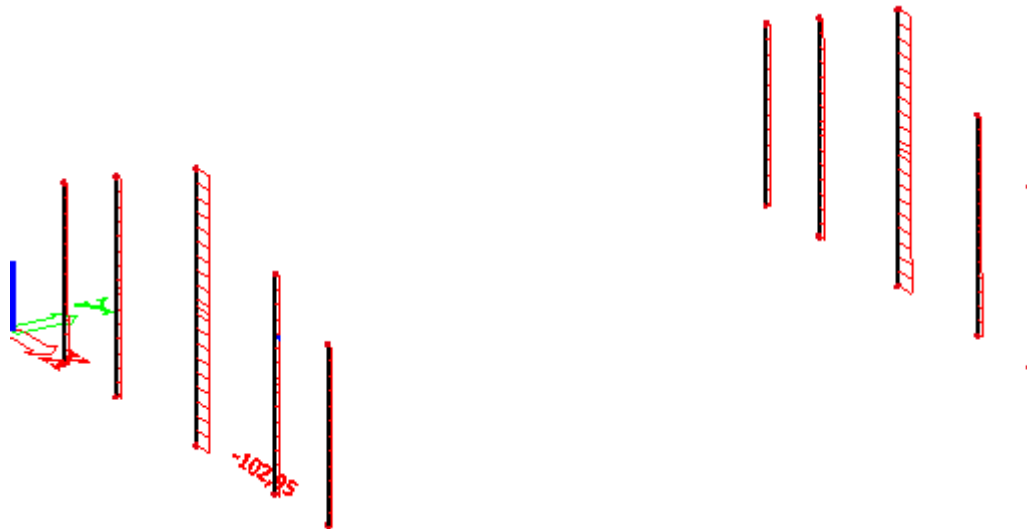
Dijagram momenta savijanja (M_y)

Poprečna sila (V_z)



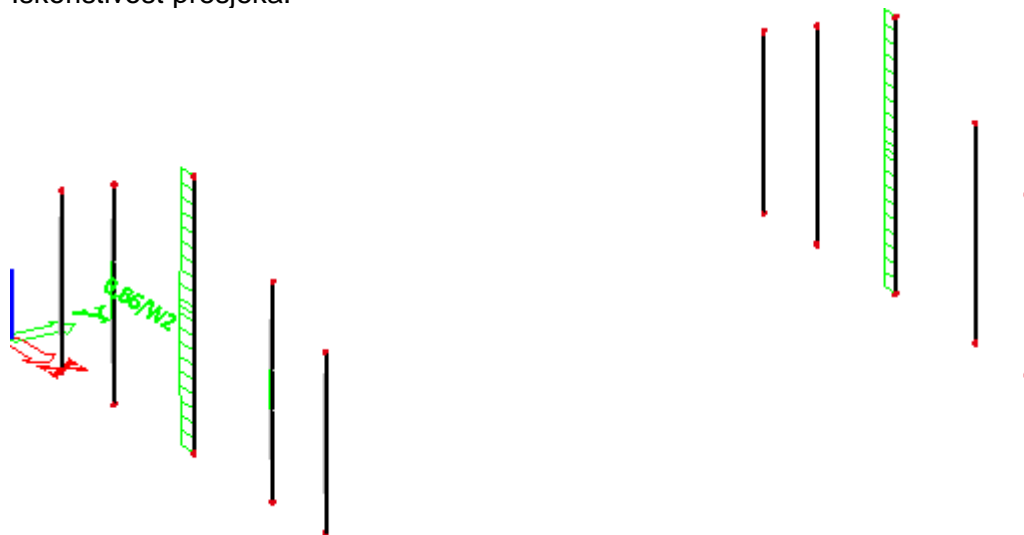
Dijagram poprečnih sila (V_z)

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 γ_M 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 k_{mod} | 0,90 |

...: SECTION CHECK ...:

Compression parallel to the grain

According to EN 1995-1-1 article 6.1.4 and formula (6.2)

| | | |
|------------------|------|-----|
| $\sigma_{c,0,d}$ | 0,8 | MPa |
| $f_{c,0,d}$ | 17,3 | MPa |
| Unity check | 0,04 | - |

Bending

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

| | | |
|------------------|------|-----|
| $\sigma_{m,y,d}$ | 0,0 | MPa |
| kh,y | 1,00 | |
| $f_{m,y,d}$ | 17,3 | MPa |
| $\sigma_{m,z,d}$ | 2,7 | MPa |
| kh,z | 1,00 | |
| $f_{m,z,d}$ | 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 | |
| $\tau_{y,d}$ | 0,0 | MPa |
| $\tau_{z,d}$ | 0,0 | MPa |
| $f_{v,d}$ | 1,9 | MPa |
| Unity check τ_y | 0,00 | - |
| Unity check τ_z | 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 β_c | 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 $\sigma_{m,crit}$ | 48,1 | MPa |
| Relative slenderness $\lambda_{rel,m}$ | 0,71 | - |
| Reduction factor kcrit | 1,00 | - |

Unity check (6.33) = 0,00 -

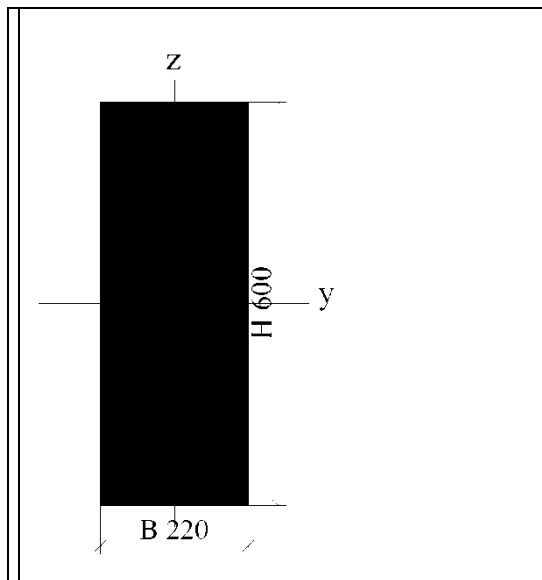
Unity check (6.35) = 0,00 + 0,24 = 0,24 -

| | | |
|---------------------------|--------|-----|
| 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

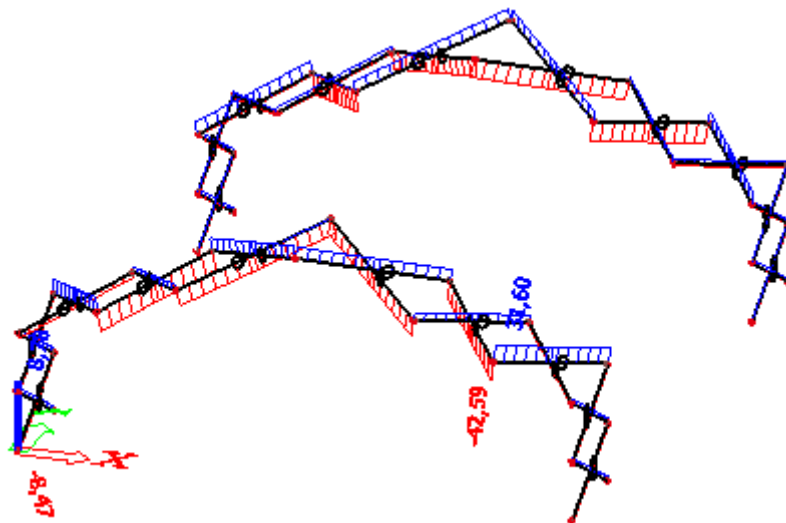
| | |
|---------------------|----------|
| Name | zabat |
| Type | RECT |
| Detailed | 220; 600 |
| Item material | GL24h |
| Fabrication | timber |
| Use 2D FEM analysis | ✓ |



| | | |
|---|------------|------------|
| 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 |
| W _{el y, z} [m ₃] | 1,3200e-02 | 4,8400e-03 |
| W _{pl 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/m] | 1,6400e+00 | 1,6400e+00 |
| M _{ply +, -} [Nm] | 3,87e+05 | 3,87e+05 |
| M _{plz +, -} [Nm] | 1,42e+05 | 1,42e+05 |

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

Uzdužna sila:



Dijagram uzudžnih sila (N)

odabrano $\varnothing 15$

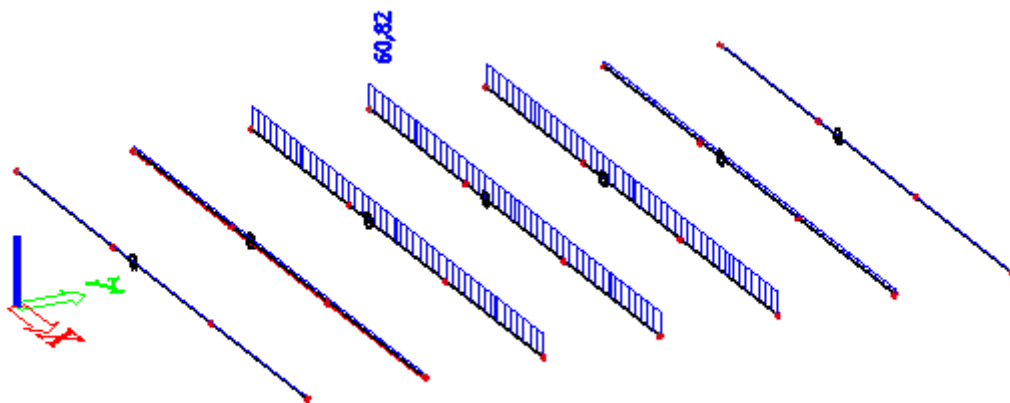
$$A = 1,767 \cdot 10^{-4} \text{ m}^2$$

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

41,52 kN > 31,60 kN - presjek zadovoljava

4.8 Dimenzioniranje zatege – S235 (poz. Z)

Uzdužna sila:



Dijagram uzudžnih sila (N)

odabrano $\varnothing 20$

$$A=3,142 \cdot 10^{-4} \text{ m}^2$$

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

$73,84 \text{ kN} > 60,82 \text{ kN}$ - 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 $\rightarrow f_{uk} = 490 \text{ MPa}$

Drvo: LLD GL24h $\rightarrow \rho_k = 380 \text{ kg/m}^3 \rightarrow \gamma_M = 1,25$

Uporabna klasa 2. \rightarrow kratkotrajno opterećenje $\rightarrow k_{mod} = 0,90$

$\alpha = 90^\circ$ -kut unosa opterećenja

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

Minimalni razmaci trnova:

