Čelična i spregnuta konstrukcija poslovno - stambene zgrade

Poljak, Marija

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Sveučilište u Zagrebu

GRAĐEVINSKI FAKULTET

Poljak Marija

Čelična i spregnuta konstrukcija poslovno-stambene zgrade

DIPLOMSKI RAD

doc. dr. sc. Ivan Ćurković

Zagreb, 2024

University of Zagreb

FACULTY OF CIVIL ENGINEERING

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Steel and composite structure of the commercial and residential building

MASTER THESIS

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Građevinski fakultet

OBRAZAC 3

POTVRDA O POZITIVNOJ OCJENI PISANOG DIJELA DIPLOMSKOG RADA

Student/ica :

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(Ime i prezime)	(JMBAG)

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(Naslov teme diplomskog rada na hrvatskom jeziku)

Steel and composite structure of the commercial and residential building

(Naslov teme diplomskog rada na engleskom jeziku)

i predlaže se provođenje daljnjeg postupka u skladu s Pravilnikom o završnom ispitu i diplomskom radu Sveučilišta u Zagrebu Građevinskog fakulteta.

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Datum: 18.9.2024.

Mentor: doc.dr.sc. Ivan Ćurković

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ZAHVALA

Zahvaljujem doc.dr.sc. Ivanu Ćurkoviću na izdvojenom vremenu, prenesenom znanju i pomoći oko izrade ovog rada.

Zahvaljujem svojoj obitelji i prijateljima na podršci.

SAŽETAK

Tlocrtne dimenzije objekta su 50 m x 35 m, a objekt ima četiri razine za korištenje: prizemlje i tri kata. Svijetla visina u poslovnim prostorima na prizemlju i prvom katu mora biti najmanje 5 m dok u stambenim prostorima mora biti najmanje 3,0 m. Vanjske strane objekta obložene su staklenom fasadom. Krovna konstrukcija je čelična i prekrivena je s čeličnim profiliranim limom. Međukatnu konstrukciju potrebno je izvesti kao spregnutu, a stupove čelične. Na betonsku ploču postavlja se završni slojevi ukupne težine cca $0{,}6\ {}^{kN}/_{m^2}$. Opterećenje instalacijama iznosi $0{,}3\ {}^{kN}/_{m^2}$.

Objekt je lociran u Karlovcu. Za nosive elemente čelične konstrukcija potrebno je koristiti kvalitetu čelika S355, a za betonske beton razreda tlačne čvrstoće C30/37. Spojeve u radioničkoj izvedbi predvidjeti kao zavarene, a na montaži kao vijčane gdje god je to moguće.

Potrebno je izraditi: tehnički opis, dispozicijski nacrt, statički proračun te radioničke nacrte glavnih konstrukcijskih elemenata.

Ključne riječi: spregnuta ploča, spregnuti nosači, čelična konstrukcija, vijčani spojevi, potresni proračun

SUMMARY

The floor plan dimensions of the building are 50 m x 35 m, and the building has four levels for use: ground floor and three floors. The clear height in business premises on the ground and first floor must be at least 5 m, while in residential premises it must be at least 3.0 m. The exterior sides of the building are covered with a glass facade. The roof structure is made of steel and is covered with a steel profiled sheet. The mezzanine structure must be constructed as a coupled one, and the columns must be steel. Finishing layers with a total weight of approx. 0.60 kN/m2 are placed on the concrete slab. The installation load is 0.30 kN/m2.

The facility is located in Karlovac. Steel quality S355 should be used for load-bearing elements of steel structures, and concrete of compressive strength class C30/37 for concrete. The joints in the workshop version should be welded, and in the assembly as screwed wherever possible.

It is necessary to create: technical description, disposition plan, static calculation, and workshop plans of the main structural elements.

Key words: composite floor, composite beams, steel construction, screws connections, seizmic calculation.

SADRŽAJ

1 UVOD

Grad Karlovac postaje vojno, strateško, gospodarsko i prometno središte Hrvatske. Uz tri povijesne ceste (Karolina, Josephina i Lousiana), ima i suvremenu autocestu koja povezuje Srednju Europu i podunavske zemlje s Jadranskim morem [1]. Razvijanjem infrastrukture nastala je potreba za stambenim i poslovnim prostorima.

Izgradnjom nove spregnuto-čelične konstrukcije na 4 kata zadovoljio bi se dio trenutnih potreba za poslovnim i stambenim prostorom. Zgrada je modernog dizajna sa staklenom fasadom, tlocrtnih dimenzija 50 m x 35 m. U radu je dan statički proračun glavne nosive konstrukcije s njenom dispozicijom, te proračun karakterističnih detalja kao i njihovi nacrti.

2 METODE I TEHNIKE RADA

Prilikom izrade diplomskog rada korišteni su sljedeći programi: za izradu nacrta korišten je Autocad 2024, za potrebe statičkog proračuna konstrukcije Robot Structural Analysis Professional 2024. Prilikom proračuna detalja korišten je program IDEA StatiCa 23.1.

Proračun je rađen u skladu s europskim Eurocode normama.

3 TEHNIČKI OPIS KONSTRUKCIJE

3.1. Općenito

Napravljen je statički proračun i dimenzioniranje višestambeno-poslovne zgrade u Karlovcu. Tlocrtna dimenzija zgrade je $50{,}00\ x\ 35{,}00\ m$. Ukupna visina objekta iznosi 18 metara. Građevina se sastoji od prizemlja u kojem se nalaze poslovni prostori te 3 kata. Vertikalni transport unutar zgrade se vrši dizalom. Okolo dizala se pružaju stepenice. Svijetla visina prva dva kata iznosi 5 m, a druga dva 3 m.

3.2. Konstrukcija

Zgrada je temeljena na temeljnoj ploči debljine 30 cm. Kvaliteta čelika iznosi S355, dok je beton C30/37. Zidovi su izvedeni kao čelični nosači ispunjeni mineralnom vunom. Korišten je čelik kvalitete S355. Vanjski slojevi zida opremljeni su vatrootpornim knaufom. U kupaonicama i kuhinji nalazi se vatro i vodootporni knauf. Unutarnje uređenje nije dio ovog rada. Spojevi su u radioničkoj izvedbi zavareni, a kod montaže vijčani.

Krov je ravan i neprohodan, a izveden je od čelične konstrukcije te prekriven pertlanim limom.

Vanjska ovojnica objekta je staklena.

3.3. Proračun

Proračun unutarnjih sila, momenata savijanja i dimenzioniranje elemenata čelične konstrukcije provedeno je u skladu s Eurocodeom.

Odabir odgovarajućeg pokrova te obloga za stijene, u ovom slučaju tankostijenog lima, proveden je prema uvjetima za krajnje granično stanje i granično stanje uporabljivosti na temelju tablica nosivosti danih od proizvođača, koje su ovjerene od odgovarajuće ustanove.

Svi glavni nosivi elementi čelične konstrukcije razmatrani su kao ravninski sustavi. Analiza konstrukcije provedena je računalnim programom Autodesk Robot Structural Analysis Professional 2024.

Proračun je napravljen u skladu s dva tehnička propisa. Prvi propis je tehnički propis za čelične konstrukcije [2], a drugi tehnički propis za spregnute konstrukcije od čelika i betona [3]. Također, prilikom projektiranja korišteno je nekoliko Eurocodova. To su Eurocode 0 [4], Eurocode 1 [5], Eurocode 3 [6], Eurocode 4 [7], Eurocode 8 [8],

3.4. Karakteristike materijala

Za izvedbu konstruktivnih elemenata korišten je beton razreda C30/37. Kvaliteta čelika za nosive čelične elemente iznosi S355.

U nastavku su prikazana svojstva odabranih materijala, njihove karakteristične i proračunske vrijednosti. Za beton i nenapetu armaturu očitana u HRN EN 1992-1-1:2013. Proračunske vrijednosti čvrstoća materijala dobivene su množenjem karakterističnih parcijalnim faktorima sigurnosti za materijal koji su prikazani u sljedećoj tablici.

Beton: C30/37

$f_{ck} = 30\ {}^{N}/_{mm^2}$ – karakteristična tlačna čvrstoća betona nakon 28 dana

$f_{ctm} = 2{,}90\ {}^{N}/_{mm^2}$ – srednja vlačna čvrstoća betona

$E_{cm} = 33\ 000\ {}^{N}/_{mm^2}$ – sekantni modul elastičnosti

$f_{cd} = 2{,}0\ {}^{kN}/_{cm^2}$ – proračunska čvrstoća betona

$$f_{cd} = \alpha_{cc} * \frac{f_{ck}}{\gamma_c} = 1{,}0 * \frac{30}{1{,}5} = 20{,}0\ {}^{N}/_{mm^2} = 2{,}0\ {}^{kN}/_{cm^2}$$

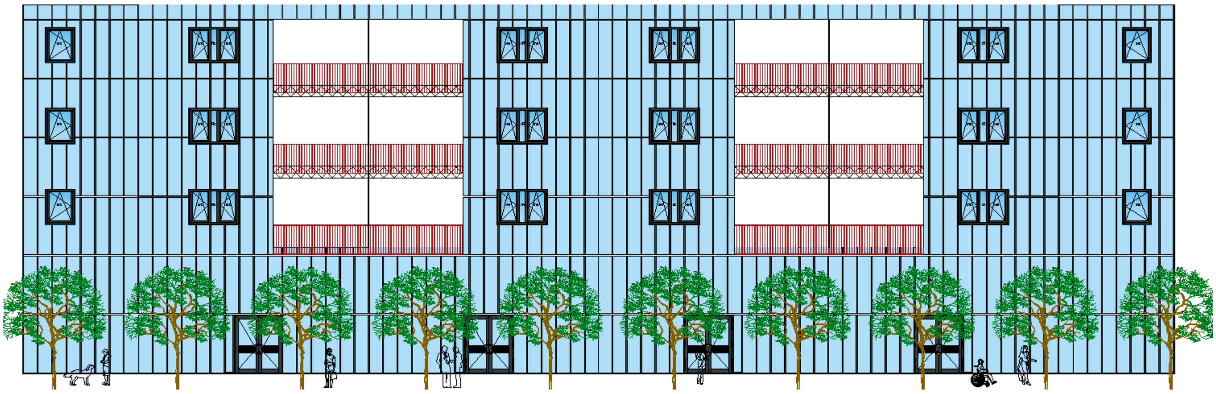
α_{cc} – koeficijent dugotrajnih učinaka na čvrstoću

3.5. Antikorozivna zaštita

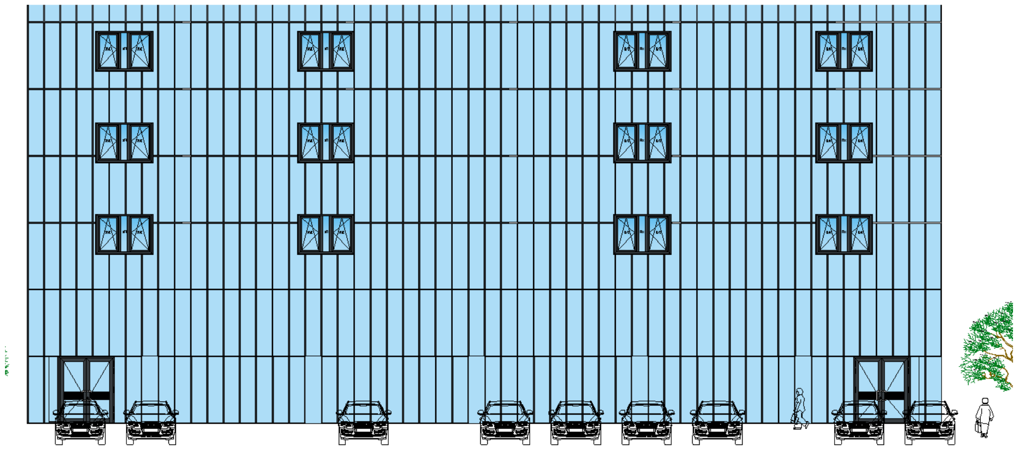
Elementi čelične konstrukcije radionički se štite s jednim temeljnim premazom na prethodno opjeskarenoj podlozi do čistoće Sa. Nakon završene montaže potrebno je popraviti sva oštećenja temeljnog radioničkog premaza. Nakon odmašćivanja površine nanosi se drugi temeljni premaz. Debljina temeljnih premaza na organskoj osnovi iznosi 2×30 μm. Završna obrada propisana je prikazom mjera zaštite od požara sredstvima s karakteristikom F30

3.6. Protupožarna zaštita

Zahtijevana vatrootpornost elemenata čelične konstrukcije je F30. Stoga se na podlogu od dva temeljna premaza nanosi zaštitno protupožarno sredstvo s karakteristikom vatrootpornosti F30 te kompatibilno s temeljnom antikorozijskom zaštitom.