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

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

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

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

$r_v = 270 \text{ mm}$ – radijus vanjske kružnice

$r_u = 210 \text{ mm}$ – 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 otpornost jednog trna je najmanja od slijedećih vrijednosti:

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

$\beta = 1.0$ –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 :

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

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

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$\alpha = 45^\circ$ -najopterećeniji trn

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

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

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

Proračunska otpornost jednog trna:

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

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

$$1,05 \cdot \frac{f_{h,\alpha,d} \cdot t_1 \cdot d}{2 + \beta} \cdot \left[\sqrt{2\beta(1 + \beta) + \frac{4\beta(2 + \beta) \cdot M_{y,Rd}}{f_{h,\alpha,d} \cdot t_1^2 \cdot d}} - \beta \right] =$$

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

$$1,15 \cdot \sqrt{\frac{2\beta}{1 + \beta}} \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} = 1,15 \cdot \sqrt{\frac{2}{1 + 1}} \cdot \sqrt{2 \cdot 322\,554 \cdot 16,32 \cdot 20} =$$

$$= 17\,687 \text{ N}$$

$$\min R_d = 17\,687 \text{ N}$$

$$\Sigma R_d = 2 \cdot \min R_d = 2 \cdot 17\,687 = 35\,374 \text{ N} = 35,37 \text{ kN}$$

Doprinos jednog trna u prihvaćanju unutrašnjih sila montažne veze:

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:

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

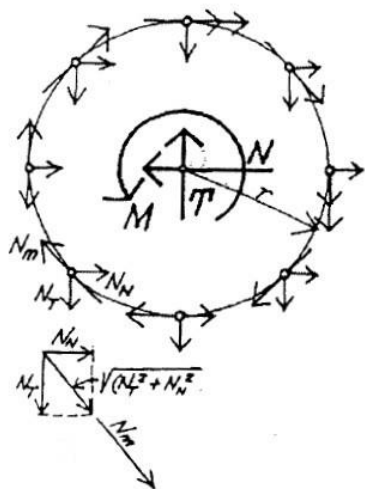
$$F_{M,d,u} = \frac{\frac{7}{16} M_{Ed}}{r \cdot n} = \frac{\frac{7}{16} \cdot 316,96}{0,21 \cdot 21} = 31,4 \text{ kN}$$

-od poprečne sile:

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

-od uzdužne sile:

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



Proračunska vrijednost sile koju preuzima 1 trn:

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

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

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

$$R_d = 35,37 \text{ kN} > F_d = 34,8 \text{ kN}$$

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

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:

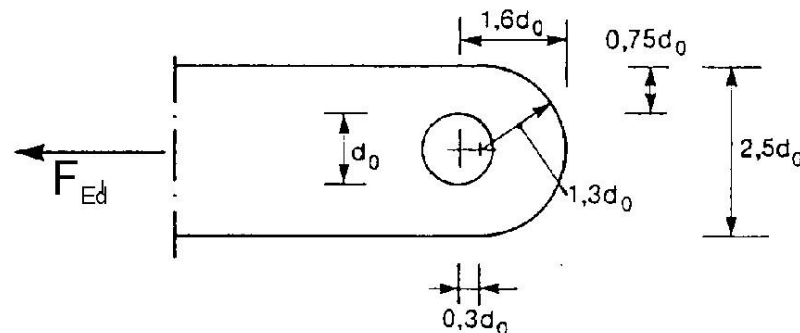
Čelik: S355 $\rightarrow f_{uk} = 490 \text{ MPa}$

Drvo: LLD GL24h $\rightarrow \rho_k = 380 \text{ kg/m}^3 \rightarrow \gamma_M = 1,25$

Uporabna klasa 2. \rightarrow kratkotrajno opterećenje $\rightarrow k_{mod} = 0,90$

5.2.1 Proračun trna i debljine pločica (P1) na zglobu

$d_{odabrano} = 26 \text{ mm}$ –promjer trna



Dimenzije pločice odabiru se prema preporukama sa slike.

Geometrijski uvjeti:

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

$$2. \quad d_0 \leq 2,5 t$$

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

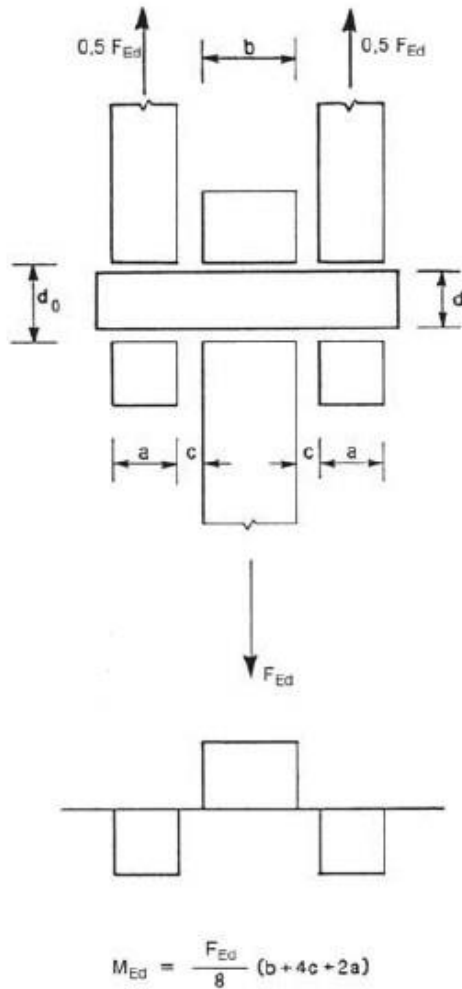
\rightarrow Uvjeti zadovoljeni \rightarrow odabrana debljina pločice $t = 14 \text{ mm}$

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:

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

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

$$F_{V,Rd} > F_{V,Ed} \rightarrow \text{Uvjet zadovoljen}$$

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:

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

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

$F_{b,Rd} > F_{b,Ed} \rightarrow$ Uvjet zadovoljen

Debljina pločice P2 i P3 je 26 mm.

Naprezanja na drvenoj gredi preko pločice P2:

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

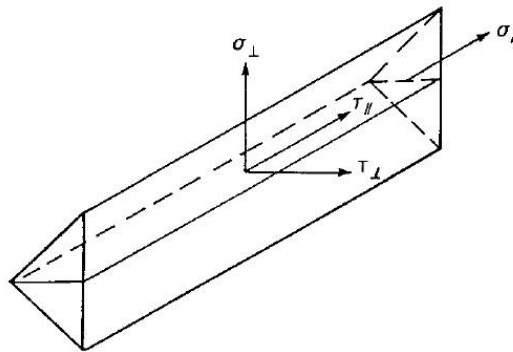
$$f_{b,Ed} = \frac{N_{Ed}}{h \cdot b_{PL}} = \frac{116\,310}{460 \cdot 26} = 11,18 \text{ Mpa} < 0,90 \cdot \frac{26,5}{1,25} = 19,08 \text{ Mpa}$$

\rightarrow Uvjet zadovoljen

5.2.2 Proračun vara između pločica P1 i P2 direktnom metodom

$a=7 \text{ mm}$ – debljina vara

$L=75 \text{ mm}$ – duljina vara



1. uvjet:

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

\rightarrow 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:

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

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

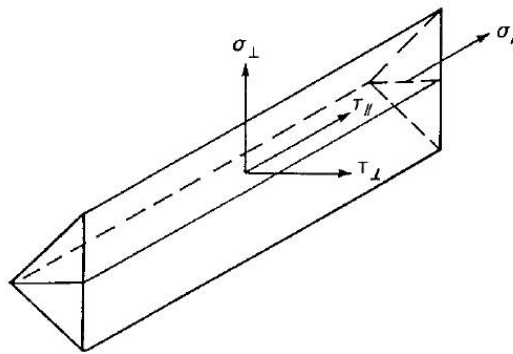
$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0,9 \cdot 1,25} = 435,55 \text{ Mpa}$$

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:

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

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

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

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 ($t_{PL} > d_{spajala}$)

$a = 4d = 4 \cdot 20 = 80 \text{ mm}$ – 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 :

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

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

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$$\alpha = 90^\circ$$

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 90 + \cos^2 90} = 20,78 \text{ N/mm}^2$$

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:

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

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

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

-od poprečne sile:

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

-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: $V_{Ed} = 76,66$, $N_{Ed} = 155,89$ kN

Kvaliteta materijala:

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

Drvo: LLD GL24h $\rightarrow \rho_k = 380$ kg/m³ $\rightarrow \gamma_M = 1,25$

Uporabna klasa 2. \rightarrow kratko opterećenje $\rightarrow k_{mod} = 0,90$

Spoj je dvorezan s čeličnim pločicama kao vanjskim elementima .

$d = 20$ mm

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

$t_{min} = 0.3d = 6$ mm

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 :

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

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

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$\alpha = 90^\circ$

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 90 + \cos^2 90} = 20,78 \text{ N/mm}^2$$

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:

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

$R_d = 29,92$ 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 $\rightarrow \rho_k = 380 \text{ kg/m}^3 \rightarrow \gamma_M = 1,25$

Uporabna klasa 2. \rightarrow kratko opterećenje $\rightarrow k_{mod} = 0,90$

5.4.1 Proračun vijaka i pločica na stupu:

Spoj je dvorezan s čeličnim pločicama kao vanjskim elementima .

$d = 20 \text{ mm}$

$a = 4d = 4 \cdot 20 = 80 \text{ mm}$ – 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 :

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

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

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$\alpha = 90^\circ$

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 90 + \cos^2 90} = 20,78 \text{ N/mm}^2$$

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:

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

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

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

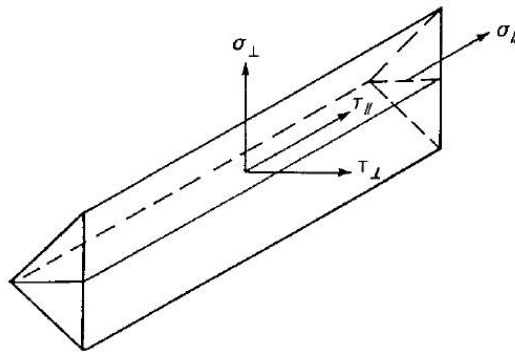
$$\eta = \frac{10,14}{29,92} = 0,34$$

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:

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

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

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

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: $d = 16\text{mm}$, $n = 2$

Preporučeni razmaci vijaka za odabrani promjer i debljinu lima $t = 10\text{ mm}$:

$e_1 = 40\text{ mm}$ → 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 vijaka na posmik: $F_{t,Rk} = \alpha \cdot f_{uk} \cdot A_S = 0,6 \cdot 500 \cdot 157 = 47,1\text{ kN}$

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

Doprinos jednog vijaka u prihvaćanju unutrašnjih sila:

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

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

→ Uvjet zadovoljen

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

5.5 SPOJ STUP-TEMELJ

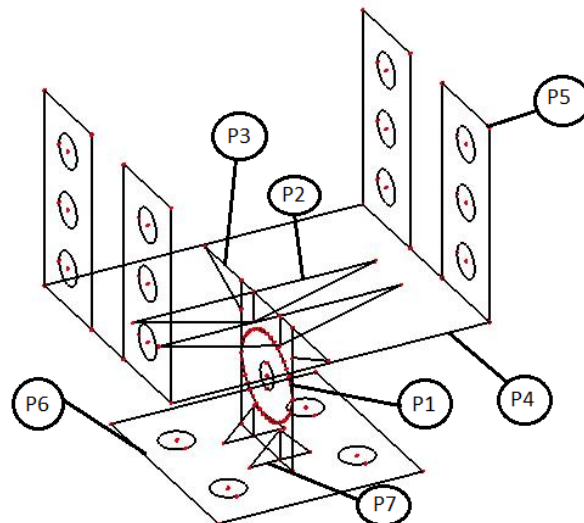
Rezne sile: $V_{Ed} = 56,68 \text{ kN}$, $N_{Ed} = 157,63 \text{ kN}$

Kvaliteta materijala:

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

Drvo: LLD GL24h $\rightarrow \rho_k = 380 \text{ kg/m}^3 \rightarrow \gamma_M = 1,25$

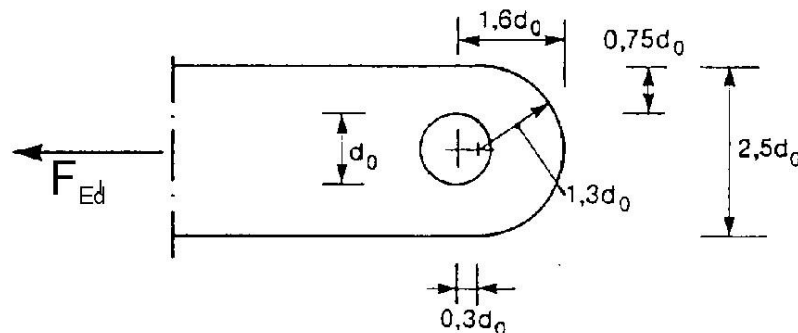
Uporabna klasa 2. \rightarrow kratko opterećenje $\rightarrow k_{mod} = 0,90$



Prikaz modela s oznakama pločica

5.5.1 Proračun trna i debljine pločica P1 na zglobu

$d_{odabrano} = 32 \text{ mm}$ –promjer trna



Preporučene dimenzije za P1 prema Eurokodu 3

Dimenzije pločice odabiru se prema preporukama sa slike 6.1.2.

Geometrijski uvjeti:

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

$$2. \quad d_0 \leq 2,5 t$$

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

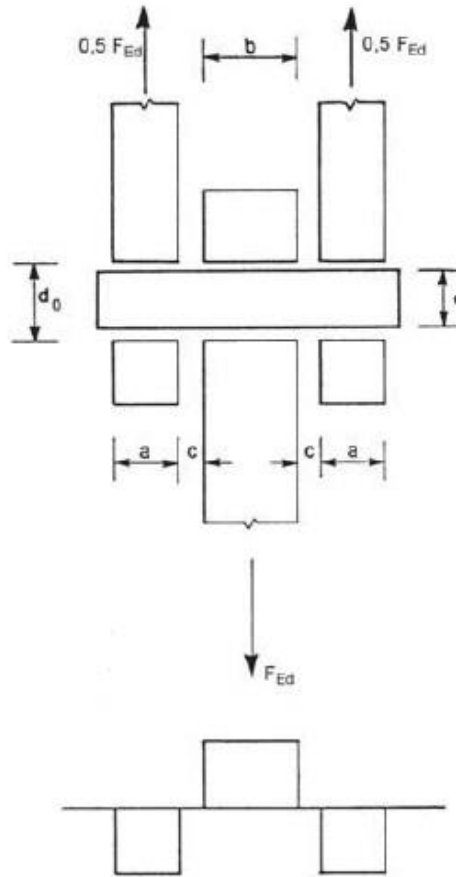
\rightarrow Uvjeti zadovoljeni \rightarrow odabrana debljina pločice $t=18 \text{ mm}$

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



$$M_{Ed} = \frac{F_{Ed}}{8} (b + 4c + 2a)$$

Moment savijanja u spajalu

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

→Uvjet zadovoljen

Posmična otpornost trna:

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

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

$$F_{V,Rd} > F_{V,Ed} \quad \rightarrow \quad \text{Uvjet zadovoljen}$$

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:

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

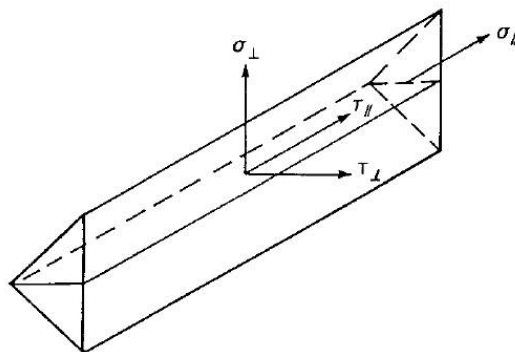
$$F_{b,Ed} = 157,63 \text{ kN}$$

$$F_{b,Rd} > F_{b,Ed} \rightarrow \text{Uvjet zadovoljen}$$

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:

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

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

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

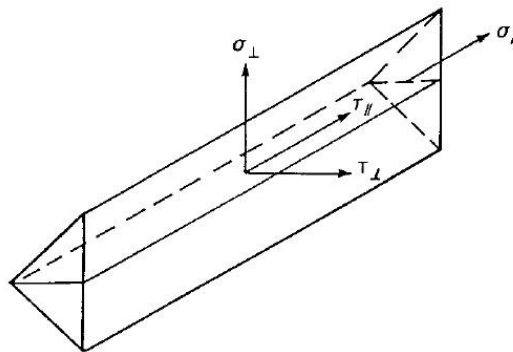
254,33 Mpa < 435,55 Mpa → Uvjet zadovoljen

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:

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

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

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

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 ($t_{PL} > d_{spajala}$)

$a = 4d = 4 \cdot 20 = 80 \text{ mm}$ – 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 :

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

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

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$$\alpha = 90^\circ$$

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 90 + \cos^2 90} = 20,78 \text{ N/mm}^2$$

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:

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

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

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:

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

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

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 prionjivosti vijka:

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

$f_{ct,d}$ – 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 | $t_{PL}(\text{mm})$ |
|---------|---------------------|
| 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 $\sigma = 500$ Mpa

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

$h = 100$ cm

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

Težina temelja:

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

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

Naprezanje ispod temelja:

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

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

$$A = 1,5 \cdot 1,5 = 2,25 \text{ (m}^2\text{)};$$

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

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

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

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

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

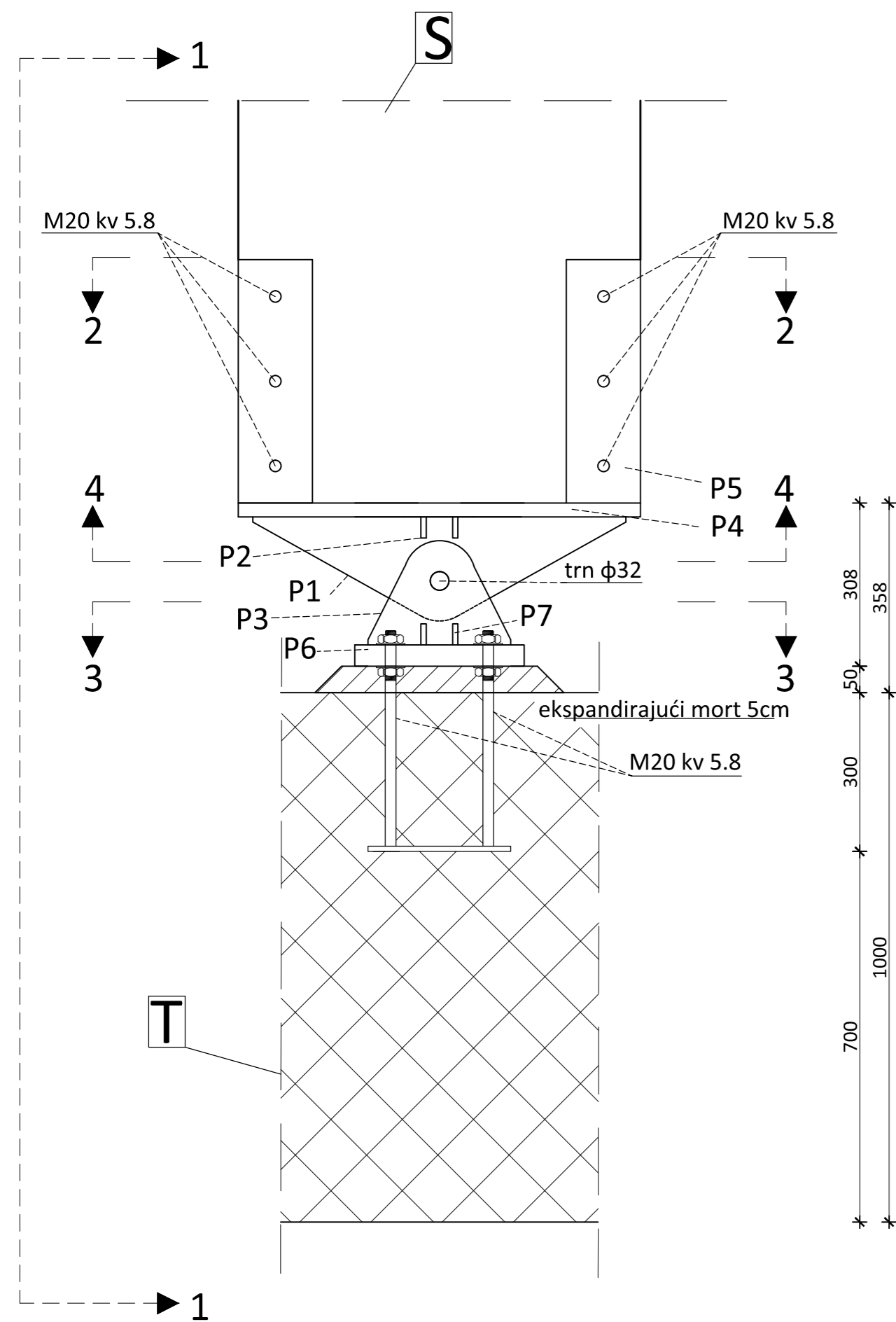
7.6 DETALJ „D“: SPOJ STUP-ZATEGA, M 1:10