Slika 1. Sjeverno i južno pročelje zgrade



Slika 2. Istočno i zapadno pročelje zgrade

4 GLOBALNA ANALIZA OPTEREĆENJA

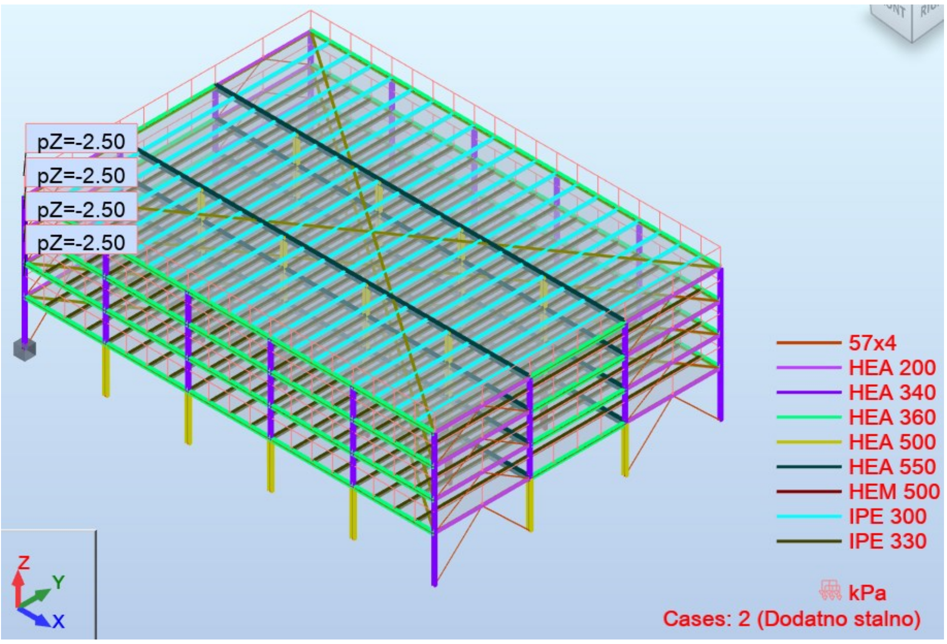
4.1. Vlastita težina nosivih elemenata

Stalno opterećenje konstrukcije sastoji se od vlastite težine konstrukcije.

Vlastita težina konstrukcije:	računa softver
Ukupno:	računa softver

4.2. Dodatno stalno opterećenje

Težina slojeva poda:	2,50 kN/m^2
Ukupno:	2,50 kN/m^2

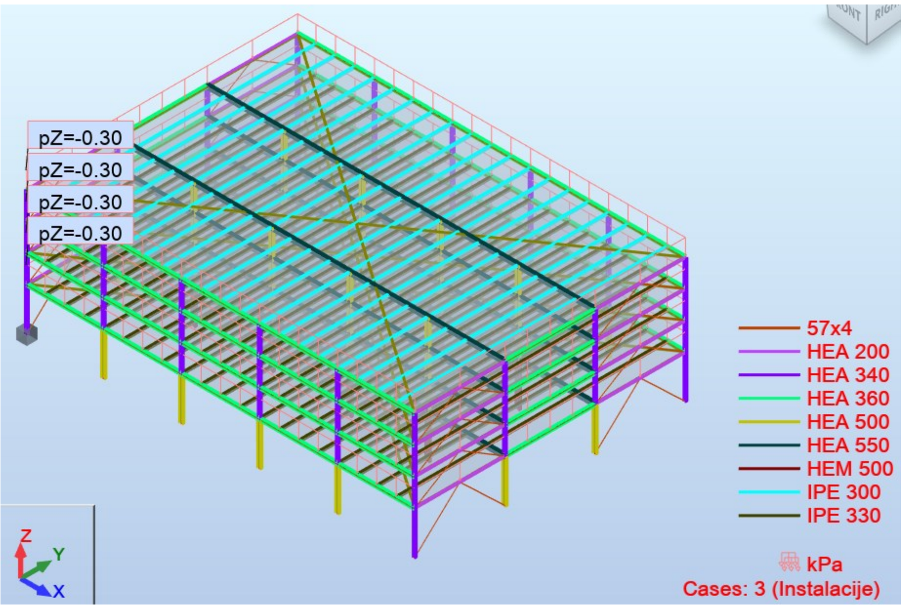


Slika 3. Prikaz dodatnog stalnog opterećenja

4.3. Opterećenje instalacijama

Opterećenje instalacijama se razmatra kao zaseban slučaj jer nisu nužno prisutne tijekom izgradnje.

Težina instalacija:	$0{,}30\ kN/m^2$
Ukupno:	$0{,}30\ kN/m^2$



Slika 4. Prikaz opterećenja instalacijama

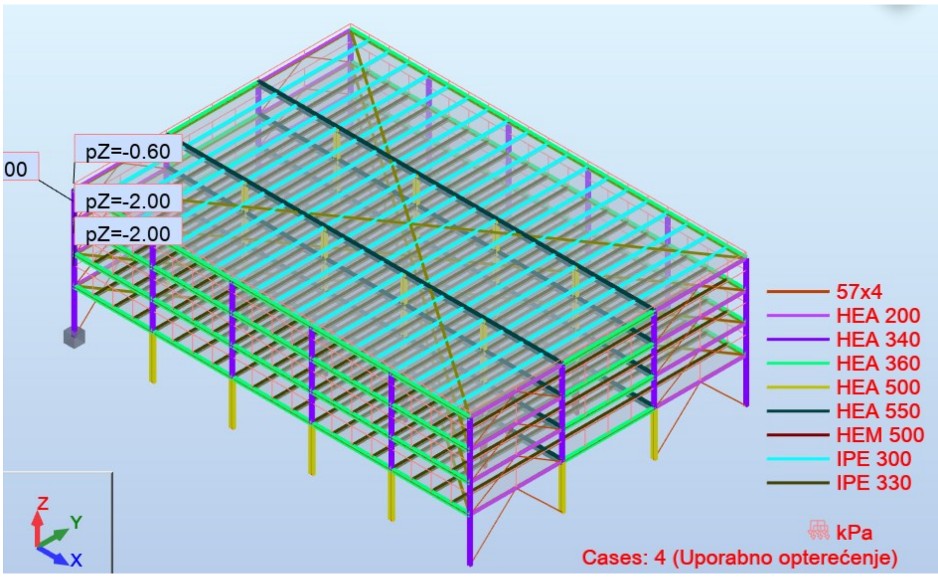
4.3. Uporabno opterećenje

Uporabna opterećenja su promjenjeiva opterećenja koja ovise o namjeni prostora. Zadaju se kao jednolika opterećenja s mogućim koncentriranim opterećenjima. Promatrana građevina nema koncentriranih uporabnih opterećenja.

Za poslovne prostore ono iznosi $3{,}00\ {}^{kN}/_{m^2}$, dok za stambeni dio iznosi $2{,}00\ {}^{kN}/_{m^2}$. Uporabno opterećenje za neprohodne krovove iznosi $0{,}60\ {}^{kN}/_{m^2}$,

Rezred uporabne površine	$q_k\ [kN/m^2]$	$Q_k\ [kN]$
A – stambene prostorije, odjeli u bolnicama, hotelske sobe		
Uobičajene prostorije	2,0	2,0
Stubišta	3,0	2,0
Balkoni	4,0	2,0
B – uredi		
Uredske prostorije	3,0	2,0
C – prostorije u kojima je moguće okupljanje ljudi		
C1 prostorije sa stolovima (škole, kavane, restorani, čitaonice, recepcije)	3,0	4,0
C2 prostorije sa nepomičnim stolovima (crkve, kina, predavaonice, čekaonice, konferencijske dvorane)	4,0	4,0
C3 prostorije bez prepreka za kretanje ljudi (izloženi prostori, pristupni prostori javnim zgradama, bolnicama, željezničkim stanicama)	5,0	4,0
C4 prostorije za fizičke aktivnosti (plesne dvorane, gimnastičarske dvorane, pozornice)	5,0	7,0
C5 prostorije za velika okupljanje ljudi (koncertne dvorane, športske dvorane)	5,0	4,0
D – prodajne prostorije		
D1 prostorije u tgovinama	5,0	4,0
D2 prostorije u trgovinama na veliko	5,0	7,0
E – prostorije sa mogućnošću gomilanja robe i stvari		
Prostorije za skladištenje[1]	6,0	7,0
F – površine za lagana vozila $\leq 30\ [kN]$	2,0	10,0
G – površine za lagana vozila $> 30\ [kN]\ \leq 160\ [kN]$	5,0	45,0
H – neprohodni krovovi osim za održavanje i popravak		
Nagib < 20° *	0,75	1,5
Nagib > 40° *	0,0	1,5
I – prohodne krovne površine	Opterećenja po razredima A-G	
K – krovne površine za specijalne namjene (heliodrom)	Opterećenja se utvrđuje za svaki pojedini slučaj	
[1]najmanja propisana opterećenja ako nije utvrđeno veće, *linearna interpolacija za među vrijednosti		

Slika 5. Karakteristične vrijednosti uporabnog opterećenja (Izvor [9])



Slika 6. Prikaz uporabnog opterećenja

4.4. Snijeg

Opterećenje snijegom je gravitacijsko djelovanje promjenjiva karaktera. Opterećenje snijegom na krovu dobiva se prema izrazu:

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

gdje je:

s_k – karakteristično opterećenje snijegom na tlu koje ovisi geografskoj lokaciji i nadmorskoj visini

μ_i – koeficijent oblika opterećenja snijegom na krovu koji ovisi o tipu i nagibu krova,

C_e – koeficijent izloženosti koji uzima u obzir uvjete puhanja vjetra

C_t – toplinski koeficijent koji uzima u obzir topljenje snijega uslijed zagrijavanja zgrade

Građevina je svrstana u II. područje djelovanja snijega na nadmorskoj visini od 112 m.

Za karakteristično opterećenje snijegom na tlu očitana je vrijednost : $s_k = 1{,}25\ kN/m^2$

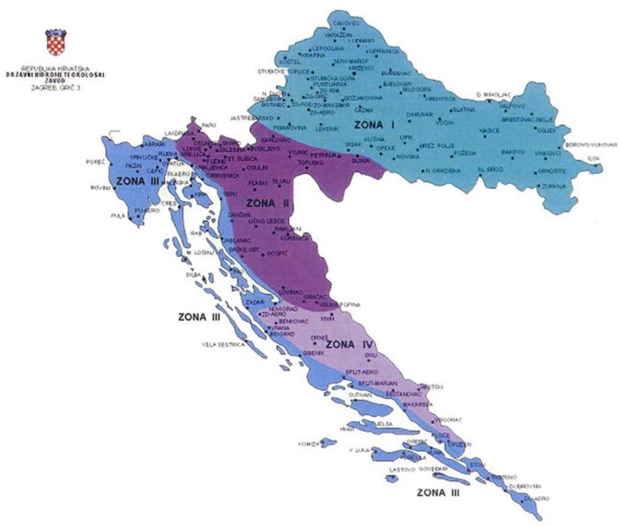
Koeficijent oblika za dvostrešni krov s nagibom krova $\alpha = 4^o$ iznosi: $\mu_i = 0{,}80$

Koeficijent izloženosti: $C_e = 1{,}0$

Toplinski koeficijent: $C_t = 1{,}0$

Ukupno promjenjivo opterećenje zbog snijega:

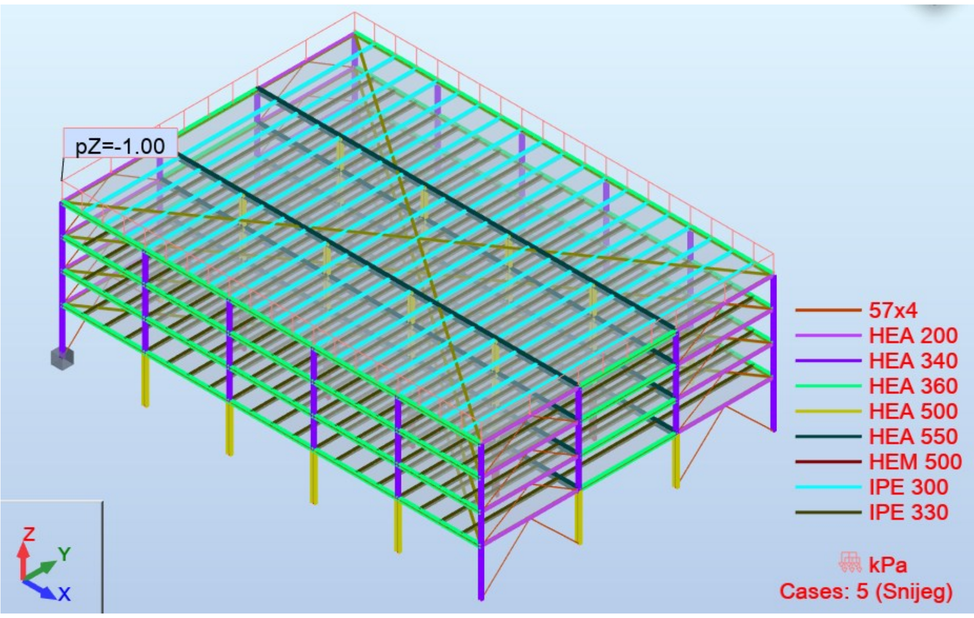
$$s = 0{,}80 \cdot 1{,}0 \cdot 1{,}0 \cdot 1{,}25 = 1{,}00\ kN/m^2$$



Slika 7. Klimatske zone za karakteristično opterećenje snijegom za razdoblje 1961-1990. [10]

Nadmorska visina do (m)	A područje	B područje	C područje	D područje
100	1,10	1,10	0,45	0,35
200	1,30	1,40	0,80	0,50
300	1,55	1,75	1,20	0,70
400	1,80	2,20	1,65	0,90
500	2,05	2,65	2,15	1,15
600	2,35	3,15	2,70	
700	2,65	3,70	3,30	
800	2,95	4,25	3,95	
900	3,25	4,90	4,65	
1000	3,60	5,55	5,40	
1100	3,95	6,25	6,20	
1200	4,30	7,00	7,05	
1300	--	7,80	7,95	
1400	--	8,65	8,90	
1500	--	9,50	9,90	
1600	--	10,40	10,95	
1700	--	11,40	12,05	
1800	--	--	13,20	

Slika 8. Karakteristično opterećenje snijegom u zonama u ovisnosti o nadmorskoj visini [10]



Slika 9. Prikaz opterećenja snijegom

4.5. Vjetar

Djelovanje vjetra je promjenjivo tijekom vremena, a djeluje ili okomito na površinu na koju puše ili paralelno s površinom duž koje puše aktivirajući trenje po samoj površini građevine.

Vjetar djeluje izravno kao tlak na vanjske površine zatvorene konstrukcije i zbog propusnosti vanjske površine djeluje neizravno na unutarnje površine.

Karakteristični pritisak vjetra određuje se na temelju osnovne brzine vjetra, v_b, i gustoće zraka, ρ, prema izrazu:

$$q_b = \frac{1}{2} \cdot \rho \cdot v_b^2 = \frac{1}{2} \cdot 1{,}25 \cdot 20^2 \cdot 10^{-3} = 0{,}25\ kN/m^2$$

Tlak vjetra koji djeluje na vanjsku površinu građevine određuje se prema izrazu:

$$w_e = q_b \cdot c_e(z_e) \cdot c_{pe}$$

Tlak vjetra koji djeluje na unutarnju površinu građevine određuje se prema izrazu:

$$w_i = q_b \cdot c_e(z_i) \cdot c_{pi}$$

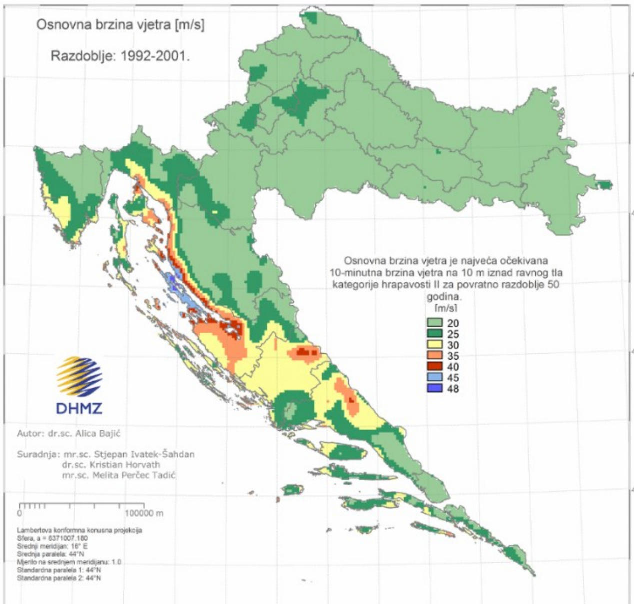
Oznake u gornjim izrazima imaju sljedeće značenje:

q_b – tlak pri osnovnoj brzini vjetra

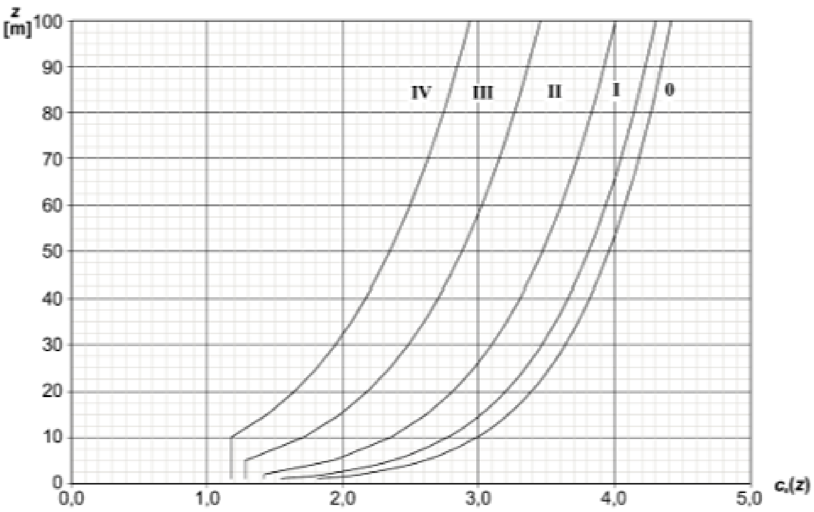
$c_e(z)$ – faktor izloženosti koji uzima u obzir hrapavost terena, topografiju i visinu iznad tla

z_e i z_i – referentne visine za vanjski i unutarnji tlak

c_{pe} i c_{pi} – koeficijenti vanjskog i unutarnjeg tlaka

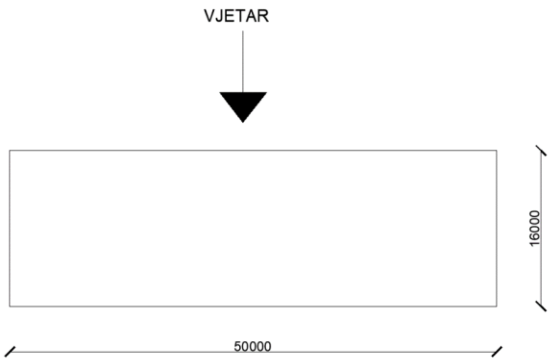


Slika 10. Osnovna brzina vjetra [10]

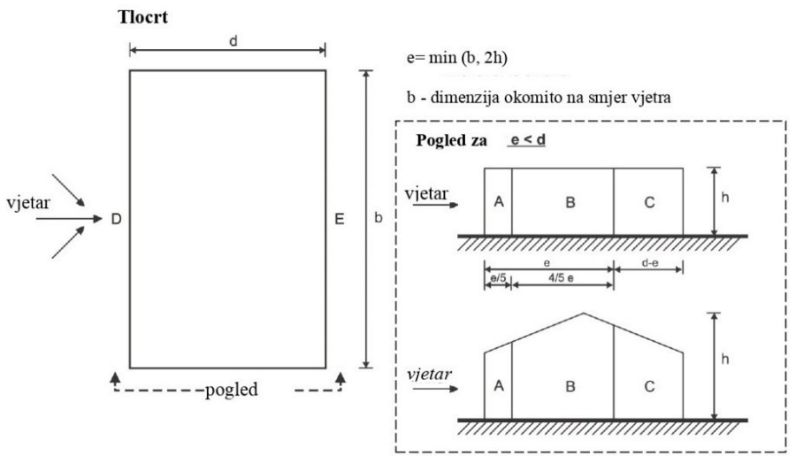


Slika 11. Koeficijent izloženosti [9]

Slučaj I- vjetar puše na poprečnu stranu objekta



Slika 12. Grafički prikaz slučaja I,II,III



Slika 13. Prikaz površina zgrade

Vanjski pritisak na vertikalne stijene

Koeficijent izloženosti za teren III. kategorije (normalna vegetacija, šume i predgrađa) iznosi:

Referentna visina: $z_e = h = 16\ m$

Koeficijent izloženosti: $c_e(z) = 2{,}05$

Koeficijent pritiska na vertikalne stijene:

$e = \min\{b; 2h\} = \min\{35;\ 32\} = 32{,}00\ m$

b – dimenzija okomita na smjer vjetar

$d = 50{,}0\ m$

$d > e \quad 50 > 32$

$\frac{h}{d} = \frac{16}{50{,}0} = 0{,}32$

Tablica 1. Određivanje veličine vertikalnih površina (slučaj I)

Površina A	$\frac{e}{5} \cdot h$	$102{,}4\ m^2$
Površina B	$\frac{4e}{5} \cdot h$	$409{,}6\ m^2$
Površina D	$b \cdot h$	$800\ m^2$
Površina E	$b \cdot h$	$800\ m^2$

Tablica 2.Koeficijenti vanjskog tlaka za pripadne vertikalne površine (slučaj I)

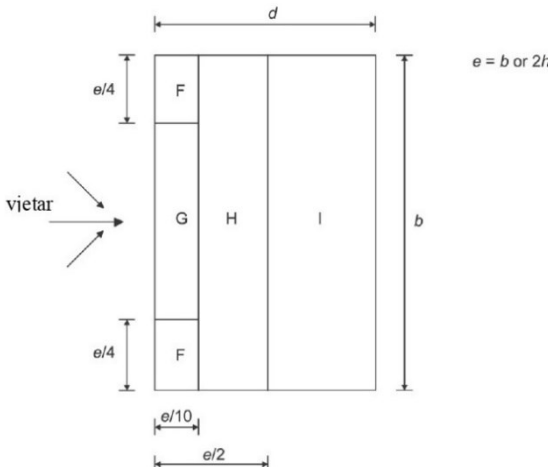
Površina A	$c_{pe,A}$	$-1{,}20$
Površina B	$c_{pe,B}$	$-0{,}80$
Površina D	$c_{pe,D}$	$+0{,}8$
Površina E	$c_{pe,E}$	$-0{,}50$

$w_e = q_b \cdot c_e(z) \cdot c_{pe}$

Tablica 3.Djelovanje vjetra na vertikalne površine (slučaj I)

Djelovanje vjetra na površinu A	$w_{e,A} = q_b \cdot c_e(z) \cdot c_{pe,A}$	$-0{,}615\ kN/m^2$
Djelovanje vjetra na površinu B	$w_{e,B} = q_b \cdot c_e(z) \cdot c_{pe,B}$	$-0{,}410\ kN/m^2$
Djelovanje vjetra na površinu D	$w_{e,D} = q_b \cdot c_e(z) \cdot c_{pe,D}$	$+0{,}410\ kN/m^2$
Djelovanje vjetra na površinu E	$w_{e,E} = q_b \cdot c_e(z) \cdot c_{pe,E}$	$-0{,}256\ kN/m^2$

<u>Vanjski pritisak na krovnu plohu</u>



Slika 14. Prikaz krovnih površina

Tablica 4.Određivanje veličina krovnih površina (slučaj I)

Površina F	$\frac{e}{10} \cdot \frac{e}{4}$	$25{,}6\ m^2$
Površina G	$\frac{e}{10} \cdot \left(b - \frac{e}{2}\right)$	$108{,}8\ m^2$
Površina H	$b \cdot \left(\frac{e}{2} - \frac{e}{10}\right)$	$640\ m^2$
Površina I	$b \cdot \left(d - \frac{e}{2}\right)$	$950\ m^2$

Tablica 5.Koeficijenti vanjskog tlaka za pripadne krovne površine (slučaj I)

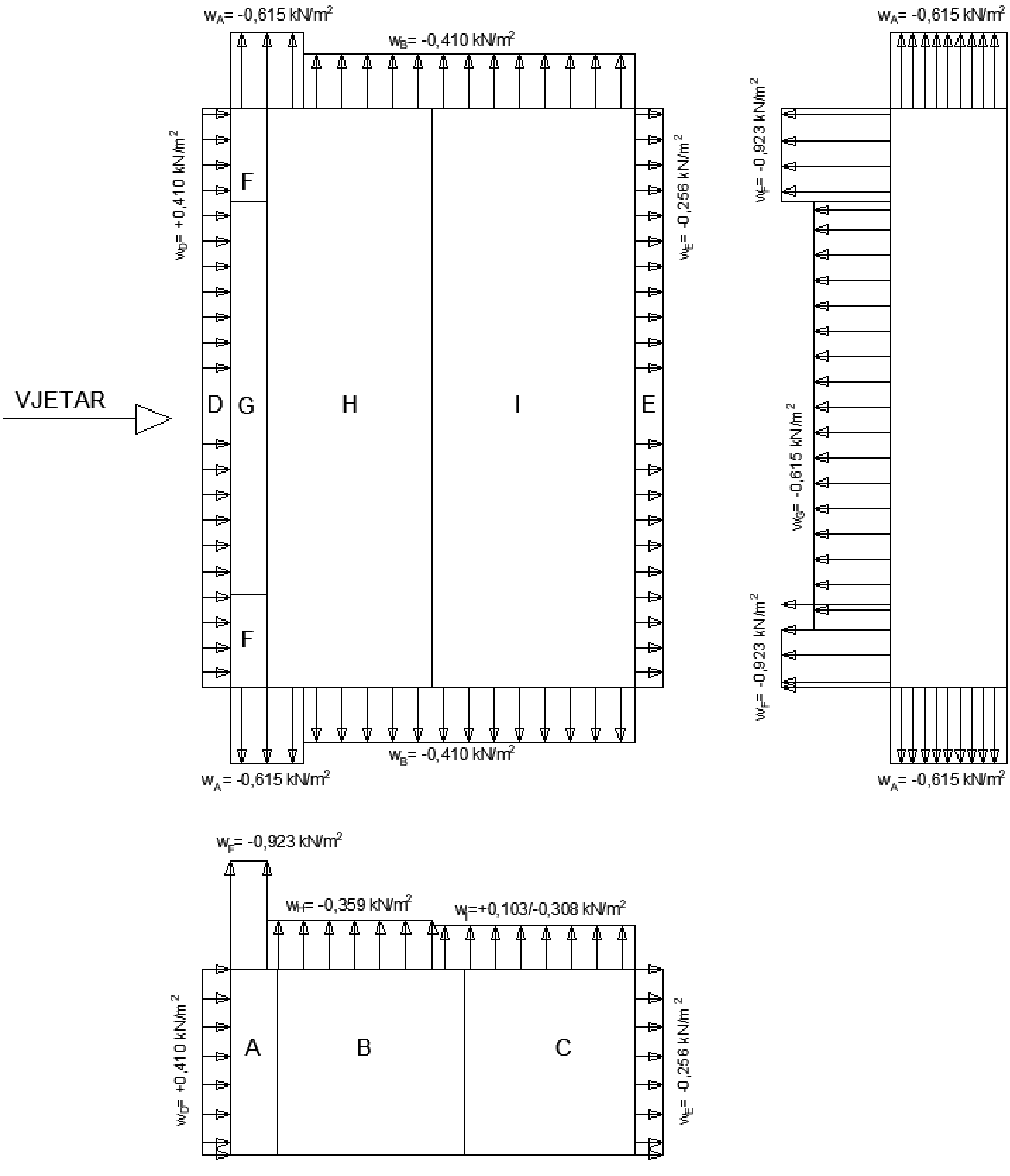
Površina F	$c_{pe,F}$	$-1,80$
Površina G	$c_{pe,G}$	$-1,20$
Površina H	$c_{pe,H}$	$-0,70$
Površina I	$c_{pe,I}$	$+0,2$
Površina I	$c_{pe,I}$	$-0,60$