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

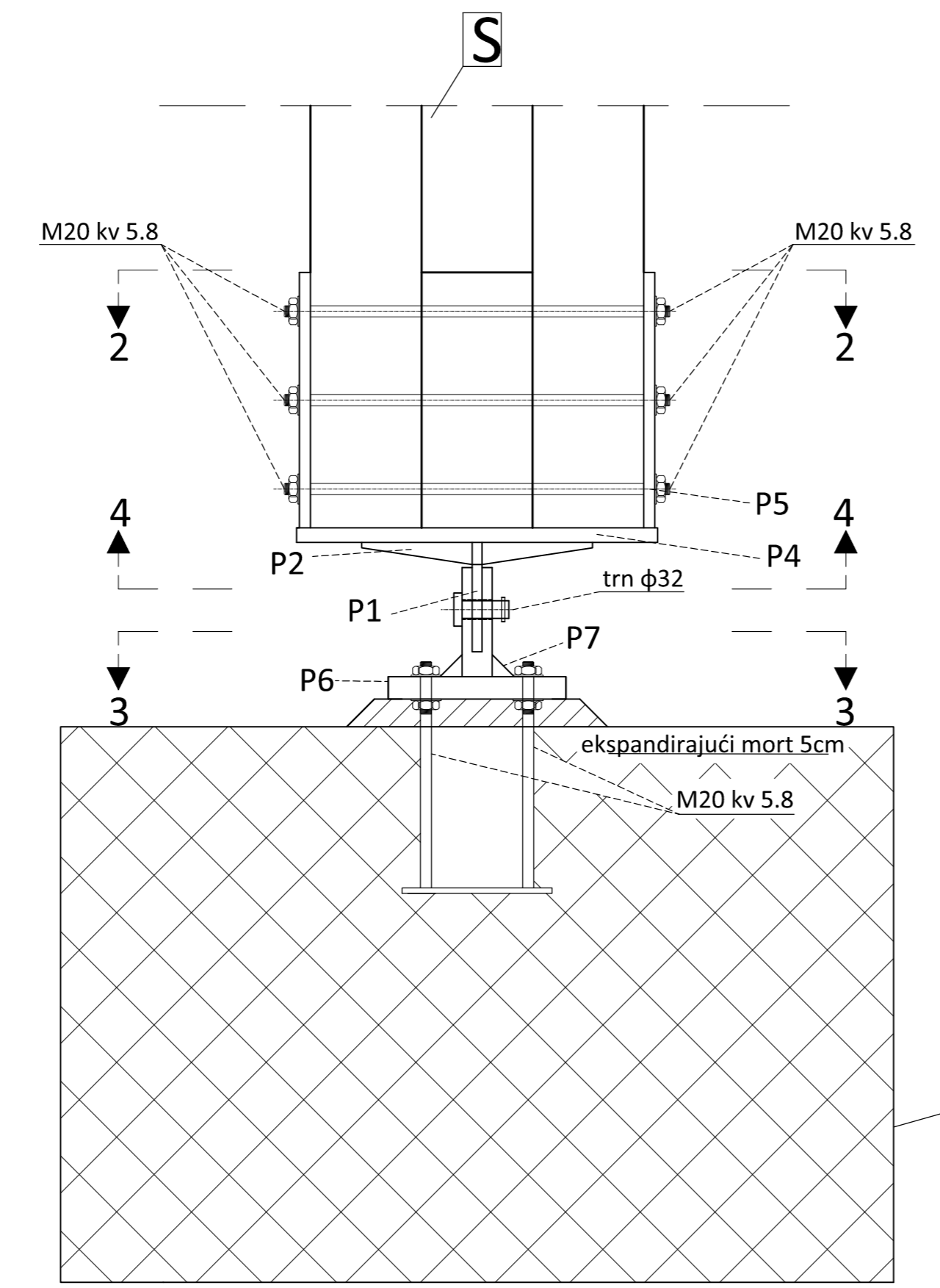
7.8 ISKAZ MATERIJALA, M 1:50

DETALJ "A" M 1:10

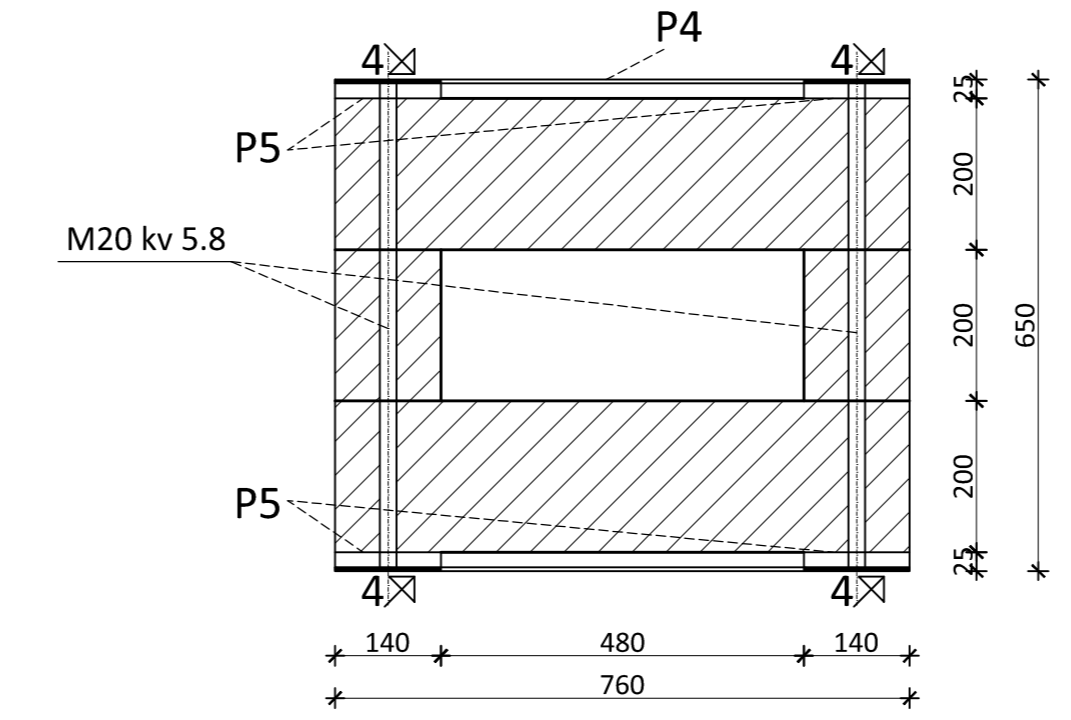
DETALJ "A"



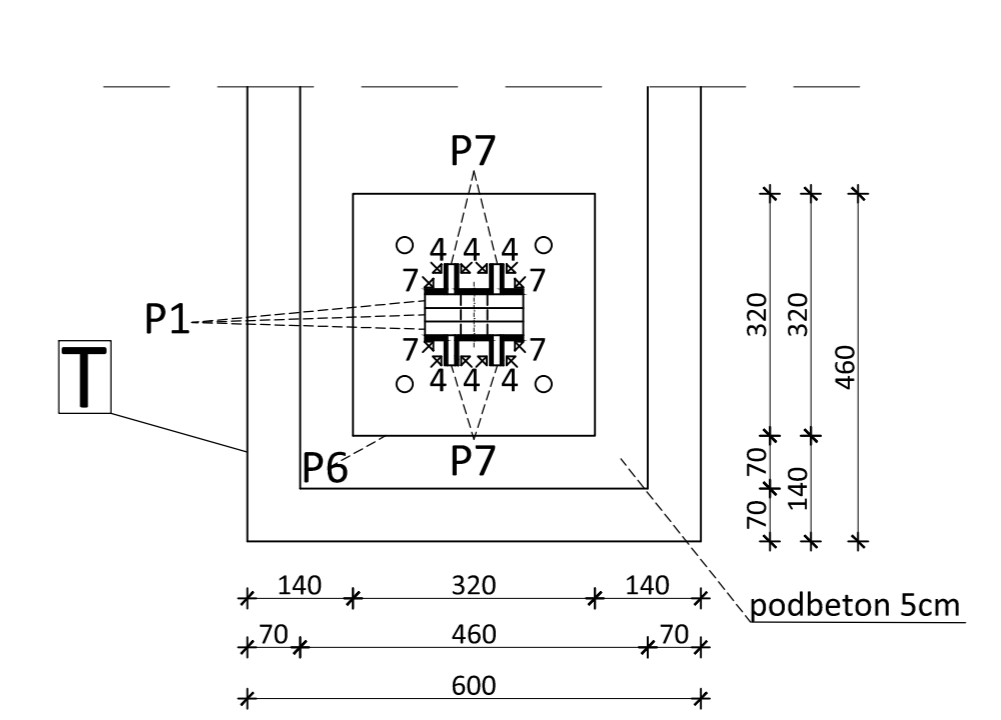
POGLED 1-1



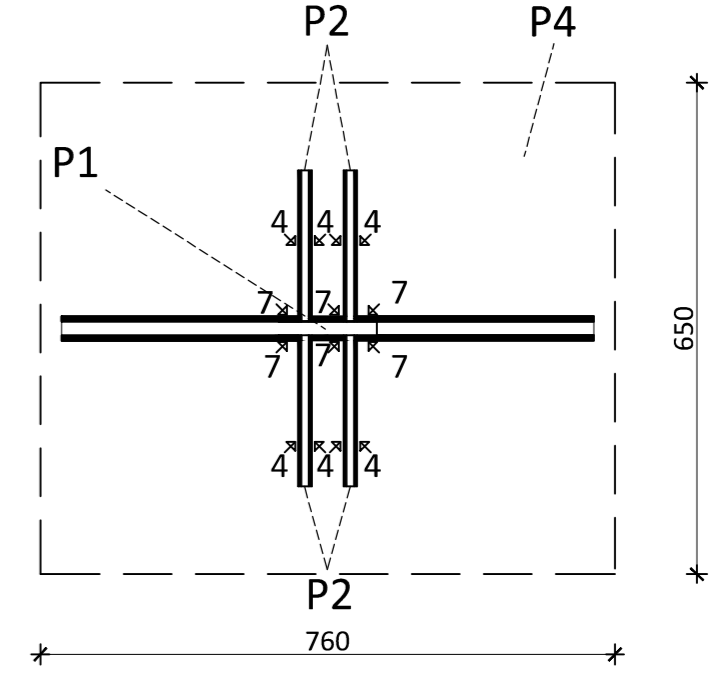
PRESJEK 2-2



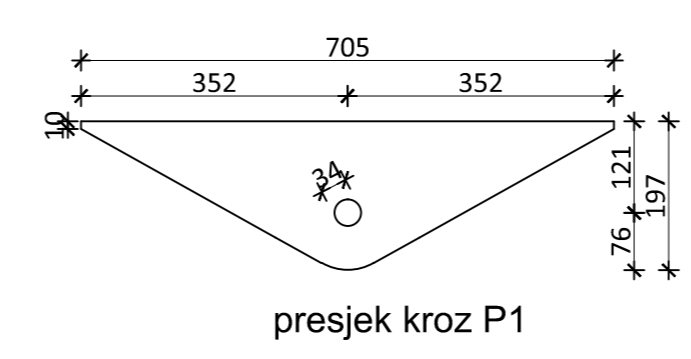
PRESJEK 3-3



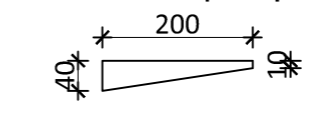
PRESJEK 4-4



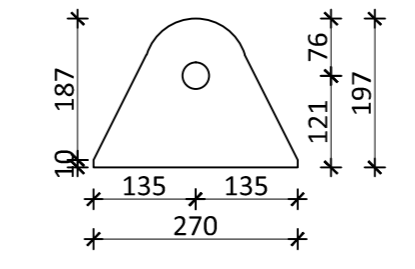
P1 S355 1 kom po spoju



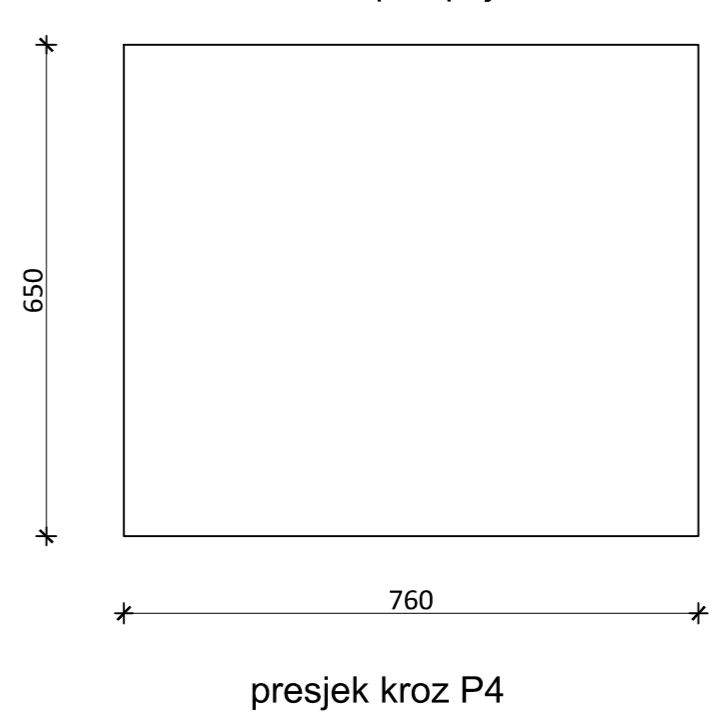
P2 200/40/10 S355 kom. 4 po spoju



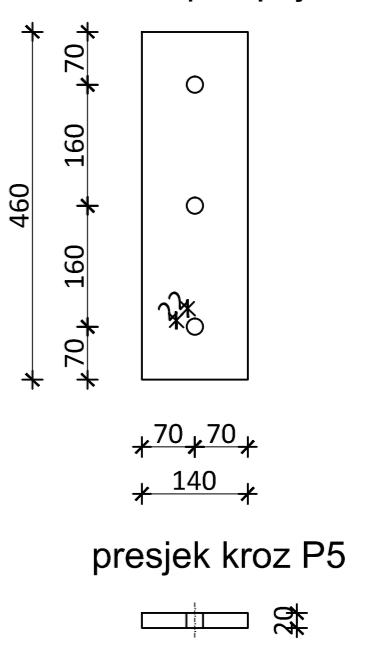
P3 S355 2 kom. po spoju



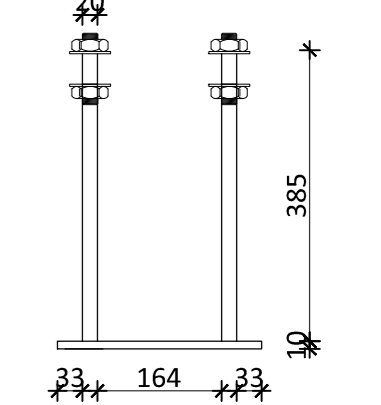
P4 760/620/26 S355 1 kom. po spoju



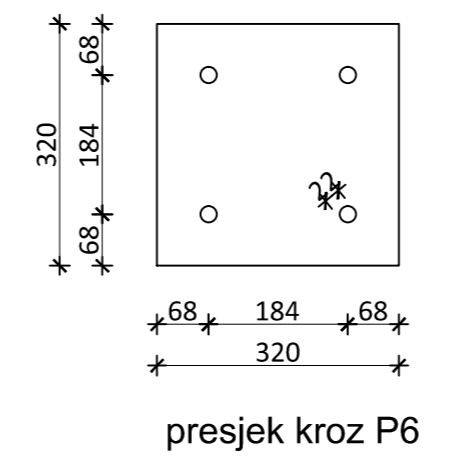
P5 140/460/20 S355 4 kom. po spoju



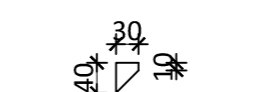
SIDRENI VIJCI M20 kv.5.8



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



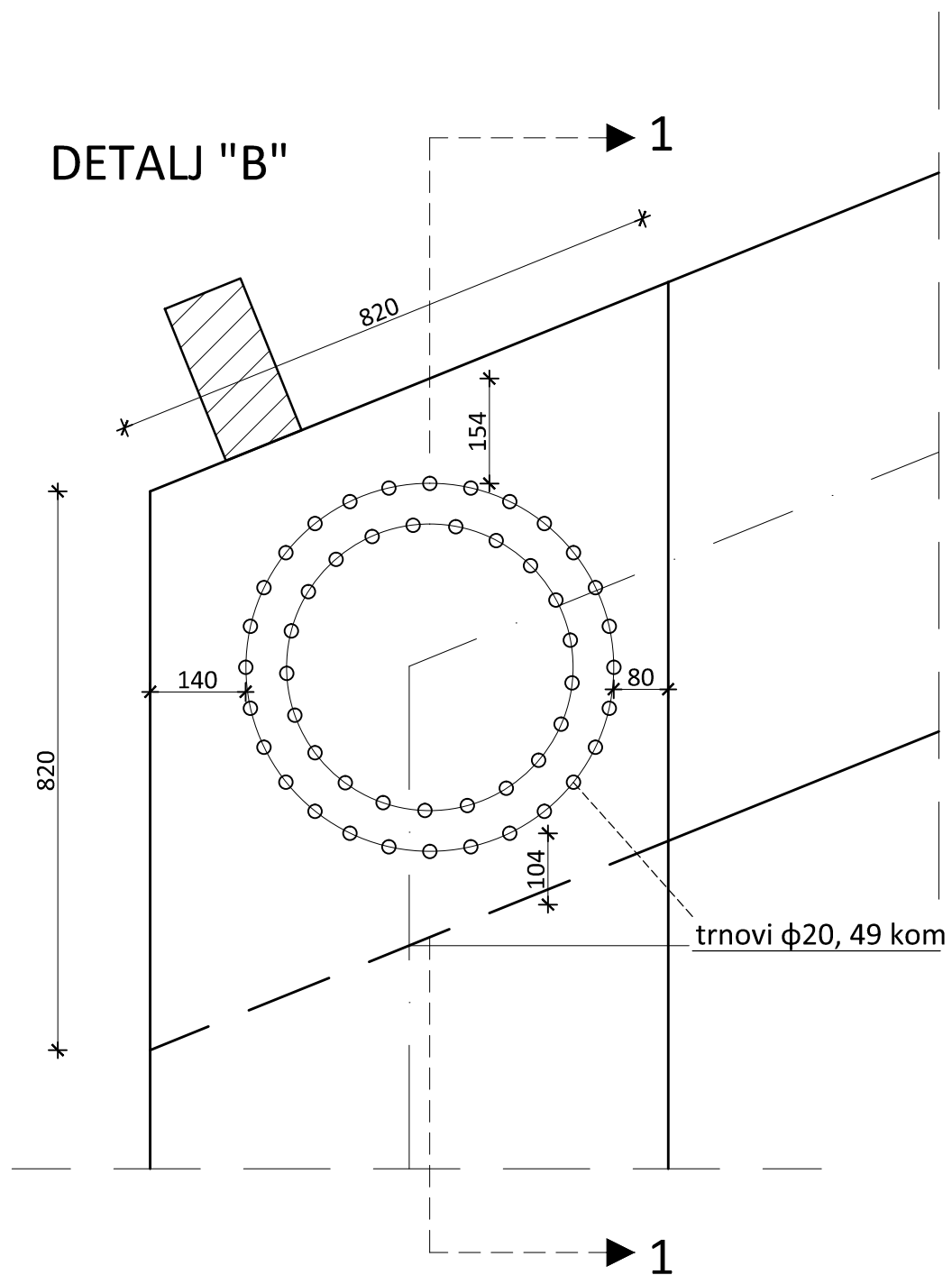
P7 30/40/10 S355 kom. 4 po spoju