Tablica 6.Djelovanje vjetra na krovne površine (slučaj I)

Djelovanje vjetra na površinu F	$w_{e,F} = q_b \cdot c_e(z) \cdot c_{pe,F}$	$-\ 0,923\ kN/m^2$
Djelovanje vjetra na površinu G	$w_{e,G} = q_b \cdot c_e(z) \cdot c_{pe,G}$	$-\ 0,615\ kN/m^2$
Djelovanje vjetra na površinu H	$w_{e,H} = q_b \cdot c_e(z) \cdot c_{pe,H}$	$-0,359\ kN/m^2$
Djelovanje vjetra na površinu I	$w_{e,I} = q_b \cdot c_e(z) \cdot c_{pe,I}$	$+\ 0,103\ kN/m^2$
Djelovanje vjetra na površinu I	$w_{e,I} = q_b \cdot c_e(z) \cdot c_{pe,I}$	$-\ 0,308\ kN/m^2$

Tablica 7. Ukupni pritisak vjetra

Površina A	$w_{i,A} = w_{e,A} - w_i$	$-\ 0,615\ kN/m^2$
Površina B	$w_{i,B} = w_{e,B} - w_i$	$-\ 0,410\ kN/m^2$
Površina C	$w_{i,C} = w_{e,C} - w_i$	$-\ 0,256\ kN/m^2$
Površina D	$w_{i,D} = w_{e,D} - w_i$	$+\ 0,410\ kN/m^2$
Površina E	$w_{i,E} = w_{e,E} - w_i$	$-\ 0,256\ kN/m^2$
Površina F	$w_{i,F} = w_{e,F} - w_i$	$-\ 0,923\ kN/m^2$
Površina G	$w_{i,G} = w_{e,G} - w_i$	$-\ 0,615\ kN/m^2$
Površina H	$w_{i,H} = w_{e,H} - w_i$	$-\ 0,359\ kN/m^2$
Površina I	$w_{i,I} = w_{e,I} - w_i$	$+\ 0,103\ kN/m^2$
	$w_{i,I} = w_{e,I} - w_i$	$-\ 0,308\ kN/m^2$



Slika 15. Prikaz opterećenja vjetrom za slučaj I

Slučaj II- vjetar puše na poprečnu stranu objekta, cpi=0,2

Vanjski pritisak na vertikalne stijene

Vanjski pritisak na vertikalne stijene i vanjski pritisak na krovnu plohu isti je kao u točki *„Slučaj 1 – vjetar puše na uzdužnu stranu objekta.“*

Vanjski pritisak na krovnu plohu

Vanjski pritisak na krovnu plohu isti je kao u točki *„Slučaj 1 – vjetar puše na uzdužnu stranu objekta.“*

Unutarnji pritisak

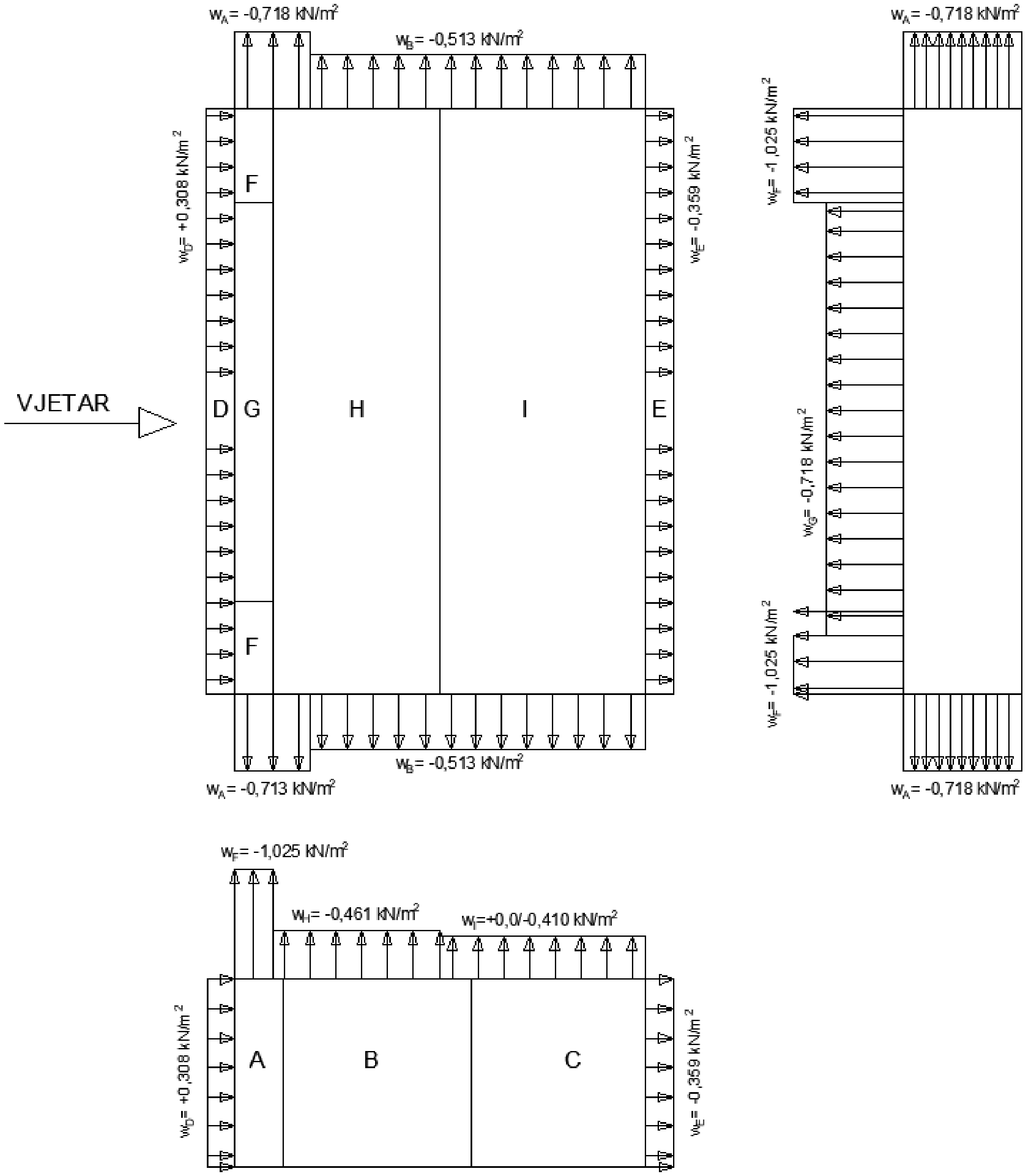
$$w_i = q_b \cdot c_e(z_i) \cdot c_{pi} = 0{,}53 \cdot 1{,}20 \cdot 0{,}20 = +0{,}103\ kN/m^2$$

Ukupni pritisak

Tlak na površinu je algebarski zbroj unutarnjeg i vanjskog tlaka.

Tablica 8. Ukupni pritisak na plovršine za slučaj II

Ukupni pritisak na površinu A	$w_{i,A} = w_{e,A} - w_i$	$-0{,}718\ kN/m^2$
Ukupni pritisak na površinu B	$w_{i,B} = w_{e,B} - w_i$	$-0{,}513\ kN/m^2$
Ukupni pritisak na površinu C	$w_{i,C} = w_{e,C} - w_i$	$-0{,}359\ kN/m^2$
Ukupni pritisak na površinu D	$w_{i,D} = w_{e,D} - w_i$	$+0{,}308\ kN/m^2$
Ukupni pritisak na površinu E	$w_{i,E} = w_{e,E} - w_i$	$-0{,}359\ kN/m^2$
Ukupni pritisak na površinu F	$w_{i,F} = w_{e,F} - w_i$	$-1{,}025\ kN/m^2$
Ukupni pritisak na površinu G	$w_{i,G} = w_{e,G} - w_i$	$-0{,}718\ kN/m^2$
Ukupni pritisak na površinu H	$w_{i,H} = w_{e,H} - w_i$	$-0{,}461\ kN/m^2$
Ukupni pritisak na površinu I	$w_{i,I} = w_{e,I} - w_i$	$0\ kN/m^2$
Ukupni pritisak na površinu I	$w_{i,I} = w_{e,I} - w_i$	$-0{,}410\ kN/m^2$



Slika 16. Prikaz opterećenja vjetrom za slučaj II

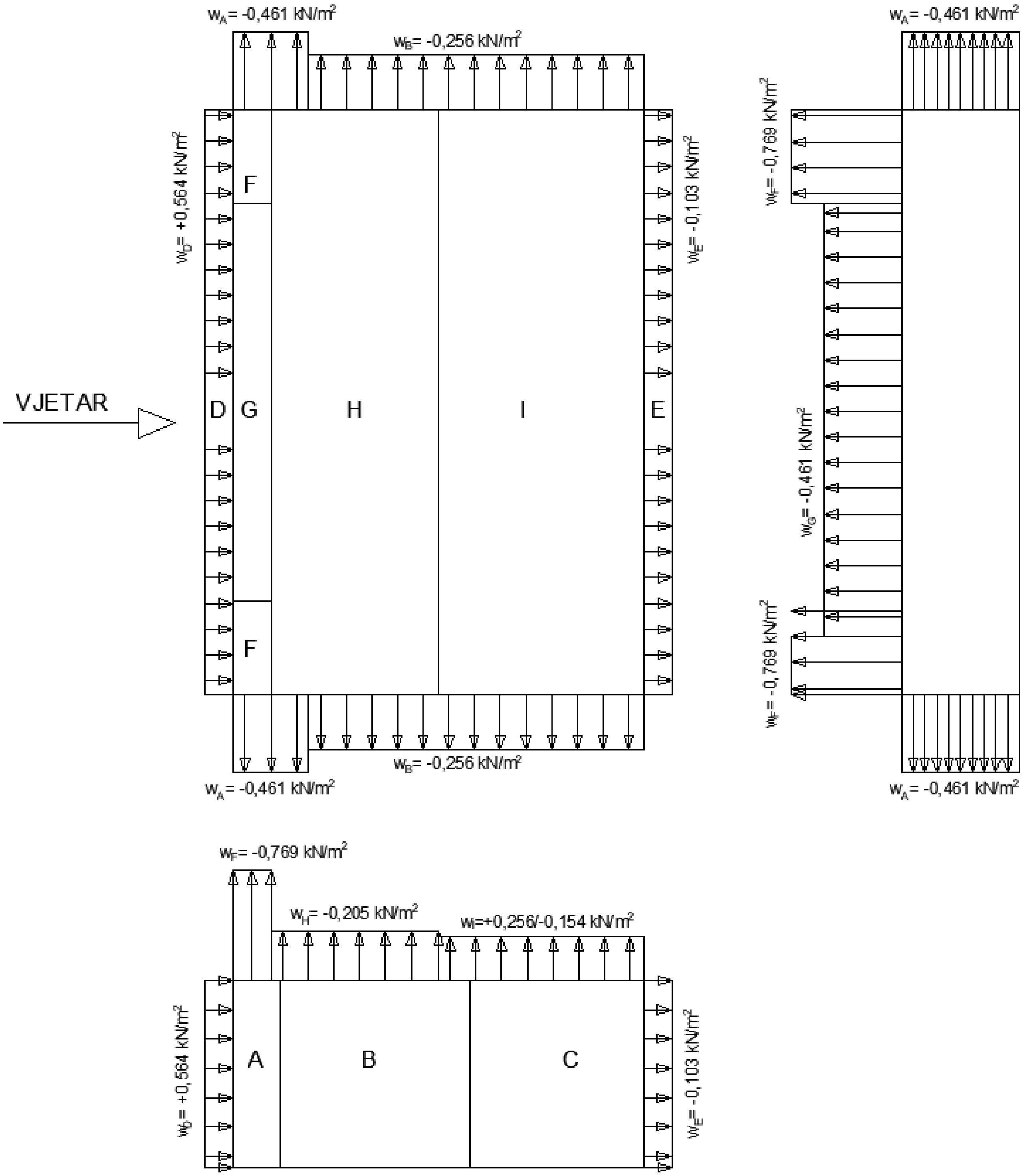
Slučaj III- vjetar puše na poprečnu stranu objekta, cpi=-0,3

<u>Ukupni pritisak</u>

Tlak na površinu je algebarski zbroj unutarnjeg i vanjskog tlaka.

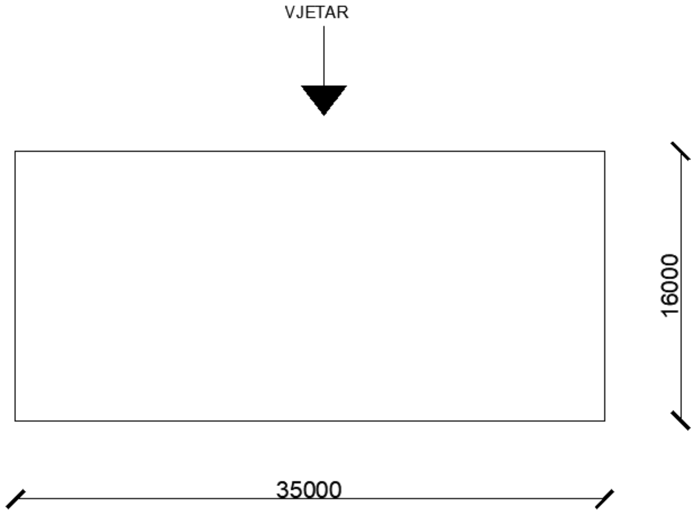
Tablica 9. Ukupni pritisak na površine za slučaj III

Ukupni pritisak na površinu A	$w_{i,A} = w_{e,A} - w_i$	$-0{,}416\ kN/m^2$
Ukupni pritisak na površinu B	$w_{i,B} = w_{e,B} - w_i$	$-0{,}256\ kN/m^2$
Ukupni pritisak na površinu C	$w_{i,C} = w_{e,C} - w_i$	$-0{,}103\ kN/m^2$
Ukupni pritisak na površinu D	$w_{i,D} = w_{e,D} - w_i$	$+0{,}564\ kN/m^2$
Ukupni pritisak na površinu E	$w_{i,E} = w_{e,E} - w_i$	$-0{,}103\ kN/m^2$
Ukupni pritisak na površinu F	$w_{i,F} = w_{e,F} - w_i$	$-0{,}769\ kN/m^2$
Ukupni pritisak na površinu G	$w_{i,G} = w_{e,G} - w_i$	$-0{,}461\ kN/m^2$
Ukupni pritisak na površinu H	$w_{i,H} = w_{e,H} - w_i$	$-0{,}205\ kN/m^2$
Ukupni pritisak na površinu I	$w_{i,I} = w_{e,I} - w_i$	$+\ 0{,}256\ kN/m^2$
Ukupni pritisak na površinu I	$w_{i,I} = w_{e,I} - w_i$	$-0{,}154\ kN/m^2$



Slika 17. Prikaz opterećenja vjetrom za slučaj III

Slučaj IV- vjetar puše na uzdužnu stranu objekta



Slika 18. Grafički prikaz slučaja IV,V,VI

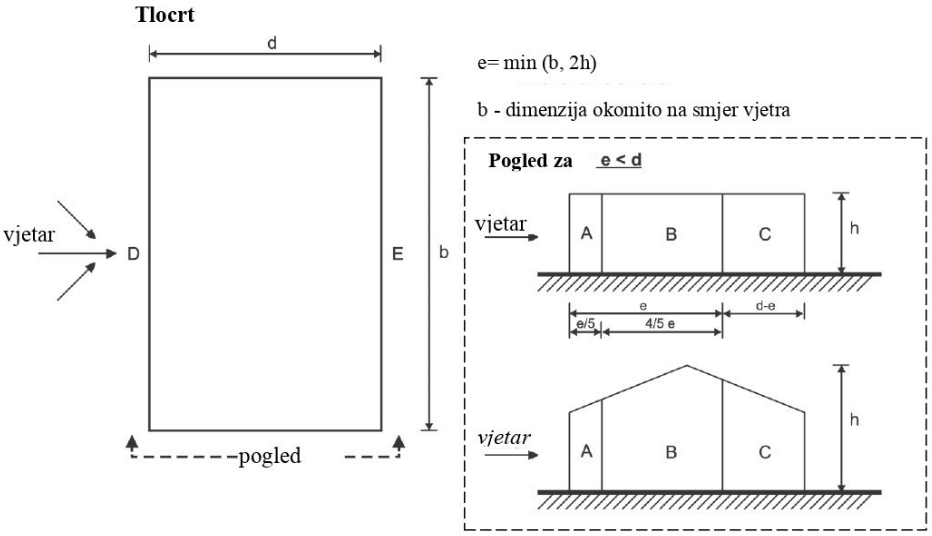
Koeficijent pritiska na vertikalne stijene:

$e = \min\{b; 2h\} = \min\{50;\ 32\} = 32\ m$

b – dimenzija okomita na smjer vjetar

$d = 35{,}0\ m \qquad \rightarrow \qquad d > e \qquad 35 > 32$

$$\frac{h}{d} = \frac{16}{50{,}00} = 0{,}320$$



Tablica 10. Određivanje veličine vertikalnih površina

Površina A	$\frac{e}{5} \cdot h$	$102{,}4\ m^2$
Površina B	$\frac{4e}{5} \cdot h$	$409{,}6\ m^2$
Površina C	$(d-e) \cdot h$	$288\ m^2$
Površina D	$b \cdot h$	$560\ m^2$
Površina E	$b \cdot h$	$560\ m^2$

Tablica 11.Koeficijenti vanjskog tlaka za pripadne vertikalne površine

Površina A	$c_{pe,A}$	$-1{,}20$
Površina B	$c_{pe,B}$	$-0{,}80$
Površina C	$c_{pe,C}$	$-0{,}50$
Površina D	$c_{pe,D}$	$+0{,}7$
Površina E	$c_{pe,E}$	$-0{,}3$

Tablica 12. Djelovanje vjetra na vertikalne površine

Djelovanje vjetra na površinu A	$w_{e,A} = q_b \cdot c_e(z) \cdot c_{pe,A}$	$-0{,}615\ kN/m^2$
Djelovanje vjetra na površinu B	$w_{e,B} = q_b \cdot c_e(z) \cdot c_{pe,B}$	$-0{,}410\ kN/m^2$
Djelovanje vjetra na površinu C	$w_{e,C} = q_b \cdot c_e(z) \cdot c_{pe,C}$	$-0{,}256\ kN/m^2$
Djelovanje vjetra na površinu D	$w_{e,D} = q_b \cdot c_e(z) \cdot c_{pe,D}$	$+0{,}410\ kN/m^2$
Djelovanje vjetra na površinu E	$w_{e,E} = q_b \cdot c_e(z) \cdot c_{pe,E}$	$-0{,}154\ kN/m^2$

Tablica 13. Određivanje veličina krovnih površina

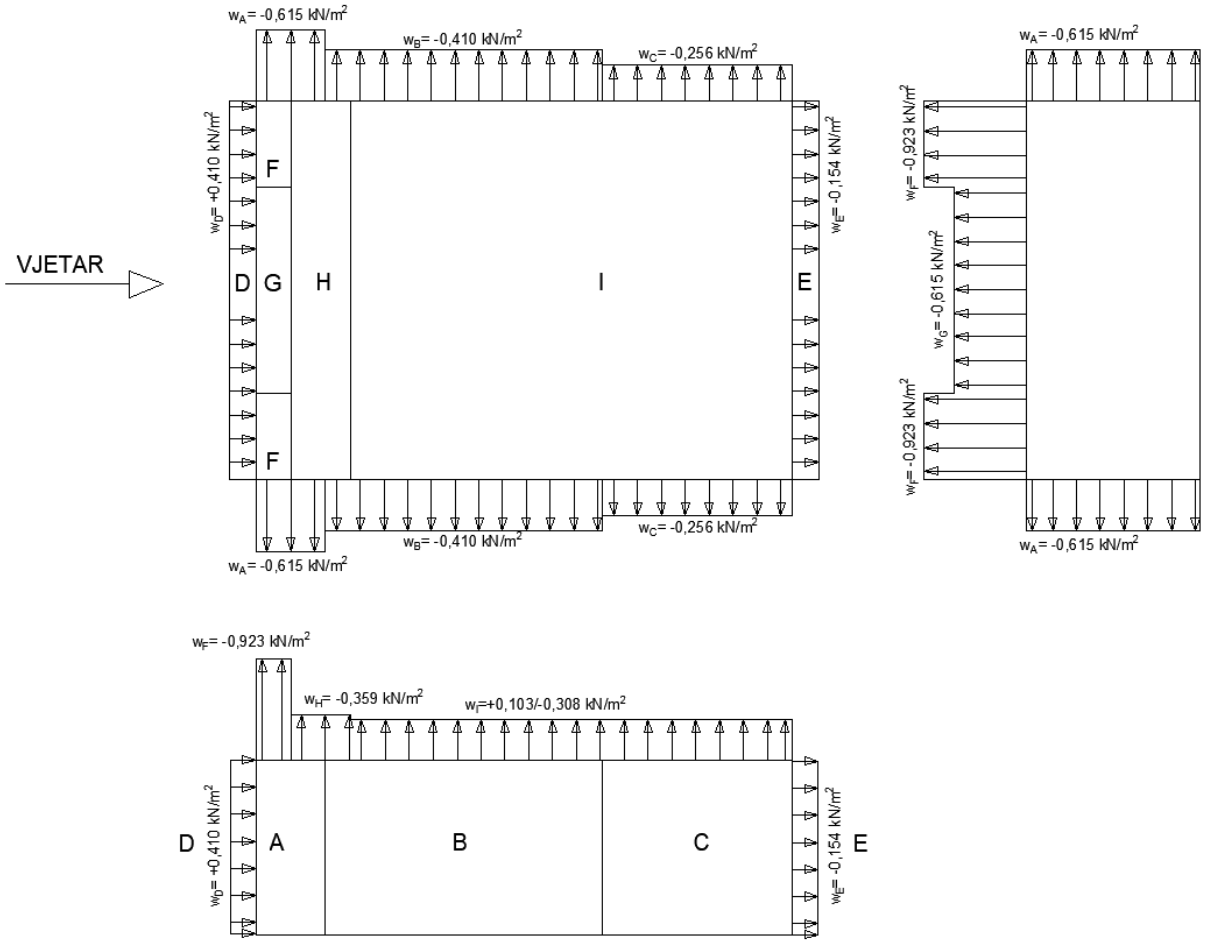
Površina F	$\frac{e}{10} \cdot \frac{e}{4}$	$25{,}60\ m^2$
Površina G	$\frac{e}{10} \cdot \left(b - \frac{e}{2}\right)$	$60{,}80\ m^2$
Površina H	$b \cdot \left(\frac{e}{2} - \frac{e}{10}\right)$	$448{,}00\ m^2$
Površina I	$b \cdot \left(d - \frac{e}{2}\right)$	$1190{,}00\ m^2$

Tablica 14. Koeficijenti vanjskog tlaka za pripadne krovne površine

Površina F	$c_{pe,F}$	$-1{,}80$
Površina G	$c_{pe,G}$	$-1{,}20$
Površina H	$c_{pe,H}$	$-0{,}70$
Površina I	$c_{pe,I}$	$+0{,}2$
Površina I	$c_{pe,I}$	$-0{,}60$

Tablica 15. Djelovanje vjetra na vertikalne površine

Djelovanje vjetra na površinu F	$w_{e,F} = q_b \cdot c_e(z) \cdot c_{pe,F}$	$-0{,}923\ kN/m^2$
Djelovanje vjetra na površinu G	$w_{e,G} = q_b \cdot c_e(z) \cdot c_{pe,G}$	$-0{,}615\ kN/m^2$
Djelovanje vjetra na površinu H	$w_{e,H} = q_b \cdot c_e(z) \cdot c_{pe,H}$	$-0{,}359\ kN/m^2$
Djelovanje vjetra na površinu I	$w_{e,I} = q_b \cdot c_e(z) \cdot c_{pe,I}$	$+0{,}103\ kN/m^2$
Djelovanje vjetra na površinu I	$w_{e,I} = q_b \cdot c_e(z) \cdot c_{pe,I}$	$-0{,}308\ kN/m^2$



Slika 19. Prikaz opterećenja vjetrom za slučaj IV

Slučaj V- vjetar puše na uzdužnu stranu objekta, cpi=0,2

Vanjski pritisak na vertikalne stijene

Vanjski pritisak na vertikalne stijene i vanjski pritisak na krovnu plohu isti je kao u točki „*Slučaj IV – vjetar puše na uzdužnu stranu objekta.*"

Vanjski pritisak na krovnu plohu

Vanjski pritisak na krovnu plohu isti je kao u točki „ *Slučaj 1 – vjetar puše na uzdužnu stranu objekta.*"

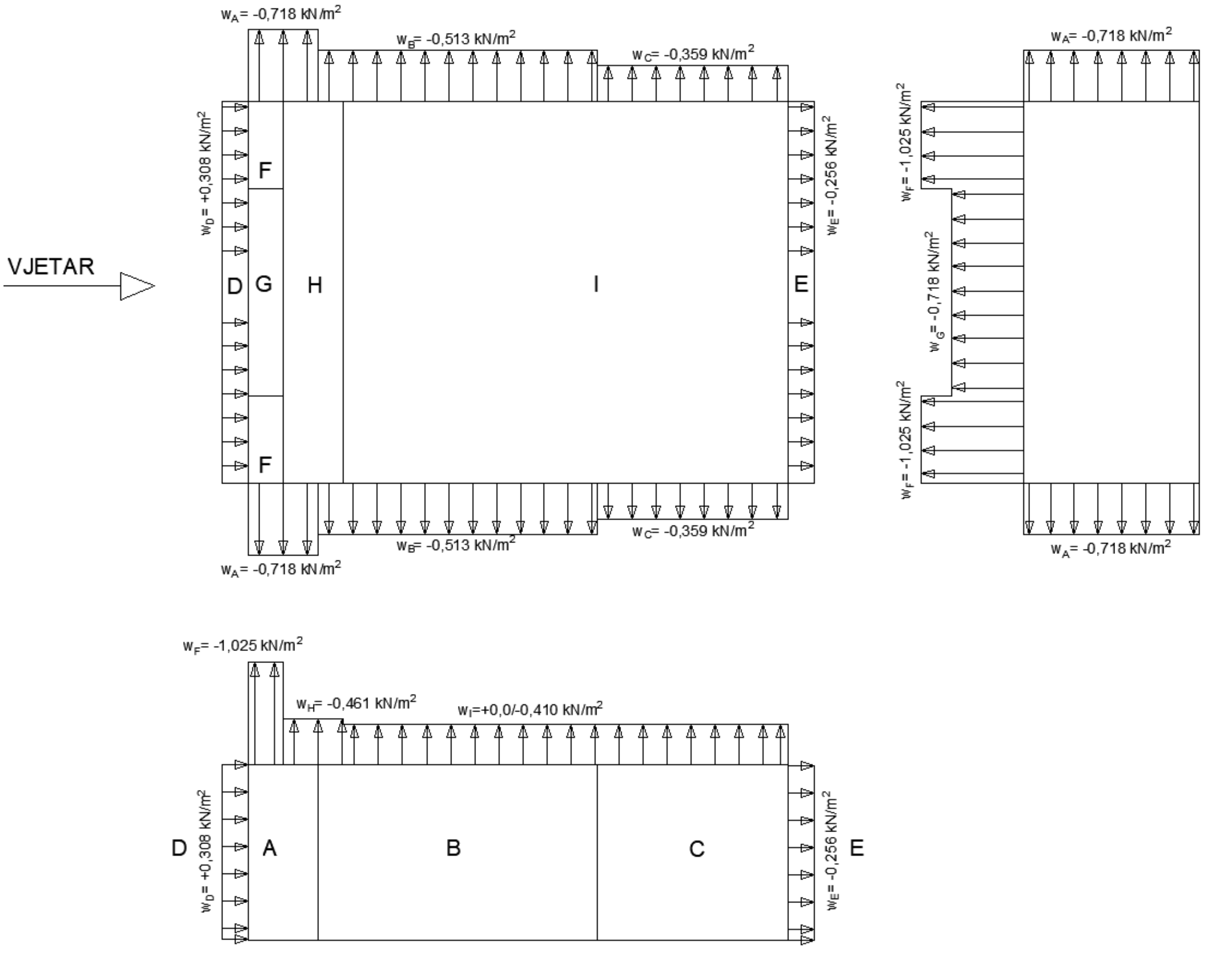
Unutarnji pritisak

$$w_i = q_b \cdot c_e(z_i) \cdot c_{pi} = 0{,}53 \cdot 1{,}20 \cdot 0{,}20 = +0{,}103\ kN/m^2$$

Tlak na površinu je algebarski zbroj unutarnjeg i vanjskog tlaka.