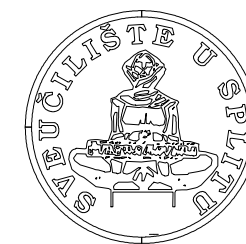
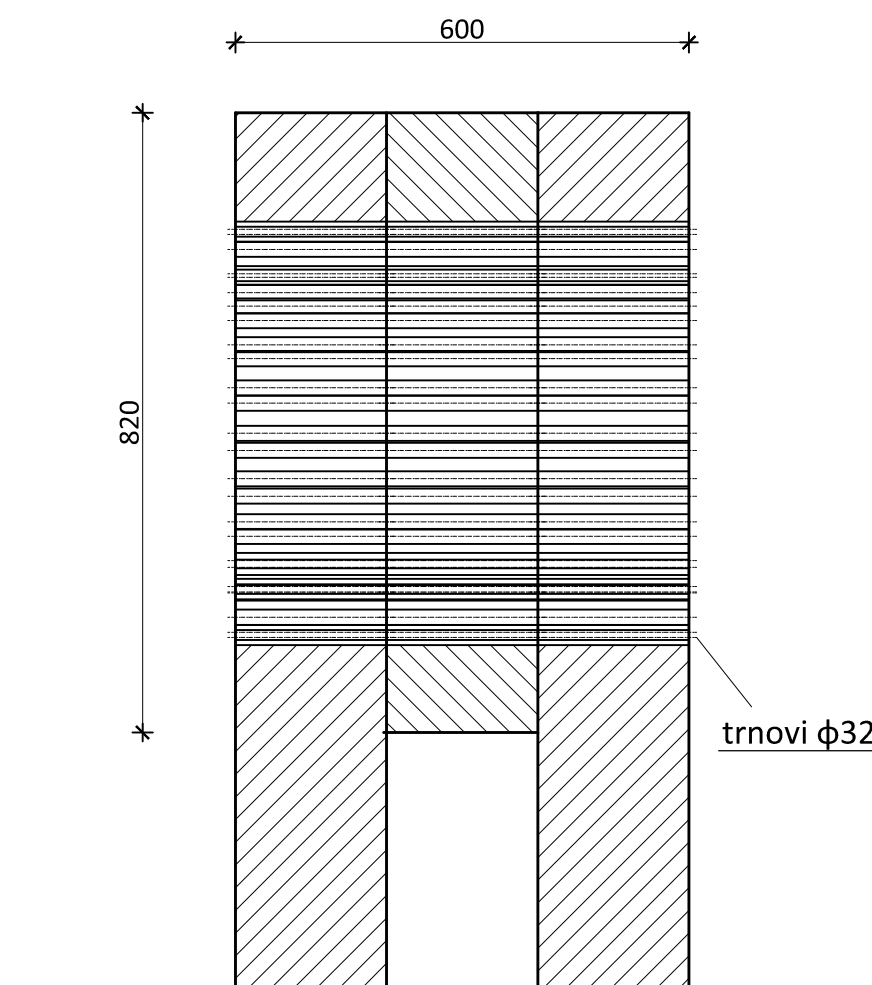
| | | |
|-------------|-----------------------------------|------------|
| | ZAVRŠNI RAD - ODK | |
| | PROGRAM: KONSTRUKCIJA DRVENE HALE | |
| | STUDENT: NIKICA KRALJEVIĆ, 4347 | |
| | SADRŽAJ: | DETALJ "A" |
| RUJAN 2018. | | 3 |

DETALJ "B"

M 1:10



POGLED 1-1



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STUDENT: NIKICA KRALJEVIĆ, 4347

SADRŽAJ: DETALJ "B"

MJERILO: 1:10

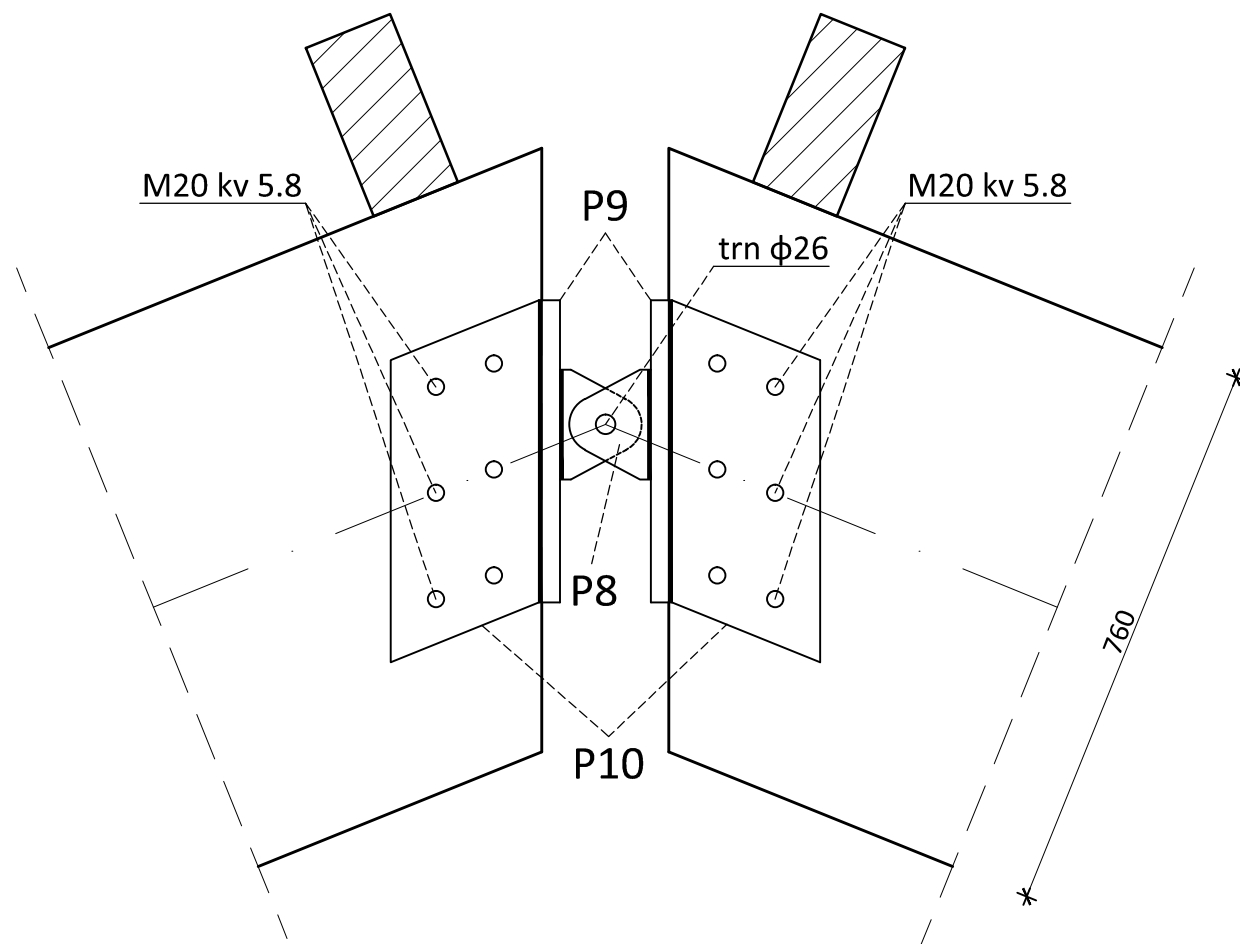
RUJAN 2018.

4

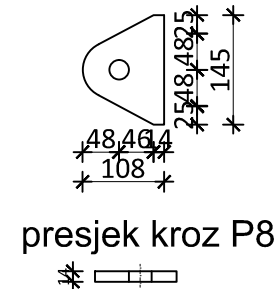
DETALJ "C"

M 1:10

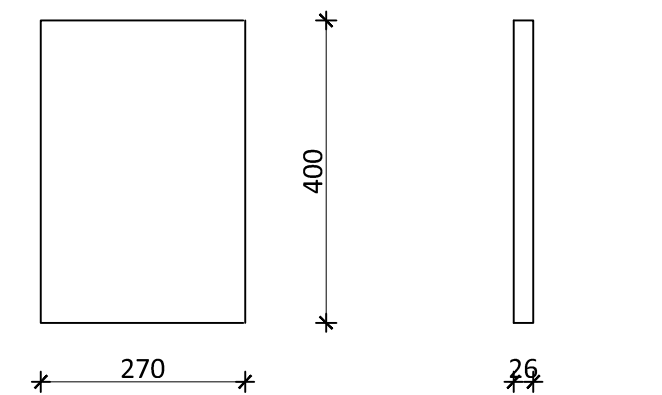
DETALJ "C"



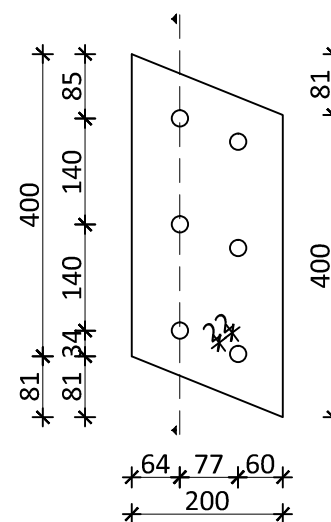
P8 S355 3 kom. po spoju



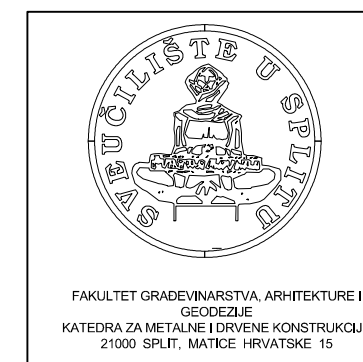
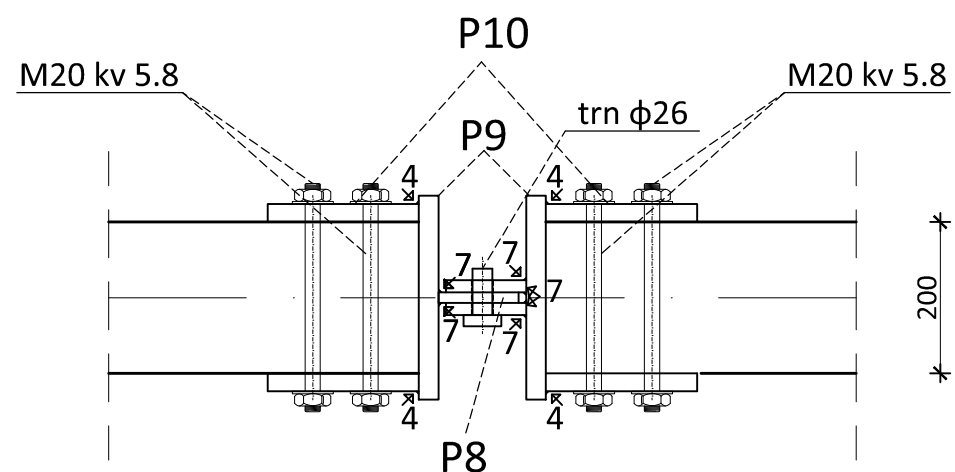
P9 270/400/26 S355
2 kom. po spoju



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

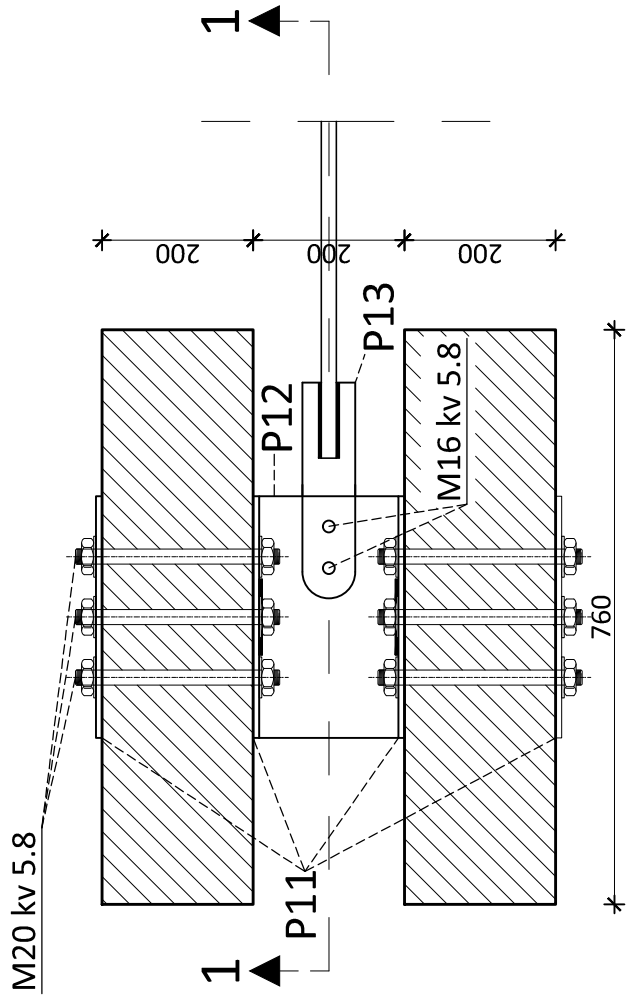


TLOCRT

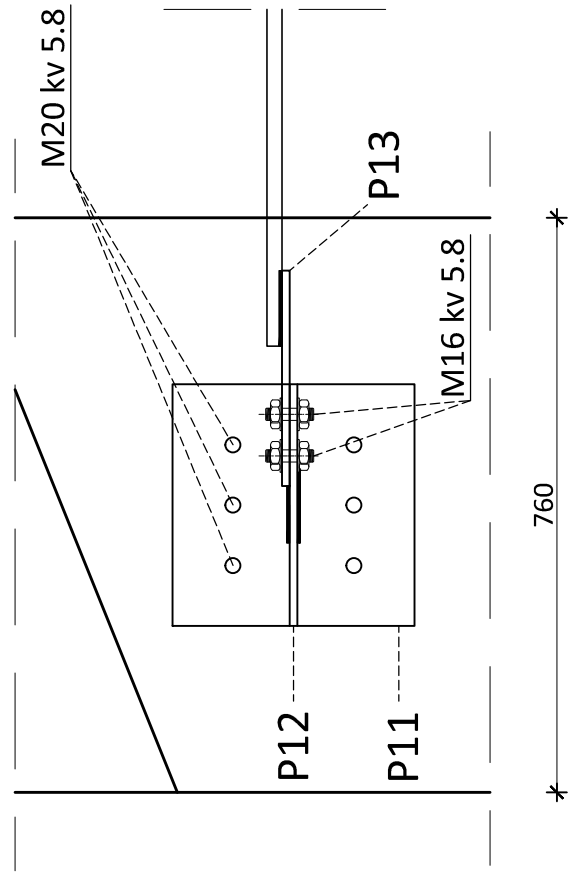


| | |
|-----------------------------------|--------------------------|
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| STUDENT: NIKICA KRALJEVIĆ, 4347 | |
| SADRŽAJ: | DETALJ "C" MJERILO: 1:10 |
| | RUJAN 2018. 5 |

DETALJ "D"

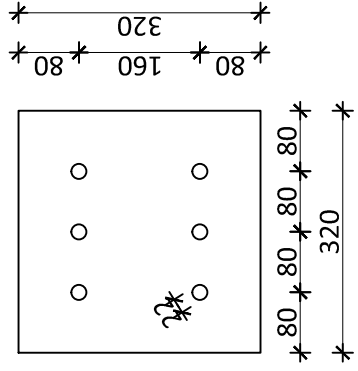


POGLED 1-1

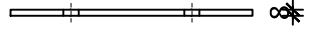


P11

320/320/8 S355
4 kom. po spoju

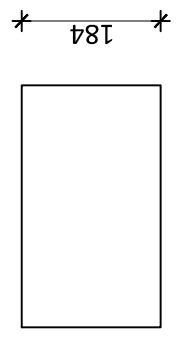


presjek kroz P14



P12

320/184/10 S355
1 kom. po spoju

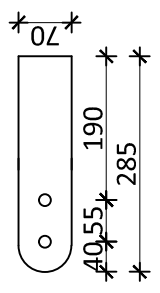


presjek kroz P12

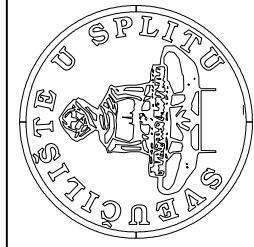
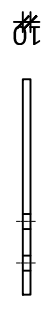


P11

285/70/10 S355
1 kom. po spoju



presjek kroz P11



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STUDENT: NIKICA KRALJEVIĆ, 4347

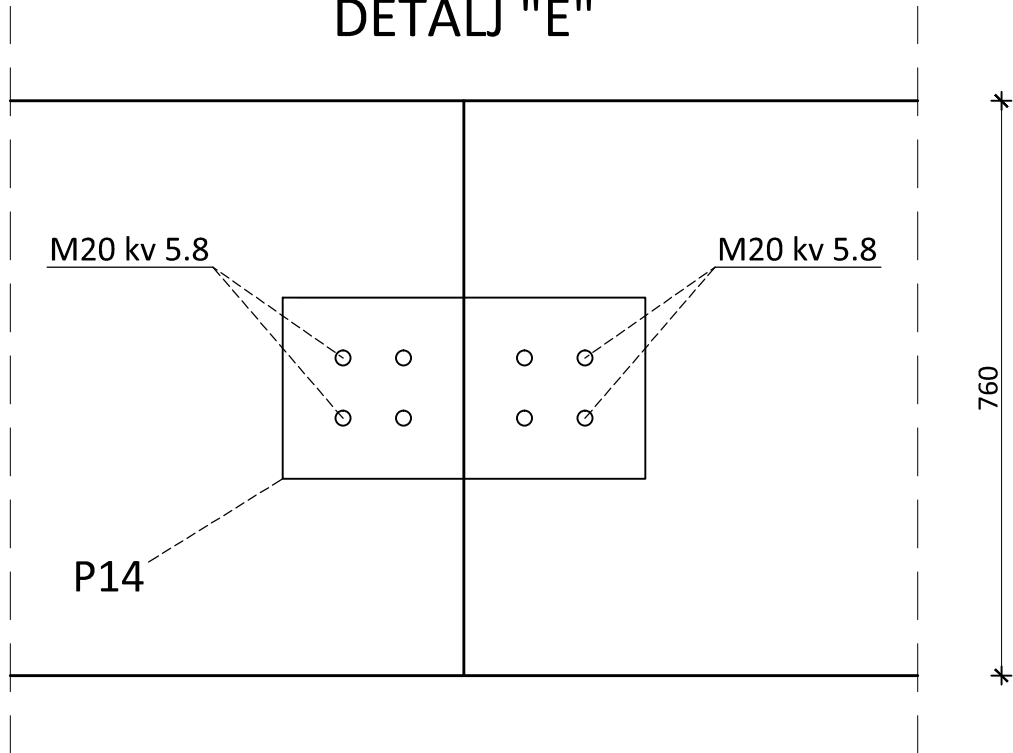
SADRŽAJ: DETALJ "A"

MJERILO: 1:10

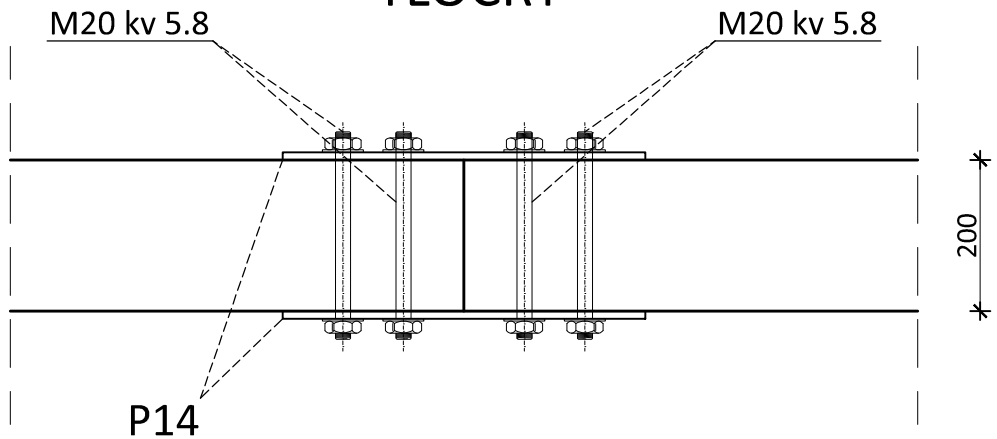
RUJAN 2018.

6

DETALJ "E"

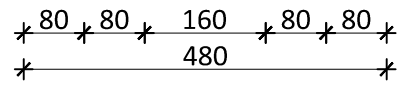
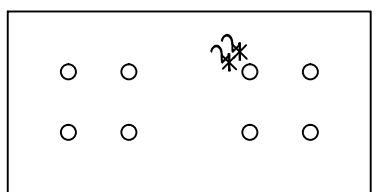


TLOCRT

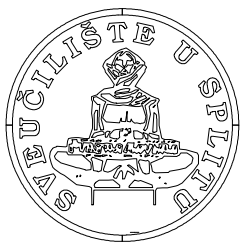
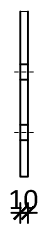


P14

480/240/10 S355
2 kom. po spoju



presjek kroz P14



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STUDENT: NIKICA KRALJEVIĆ, 4347

SADRŽAJ: DETALJ "E"

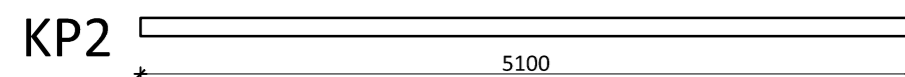
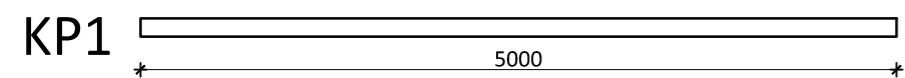
MJERILO: 1:10

RUJAN 2018.