Tablica 16. Ukupni pritisak

Ukupni pritisak na površinu A	$w_{i,A} = w_{e,A} - w_i$	$-0{,}718\ kN/m^2$
Ukupni pritisak na površinu B	$w_{i,B} = w_{e,B} - w_i$	$-0{,}513\ kN/m^2$
Ukupni pritisak na površinu C	$w_{i,C} = w_{e,C} - w_i$	$-0{,}359\ kN/m^2$
Ukupni pritisak na površinu D	$w_{i,D} = w_{e,D} - w_i$	$+0{,}308\ kN/m^2$
Ukupni pritisak na površinu E	$w_{i,E} = w_{e,E} - w_i$	$-0{,}256\ kN/m^2$
Ukupni pritisak na površinu F	$w_{i,F} = w_{e,F} - w_i$	$-1{,}025\ kN/m^2$
Ukupni pritisak na površinu G	$w_{i,G} = w_{e,G} - w_i$	$-0{,}718\ kN/m^2$
Ukupni pritisak na površinu H	$w_{i,H} = w_{e,H} - w_i$	$-0{,}461\ kN/m^2$
Ukupni pritisak na površinu I	$w_{i,I} = w_{e,I} - w_i$	$0\ kN/m^2$
Ukupni pritisak na površinu I	$w_{i,I} = w_{e,I} - w_i$	$-0{,}410\ kN/m^2$



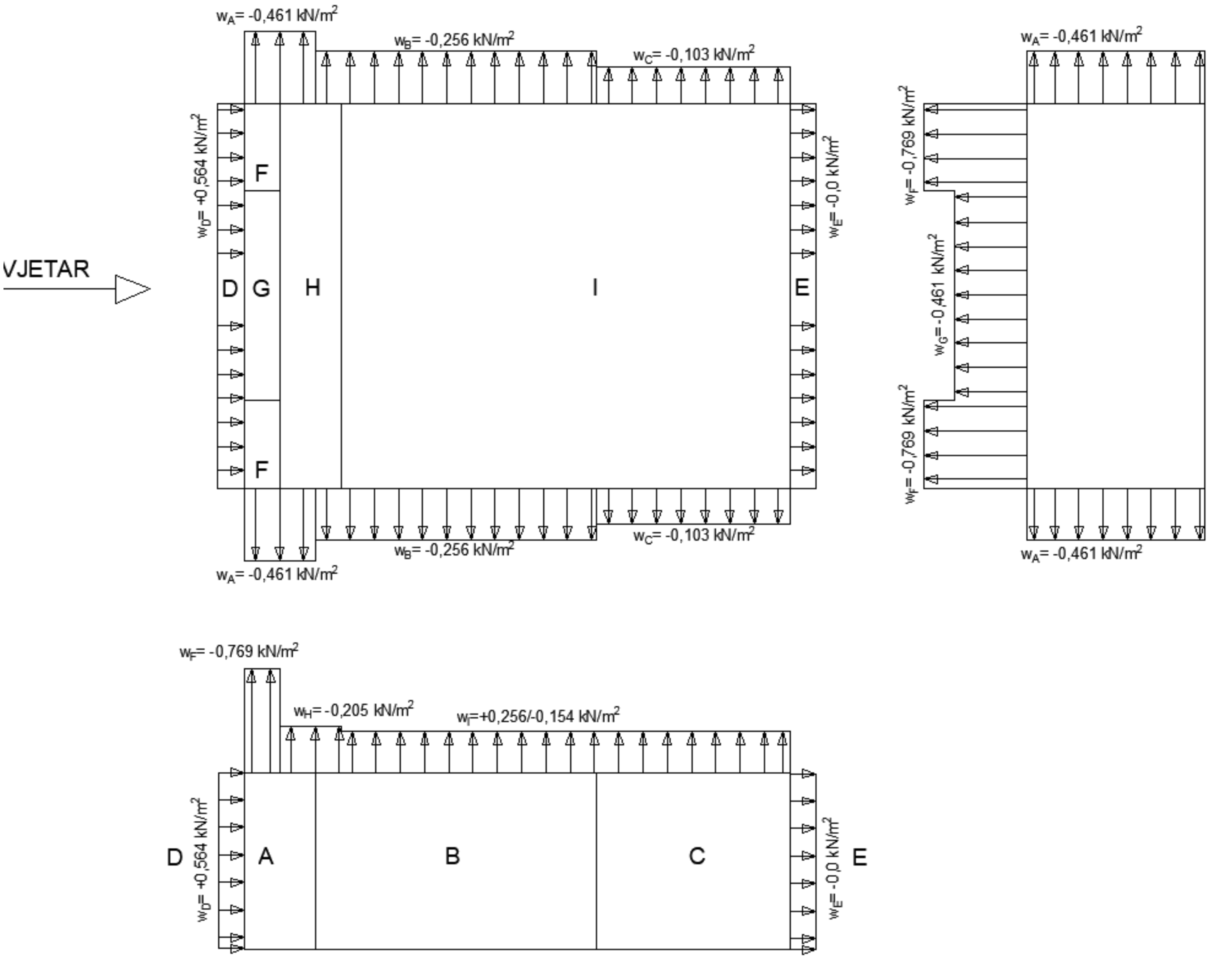
Slika 20. Prikaz opterećenja vjetrom za slučaj V

Slučaj VI- vjetar puše na uzdužnu stranu objekta, cpi=-0,3

Tlak na površinu je algebarski zbroj unutarnjeg i vanjskog tlaka.

Tablica 17. Ukupni pritisak

Ukupni pritisak na površinu A	$w_{i,A} = w_{e,A} - w_i$	$-0{,}461\ kN/m^2$
Ukupni pritisak na površinu B	$w_{i,B} = w_{e,B} - w_i$	$-0{,}256\ kN/m^2$
Ukupni pritisak na površinu C	$w_{i,C} = w_{e,C} - w_i$	$-0{,}103\ kN/m^2$
Ukupni pritisak na površinu D	$w_{i,D} = w_{e,D} - w_i$	$+0{,}564\ kN/m^2$
Ukupni pritisak na površinu E	$w_{i,E} = w_{e,E} - w_i$	$-0{,}000\ kN/m^2$
Ukupni pritisak na površinu F	$w_{i,F} = w_{e,F} - w_i$	$-0{,}769\ kN/m^2$
Ukupni pritisak na površinu G	$w_{i,G} = w_{e,G} - w_i$	$-0{,}461\ kN/m^2$
Ukupni pritisak na površinu H	$w_{i,H} = w_{e,H} - w_i$	$-0{,}205\ kN/m^2$
Ukupni pritisak na površinu I	$w_{i,I} = w_{e,I} - w_i$	$+\ 0{,}256\ kN/m^2$
Ukupni pritisak na površinu I	$w_{i,I} = w_{e,I} - w_i$	$-0{,}154\ kN/m^2$



Slika 21. Prikaz opterećenja vjetrom za slučaj VI

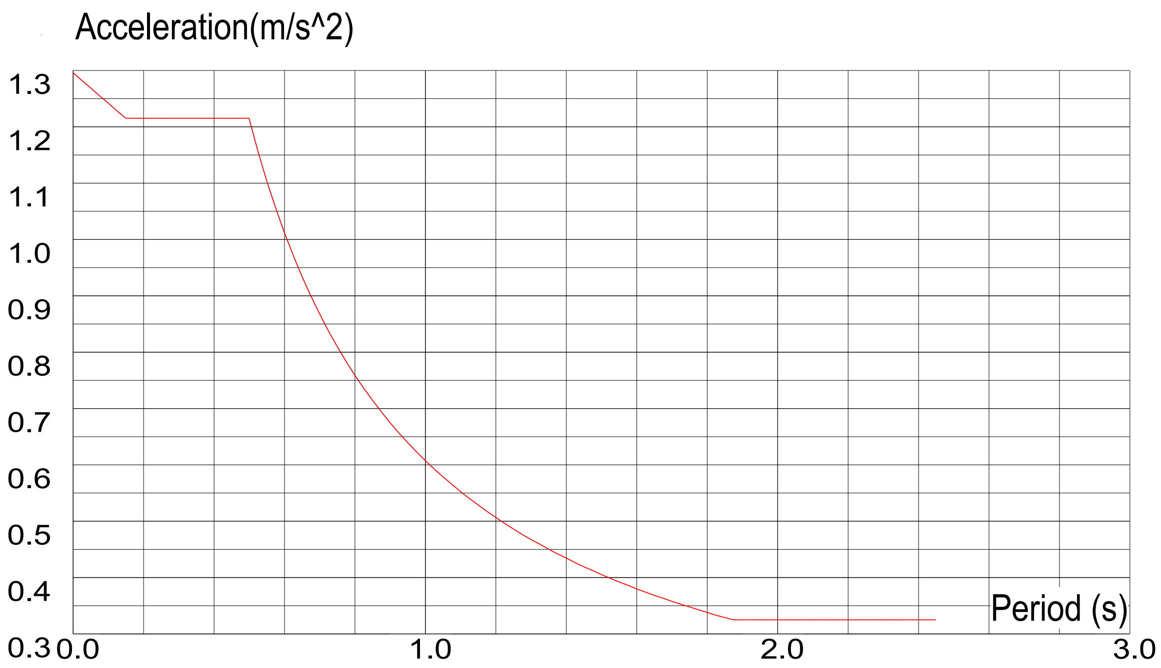
4.6. Potres

Potresno djelovanje određeno je prema HRN EN 1998-1:2011.

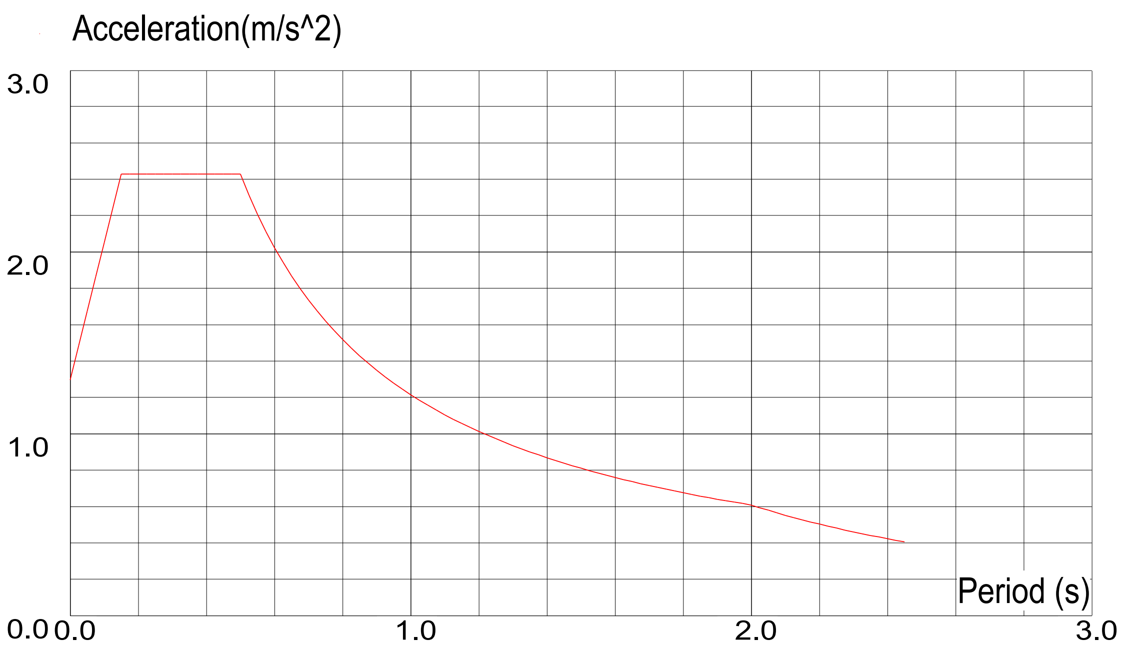
Građevina je smještena u Karlovcu. Uz pomoć online aplikacije dostupne na stranicama Geofizičkog odsjeka (Prirodoslovno-matematički fakultet Sveučilišta u Zagreb) i Hrvatskog zavoda za norme očitana je vrijednost ag = 0,165 g, poredbena vršna ubrzanja temeljnog tla, za temeljno tlo tipa A s vjerojatnošću premašaja 10 % u 50 godina, za poredbeno razdoblje potresa TNCR = 475 godina Pretpostavka jest da se objekt temelji se na tlu razreda A te se iz Tablice očitavaju potresni parametri za tlo razreda B za spektre tipa 1 i 2.

Slika 22. Seizmološka karta

Prema Eurocodeu factor ponašanja u smjeru okvira, u ovom slučaju smjer x, je 4 dok je u smjeru suprotnom od smjera okvira, dakle smjer y 2.



Slika 23. Proračunski sprektar za smjer x



Slika 24. Proračunski spektar za smjer y

5 KOMBINACIJE OPTEREĆENJA

U ovom pod poglavlju izdvojeni su izrazi iz norme HRN EN 1990:2011 koji se koriste za analizu opterećenja i ponavljaju u nastavka proračuna.

Kombinacije opterećenja za granično stanje nosivosti (GSN)

Osnovna kombinacija opterećenja (stalna i prolazna proračunska situacija):

$$\sum_{j}(\gamma_{G,j} * G_{k,j}) + \gamma_P * P_k + \gamma_{Q,1} * Q_{k,1} + \sum_{i>1}(\gamma_{Q,i} * \psi_{0,i} * Q_{k,i})$$

Izvanredna kombinacija opterećenja (seizmička proračunska situacija):

$$\sum_{j} G_{k,j} + \gamma_1 * A_{Ek} + P_k + \sum_{i>1} \psi_{2,i} * Q_{k,i}$$

Kombinacije opterećenja za granično stanje uporabljivosti (GSU)

Karakteristična (rijetka) kombinacija djelovanja:

$$\sum_{j} G_{k,j} + P_k + Q_{k,1} + \sum_{i>1} \psi_{0,i} * Q_{k,i}$$

Česta kombinacija djelovanja:

$$\sum_{j} G_{k,j} + P_k + \psi_{1,1} * Q_{k,1} + \sum_{i>1} \psi_{2,i} * Q_{k,i}$$

Nazovistalna kombinacija djelovanja:

$$\sum_{j} G_{k,j} + P_k + \sum_{i>1} \psi_{2,i} * Q_{k,i}$$

Tablica 18. Koeficijenti sigurnosti

	γ_g	γ_q	γ_p
Nepovoljno	1,35	1,50	1,00
Povoljno	1,00	-	1,00
Izvedba i montaža	1,00	-	1,00

Tablica 19. Koeficijenti kombinacije

Djelovanje	Koeficijent kombinacije		
	ψ_0	ψ_1	ψ_2
Uporabno opterećenje u zgradama			
Kategorija D: trgovine	0,7	0,7	0,6
Kategorija H: krovovi	0	0	0
Opterećenje snijegom u zgradama			
Za gradilišta na visini H<1000 m.n.m.	0,5	0,2	0
Opterećenje vjetrom na zgrade	0,6	0,2	0

5.1. Popis korištenih kombinacija

Case	Label	Case name	Nature	Analysis type
1	DL1	DL1	Structural	Static - Linear
2	DL2	Dodatno stalno	Structural	Static - Linear
3	DL3	Instalacije	Structural	Static - Linear
4	DL31	Uporabno opterećenje	Category A	Static - Linear
5	DL311	Snijeg	snow	Static - Linear
6	DL3111	Vjetar I	wind	Static - Linear
7	WIND21	Vjetar Ib	wind	Static - Linear
8	WIND211	Vjetar II	wind	Static - Linear
9	WIND2111	Vjetar IIIa	wind	Static - Linear
10	WIND21111	Vjetar IIIb	wind	Static - Linear
11	WIND211111	Vjetar IVa	wind	Static - Linear
12	WIND212	Vjetar IVb	wind	Static - Linear
13	WIND2112	Vjetar Va	wind	Static - Linear
14	WIND91	Vjetar VIa	wind	Static - Linear
15	WIND911	Vjetar VIb	wind	Static - Linear
20	LL2	LL2-krov	Category A	Static - Linear
26	MOD26	Modal		Modal
27	SEI_X27	Seismic EC 8 Direction_X	seismic	Seismic-EC 8
28	SEI_Y28	Seismic EC 8 Direction_Y	seismic	Seismic-EC 8

Slika 25. Popis slučajeva opterećenja

Combinations	Name	Analysis type	Combination	Case nature	Definition
17	GSN1	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+5)*1.50+6*0.90
18	GSN2	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+5)*1.50+9*0.90
19	GSN3	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+5)*1.50+11*0.90
20	GSN4	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+5)*1.50+13*0.90
21	GSN5	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+5)*1.50+14*0.90
22	GSN6	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+6)*1.50+5*0.75
23	GSN7	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+9)*1.50+5*0.75
24	GSN8	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+11)*1.50+5*0.75
25	GSN9	Nonlin. Combinati	ULS	Structural	(1+2+3)*1.35+(4+14)*1.50+5*0.75
26	GSN10	Nonlin. Combinati	ULS	Structural	(1+3)*1.00+7*1.50
27	GSN11	Nonlin. Combinati	ULS	Structural	(1+3)*1.00+8*1.50
28	GSN12	Nonlin. Combinati	ULS	Structural	(1+3)*1.00+10*1.50
29	GSN13	Nonlin. Combinati	ULS	Structural	(1+3)*1.00+12*1.50
30	GSN14	Nonlin. Combinati	ULS	Structural	(1+3)*1.00+15*1.50
31	GSU1	Nonlin. Combinati	ULS	Structural	(1+2+3+4+5)*1.00+6*0.60
32	GSU2	Nonlin. Combinati	ULS	Structural	(1+2+3+4+5)*1.00+9*0.60
33	GSU3	Nonlin. Combinati	ULS	Structural	(1+2+3+4+5)*1.00+11*0.60
34	GSU4	Nonlin. Combinati	ULS	Structural	(1+2+3+4+5)*1.00+14*0.60
35	GSU5	Nonlin. Combinati	ULS	Structural	(1+2+3+6)*1.00+(4+5)*0.50
36	GSU6	Nonlin. Combinati	ULS	Structural	(1+2+3+9)*1.00+(4+5)*0.50
37	GSU7	Nonlin. Combinati	ULS	Structural	(1+2+3+11)*1.00+(4+5)*0.50
38	GSU8	Nonlin. Combinati	ULS	Structural	(1+2+3+14)*1.00+(4+5)*0.50
39	GSU9	Nonlin. Combinati	ULS	Structural	(1+3+6)*1.00
40	GSU10	Nonlin. Combinati	ULS	Structural	(1+3+7)*1.00
41	GSU11	Nonlin. Combinati	ULS	Structural	(1+3+8)*1.00
42	GSU12	Nonlin. Combinati	ULS	Structural	(1+3+9)*1.00
43	GSU13	Nonlin. Combinati	ULS	Structural	(1+3+10)*1.00
44	GSU14	Nonlin. Combinati	ULS	Structural	(1+3+11)*1.00
45	GSU15	Nonlin. Combinati	ULS	Structural	(1+3+12)*1.00
46	GSU16	Nonlin. Combinati	ULS	Structural	(1+3+13)*1.00
47	GSU17	Nonlin. Combinati	ULS	Structural	(1+3+14)*1.00
48	GSU18	Nonlin. Combinati	ULS	Structural	(1+3+15)*1.00

Slika 26. Popis kombinacija zadanih u softweru

6 PRORAČUN SPREGNUTIH PLOČA

6.1. Krovna ploča

Krovna ploča je napravljena od betona klase C30/37. Lim je COFRAPLUS 45.

Opterećenja koja djeluju na krovnu ploču su vlastita težina, dodatno stalno opterećenje, uporabno opterećenje i snijeg. Lim je odabran prema tablici danoj od proizvođača lima [4].

6.1.1. Opterećenja

a) Vlastita težina

   Tablica opterećenja ne uzima u obzir vlastitu težinu ploče.

b) Dodatno stalno opterećenje

   U dodatno stalno opterećenje se ubrajaju završni slojevi krovne ploče. Pretpostavljena težina završnog sloja je $250\ {}^{kg}/_{m^2}$.

c) Uporabno opterećenje

   Prema Eurocodu uporabno opterećenje za neprohodne krovove je $0{,}6\ {}^{kN}/_{m^2} = 60\ {}^{kg}/_{m^2}$.

d) Snijeg

Opterećenje snijega iz poglavlja *4.4. Snijeg* iznosi:

$$s = 1{,}104\ {}^{kN}/_{m^2} = 110{,}00\ {}^{kg}/_{m^2}$$

Structural performance

Acceptable unweighted q values with g' = 0 in kg/m²

A calculation using Cofra 5 might optimise the design according to the project requirements

Single span L

Thickness of the slab [cm]	Span [m]																				
	1,50	1,60	1,70	1,80	1,90	2,00	2,10	2,20	2,30	2,40	2,50	2,60	2,70	2,80	2,90	3,00	3,10	3,20	3,30	3,40	3,50
18	1685	1513	1366	1239	1129	1032	946	870	801	740	684	634	587	545	506	470	436	404	374	347	321
17	1618	1452	1310	1187	1081	987	905	831	765	706	653	604	560	520	482	448	415	384	356	330	305
16	1551	1390	1253	1135	1033	943	863	793	730	673	622	575	533	494	458	426	394	365	338	312	289
15	1484	1329	1197	1083	985	898	822	754	694	639	590	546	505	468	435	403	373	345	319	295	273
14	1417	1268	1141	1031	937	854	780	716	658	606	559	517	478	443	411	381	352	325	301	278	257
13	1351	1207	1084	979	888	809	739	677	622	572	528	487	451	417	387	358	331	306	283	261	241
12	1284	1145	1028	927	840	764	698	639	586	539	497	458	423	392	363	336	310	286	264	244	225
11	1217	1084	972	875	792	720	656	600	550	505	465	429	396	366	339	314	289	267	246	227	209
10	1150	1023	915	823	744	675	615	562	514	472	434	400	369	341	315	291	268	247	228	-	-
9	1083	962	859	771	696	631	573	523	478	438	403	371	342	315	291	-	-	-	-	-	-
	Without propping								With propping												

Slika 27. Tablica odabira debljine krovne ploče [11]

Ukupno opterećenje na krovnu ploču iznosi $250 + 60 + 110 = 420{,}00\ {}^{kg}/_{m^2}$

Odabrana debljina ploče je 10 cm.

6.1.2. Otpornost na savijanje

$f_{yd} = 35\ {}^{kN}/_{cm^2}$

$f_{cd} = 2{,}0\ {}^{kN}/_{cm^2}$

$A_{pe} = 10{,}88\ cm^2$

$d_p = 4{,}5 + 10 - 1{,}5 = 13{,}00\ cm$

$q_{Ed,II} = 1{,}35 * g_{vl} + 1{,}5 * s + 1{,}5q = 1{,}35 * 5{,}13 + 1{,}5 * 1{,}104 + 1{,}5 * 0{,}6 = 9{,}48\ {}^{kN}/_{m^2}$

$g_{vl} = g_{dodatno\ stalno} + g_{lim} + g_{beton} = 2{,}5 + 0{,}13 + 2{,}5 = 5{,}13\ {}^{kN}/_{m^2}$

$$x_{pl} = \frac{A_{pe} * f_{yd}}{b * 0{,}85 * f_{cd}} = \frac{10{,}88 * 35}{100 * 0{,}85 * 2} = 2{,}24\ cm\ < 10\ cm$$
$$\rightarrow N.O. je\ u\ betonu\ iznad\ lima$$

$$M_{Rd} = A_{pe} * f_{yd} * \left(d_p - \frac{A_{pe} * f_{yd}}{1{,}7 * b * f_{cd}}\right) = 10{,}88 * 35 * \left(13 - \frac{10{,}88 * 35}{1{,}7 * 100 * 2}\right)$$
$$= 45{,}23\ \ kNm$$

$$M_{Sd} = \frac{q_{Ed} * L^2}{8} = \frac{9{,}48 * 2{,}5^2}{8} = 7{,}41\ kNm$$

$$\frac{M_{Sd}}{M_{Rd}} = \frac{7{,}40}{45{,}23} = 0{,}164 \rightarrow iskorištenost\ profila\ je\ 16{,}4\%$$

6.1.3. Granično stanje uporabljivosti

$\delta = \frac{250}{180} = 1{,}4\ cm$

$0{,}1 * h_c = 0{,}1 * 10 = 1 < 1{,}4 \rightarrow nema\ nagomilavanja\ betona$

Prema HRN EN

$1{,}4 < 2{,}0 \rightarrow uvijet\ je\ zadovoljen!$

6.2. Međukatna ploča

Međukatna ploča je napravljena od betona klase C30/37. Lim je COFRAPLUS 45.