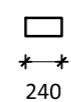
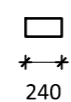
7

ISKAZ MATERIJALA M 1:50

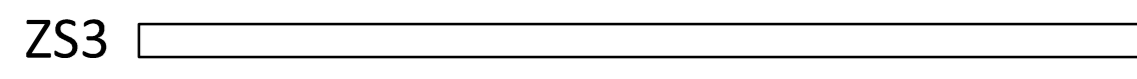
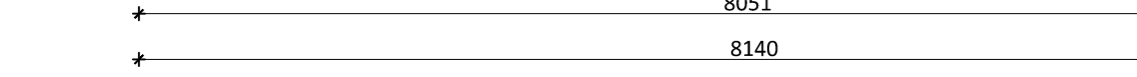
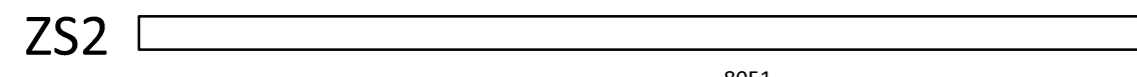
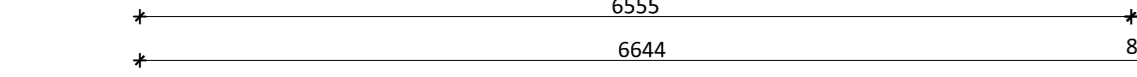
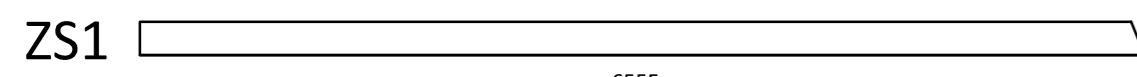
SEKUNDARNI NOSAČI NA KROVU



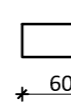
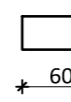
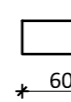
Poprečni presjek



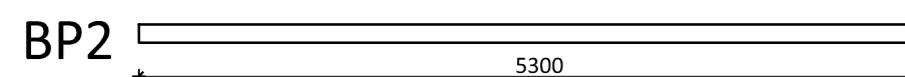
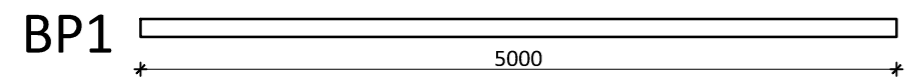
ZABATNI STUP



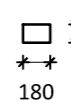
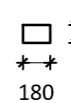
Poprečni presjek



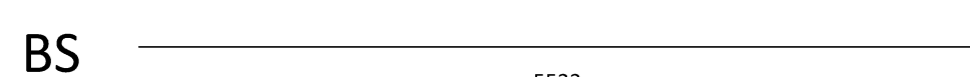
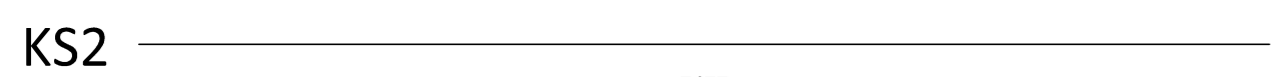
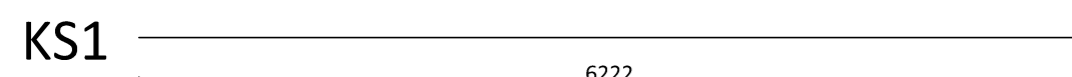
SEKUNDARNI BOČNI NOSAČI



Poprečni presjek



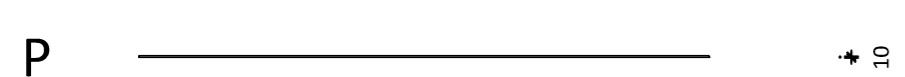
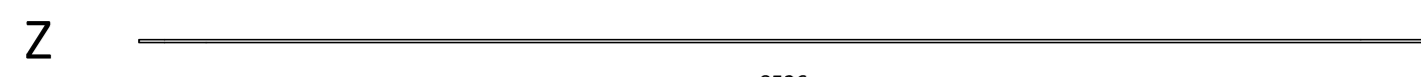
DIJAGONALE SPREGOVA



Poprečni presjek



ZATEGA I PRIDRŽANJE

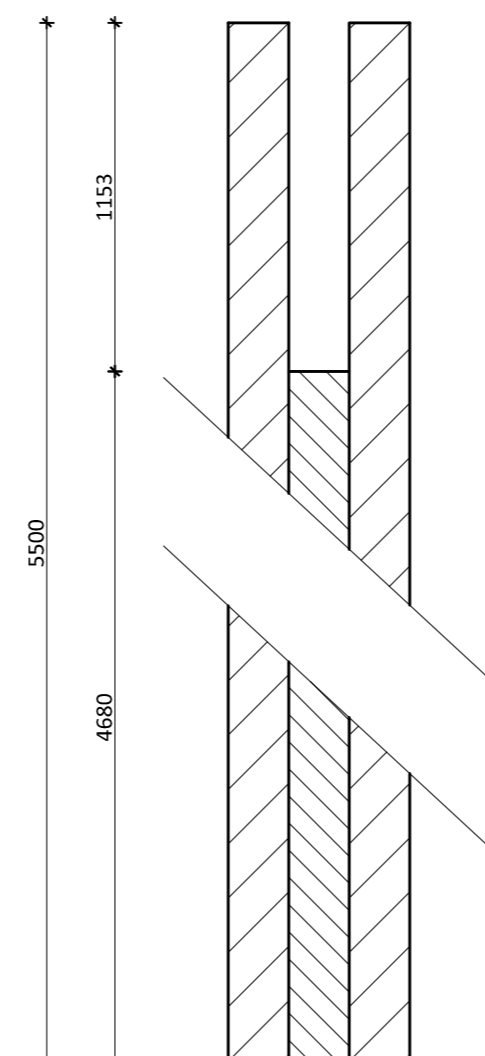


Poprečni presjek

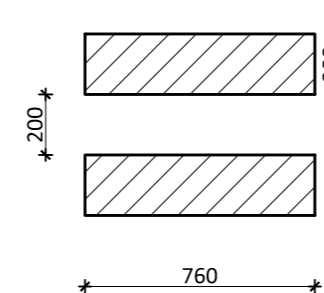


S-STUP GLAVNOG OKVIRA M 1:25

POGLED 1-1

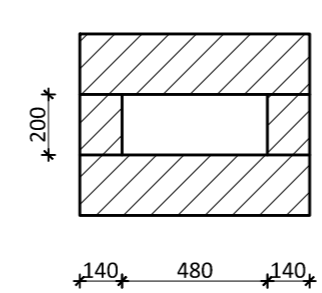


-Poprečni presjek na vrhu stupa:



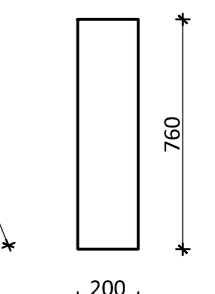
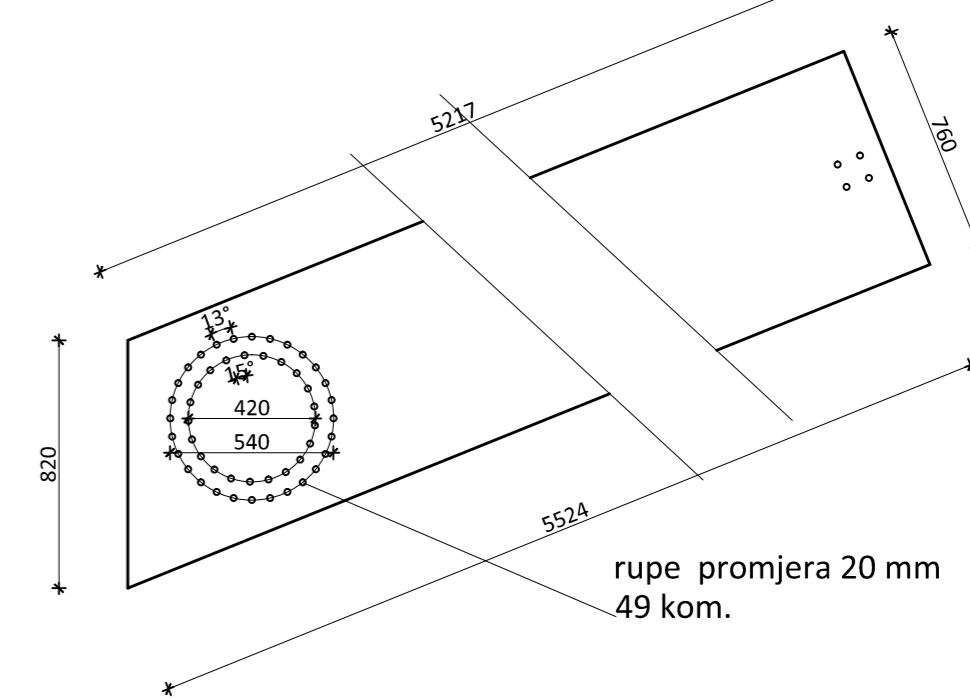
1

-Poprečni presjek na dnu stupa:



G1 -GREDA GLAVNOG OKVIRA M 1:25

Poprečni presjek

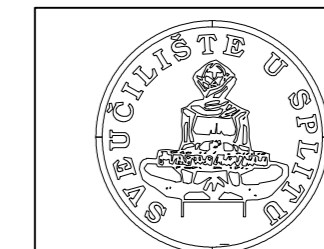
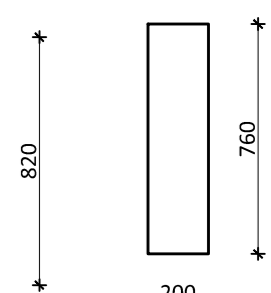


rupe promjera 20 mm 49 kom.

rupe promjera 20 mm 49 kom.

G2 -GREDA GLAVNOG OKVIRA M 1:25

Poprečni presjek



FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
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|----------|--------------------------|---------------|
| KOLEGIJ: | ZAVRŠNI RAD - ODK | |
| PROGRAM: | KONSTRUKCIJA DRVENE HALE | |
| STUDENT: | NIKICA KRALJEVIĆ, 4347 | |
| 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