Opterećenja koja djeluju na međukatnu ploču su vlastita težina, dodatno stalno opterećenje te uporabno opterećenje. Lim je odabran prema tablici danoj od proizvođača lima [4]

6.2.1. Opterećenja

a) Vlastita težina

Tablica opterećenja ne uzima u obzir vlastitu težinu ploče.

b) Dodatno stalno opterećenje

U dodatno stalno opterećenje se ubrajaju završni slojevi krovne ploče. Pretpostavljena težina završnog sloja je 250 $^{kg}/_{m^2}$.

c) Uporabno opterećenje

Opterećenje tijekom uporabe iz poglavlja *2.4. Uporabno opterećenje* iznosi:

$$q = 2{,}0\ ^{kN}/_{m^2} = 200{,}00\ ^{kg}/_{m^2}$$

Structural performance

Acceptable unweighted q values with g' = 0 in kg/m²

A calculation using Cofra 5 might optimise the design according to the project requirements

Single span L

Thickness of the slab [cm]	Span [m]																					
	1,50	1,60	1,70	1,80	1,90	2,00	2,10	2,20	2,30	2,40	2,50	2,60	2,70	2,80	2,90	3,00	3,10	3,20	3,30	3,40	3,50
18	1685	1513	1366	1239	1129	1032	946	870	801	740	684	634	587	545	506	470	436	404	374	347	321
17	1618	1452	1310	1187	1081	987	905	831	765	706	653	604	560	520	482	448	415	384	356	330	305
16	1551	1390	1253	1135	1033	943	863	793	730	673	622	575	533	494	458	426	394	365	338	312	289
15	1484	1329	1197	1083	985	898	822	754	694	639	590	546	505	468	435	403	373	345	319	295	273
14	1417	1268	1141	1031	937	854	780	716	658	606	559	517	478	443	411	381	352	325	301	278	257
13	1351	1207	1084	979	888	809	739	677	622	572	528	487	451	417	387	358	331	306	283	261	241
12	1284	1145	1028	927	840	764	698	639	586	539	497	458	423	392	363	336	310	286	264	244	225
11	1217	1084	972	875	792	720	656	600	550	505	465	429	396	366	339	314	289	267	246	227	209
10	1150	1023	915	823	744	675	615	562	514	472	434	400	369	341	315	291	268	247	228	-	-
9	1083	962	859	771	696	631	573	523	478	438	403	371	342	315	291	-	-	-	-	-	-
	Without propping								With propping													

Slika 28. Tablica odabira debljine međukatne ploče [11]

Ukupno opterećenje na krovnu ploču iznosi $250 + 200{,}00 = 450{,}00\ {}^{kg}/_{m^2}$

Odabrana debljina ploče je 11 cm.

6.2.2. Otpornost na savijanje

$f_{yd} = 35{,}5\ {}^{kN}/_{cm^2}$

$f_{cd} = 2{,}0\ {}^{kN}/_{cm^2}$

$A_{pe} = 10{,}88\ cm^2$

$d_p = 4{,}5 + 11 - 1{,}5 = 14{,}00\ cm$

$q_{Ed} = 1{,}35 * g_{vl} + 1{,}5q = 1{,}35 * 2{,}5 + 1{,}5 * 2 = 6{,}38\ {}^{kN}/_{m^2}$

$g_{vl} = g_{dodatno\ stalno} = 255\ {}^{kg}/_{m^2} = 2{,}5\ {}^{kN}/_{m^2}$

$$x_{pl} = \frac{A_{pe} * f_{yd}}{b * 0{,}85 * f_{cd}} = \frac{10{,}88 * 35}{100 * 0{,}85 * 2} = 2{,}24\ cm\ < 11\ cm$$

$$\rightarrow N.O.\ je\ u\ betonu\ iznad\ lima$$

$$M_{Rd} = A_{pe} * f_{yd} * \left(d_p - \frac{A_{pe} * f_{yd}}{1{,}7 * b * f_{cd}}\right) = 10{,}88 * 35 * \left(14 - \frac{10{,}88 * 35}{1{,}7 * 100 * 2}\right) = 49{,}04\ kNm$$

$$M_{Sd} = \frac{q_{Ed} * L^2}{8} = \frac{6{,}39 * 2{,}5^2}{8} = 4{,}99\ kNm$$

$$\frac{M_{Sd}}{M_{Rd}} = \frac{4{,}99}{49{,}04} = 0{,}102 \rightarrow iskorištenost\ profila\ je\ 10\%$$

6.2.3. Granično stanje uporabljivosti

$\delta = \frac{250}{180} = 1{,}4\ cm$

$0{,}1 * h_c = 0{,}1 * 11 = 1{,}1 < 1{,}4 \rightarrow nema\ nagomilavanja\ betona$

Prema HRN EN

$$1{,}4 < 2{,}0 \rightarrow uvijet\ je\ zadovoljen!$$

7 SPREGNUTI NOSAČ

7.1. Spregnuti nosač krovne ploče

7.1.1. Ulazni podaci

Odabrani profil:	IPE 300
Tip poprečnog presjeka:	Toplo dogotovljeni
Površina poprečnog presjeka:	$A = 53{,}8\ cm^2$
Visina hrpta:	$h = 300\ mm$
Debljina hrpta:	$t_w = 7{,}1\ mm$
Širina pojasnice:	$b = 150\ mm$
Debljina pojasnice:	$t_f = 10{,}7\ mm$
Radijus:	$r = 15{,}0\ m$
Klasa čelika:	S355
Marka betona:	C30/37

7.1.2. Opterećenja

e= 2.5 m

$g_c = h_c * e * \gamma_c = 0{,}1 * 2{,}5 * 25 = 6{,}25\ {kN}/_{m'} \rightarrow beton$

$g_A = A * 10^{-2} = 53{,}8 * 10^{-2} = 0{,}538\ {kN}/_{m'} \rightarrow nosač$

$g_k = 0{,}3 * 2{,}5 = 0{,}75\ {kN}/_{m'} \rightarrow instalacije$

$g_{lim} = 0{,}13 * 2{,}5 = 0{,}325\ {kN}/_{m'} \rightarrow lim$

$g_s = 1{,}104 * 2{,}5 = 2{,}76\ {kN}/_{m'} \rightarrow snijeg$

$q = 0{,}6 * 2{,}5 = 1{,}5\ {kN}/_{m'} \rightarrow uporabno$

$g_{dodatno} = 2{,}2 * 2{,}5 = 5{,}5\ {kN}/_{m'} \rightarrow dodatno\ stalno$

$g_{ser} = 0{,}75 * 2{,}5 = 1{,}875\ {kN}/_{m'} \rightarrow servisno\ opterećenje$

$$q_{ed,I} = 1{,}35 * (g_c + g_A + g_{lim}) + 1{,}5 * g_{ser}$$
$$= 1{,}35 * (6{,}25 + 0{,}538 + 0{,}325) + 1{,}5 * 1{,}875 = 12{,}41\ ^{kN}/_{m'}$$
$$\rightarrow proračunsko\ opterećenje\ za\ prvu\ fazu$$

$$q_{ed,II} = 1{,}35 * (g_c + g_A + g_k + g_{lim} + g_{dodatno}) + 1{,}5 * g_s$$
$$= 1{,}35 * (6{,}25 + 0{,}538 + 0{,}75 + 0{,}325 + 5{,}5) + 1{,}5 * 2{,}76 = 22{,}18\ ^{kN}/_{m'}$$
$$\rightarrow proračunsko\ opterećenje\ za\ drugu\ fazu$$

$$M_{ed,I} = \frac{q_{ed,I} * L^2}{8} = \frac{12{,}41 * 11{,}68^2}{8} = 211{,}63\ kNm$$
$$M_{ed,II} = \frac{q_{ed,II} * L^2}{8} = \frac{22{,}18 * 11{,}68^2}{8} = 378{,}28\ kNm$$
$$V_{ed,I} = \frac{q_{ed,I} * l}{2} = \frac{12{,}41 * 11{,}68}{2} = 72{,}47\ kN$$
$$V_{ed,II} = \frac{q_{ed,I} * l}{2} = \frac{22{,}18 * 11{,}68}{2} = 129{,}53\ kN$$

Sudjelujuća širina

$$b_{e1} = b_{e2} = \frac{L}{8} = \frac{11{,}68}{8} = 1{,}46$$
$$b_{eff} = 2 * b_{e1} = 2 * 1{,}46 = 2{,}92m > 2{,}5m$$
$$b_{eff} = 2{,}5\ m$$

7.1.3. Faza I

7.1.3.1. Teorija plastičnosti

$$W_{PL,y} = 628\ cm^2$$
$$M_{pl,y} = W_{PL,y} * f_{yd} = 21420{,}7\ kNcm = 222{,}94\ kNm$$
$$222{,}94\ kNm > 211{,}63\ kNm$$
$$\frac{211{,}63}{222{,}94} = 0{,}95 \rightarrow iskorištenost\ profila\ u\ prvoj\ fazi\ je\ 95\%$$

Otpornost na bočno torzijsko izvijanje

Elastični kritični moment bočnog torzijskog izvijanja:

$$M_{cr} = C_1 \cdot \frac{\pi^2 \cdot E \cdot I_z}{L^2} \cdot \left[\sqrt{\frac{I_w}{I_z} + \frac{L^2 \cdot G \cdot I_t}{\pi^2 \cdot E \cdot I_z} + \left(C_2 \cdot z_g\right)^2} - C_2 \cdot z_g \right]$$

Modul elastičnosti	$E = 210000\ N/mm^2$
Modul posmika	$G = 80769{,}23\ N/mm^2$
Konstanta krivljenja	$I_w = 7{,}058 \cdot 10^{10}\ mm^6$
Moment tromosti	$I_z = 4200000\ mm^4$
Torzijska konstanta	$I_t = 160000\ mm^4$
Raspon	$L = 3750\ mm$

Vrijednost proračunatog M_{cr}:

$$M_{cr} = 125{,}15\ kNm$$

Bezdimenzionalna vitkost:

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}} = \sqrt{\frac{484{,}0 \cdot 23{,}5}{12515}} = 0{,}953$$

Faktor redukcije:

$$\frac{h}{b} = \frac{270}{135} = 2{,}00 \ \rightarrow \ mjerodavna\ krivulja\ izvijanja\ \boldsymbol{a} \ \rightarrow \ \alpha_{LT} = 0{,}21$$

$$\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\overline{\lambda}_{LT} - 0{,}2\right) + \overline{\lambda}_{LT}^2\right] = 0{,}5 \cdot [1 + 0{,}21 \cdot (0{,}952 - 0{,}2) + 0{,}952^2]$$

$$\Phi_{LT} = 1{,}032$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \overline{\lambda_{LT}}^2}} = \frac{1}{1{,}032 + \sqrt{1{,}032^2 - 0{,}952^2}} = 0{,}699 < 1$$

Računska otpornost:

$$M_{b,Rd} = \chi_{LT} \cdot \frac{W_{pl,y} \cdot f_y}{\gamma_{M1}} = 0{,}699 \cdot \frac{484{,}0 \cdot 23{,}5}{1{,}0} = 79{,}50\ kNm$$

$$M_{Ed,y} = 34{,}83\ kNm < M_{b,Rd} = 79{,}50\ kNm$$

$$\frac{M_{Ed,y}}{M_{b,Rd}} = \frac{34{,}83}{79{,}50} = 0{,}440 < 1{,}0 \ \rightarrow Iskoristivost\ je\ 43{,}8\ \%$$

7.1.4. Faza II

7.1.4.1. Klasifikacija poprečnog presjeka

Hrbat

$$\frac{c}{t} = \frac{h - 2\ \cdot\ t_f - 2\ \cdot r}{t_w} = \frac{300{,}0 - 2\ \cdot\ 10{,}7 - 2\ \cdot 15{,}0}{7{,}1} = 35{,}01$$

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{355}} = 0{,}81$$

$$33 \cdot\ \varepsilon = 33\ \cdot 0{,}81\ = 26{,}73$$

$$35{,}01 > 26{,}73$$

$$72 \cdot\ \varepsilon = 72\ \cdot 0{,}81\ = 58{,}32$$

$$35{,}01 < 58{,}32$$

Hrbat je svrstan u klasu 2.

Pojasnica

$$\frac{c}{t} = \frac{\frac{b - t_w - 2\ \cdot r}{2}}{t_f} = \frac{\frac{150{,}00 - 7{,}1 - 2\ \cdot 15{,}0}{2}}{10{,}7} = 5{,}28$$

$$9\ \cdot\ \varepsilon = 9\ \cdot 0{,}81 = 7{,}29$$

$$5{,}28 < 7{,}29$$

Pojasnica je svrstana u klasu 1.

Poprečni presjek svrstan je u klasu 2.

7.1.4.2. Teorija plastičnosti

$$N_{CF} = b_{eff} * h_c * 0{,}85 * f_{cd} = 250 * 10 * 0{,}85 * 2 = 4\ 250\ kN$$

$$N_A = A * f_{yd} = 53{,}8 * 35{,}5 = 1909{,}9\ kN$$

$$N_{CF} > N_A\ \rightarrow N.O. je\ u\ betonskoj\ ploči - CJELI\ NOSAČ\ JE\ U\ VLAKU$$

$$x_{pl} = \frac{A_a * f_{yd}}{0{,}85 * f_{cd} * b_{eff}} = \frac{53{,}8 * 35{,}5}{0{,}85 * 2 * 250} = 4{,}49\ cm$$

Otpornost na savijanje

$$M_{pl,Rd} = A_a * f_{yd} * \left(z + h_c - 0{,}5 * x_{pl}\right) = 53{,}8 * 35{,}5 * (15 + 10 - 0{,}5 * 4{,}49)$$
$$= 434{,}59\ kNm$$

$$\frac{M_{ed}}{M_{pl,Rd}} = \frac{378{,}28}{434{,}59} = 0{,}87\ \rightarrow iskorištenost\ profila\ u\ drugoj\ fazi\ je\ 87\%$$

Otpornost na poprečnu silu

Provjera na izbočavanja hrpta na posmik

$$h_w = h - 2 \cdot t_f = 300{,}0 - 2 \cdot 10{,}7 = 278{,}60\ mm$$

$$\frac{h_w}{t_w} < \frac{72 \cdot \varepsilon}{\eta}$$

$$\frac{278{,}60}{7{,}1} < \frac{72 \cdot 0{,}81}{1{,}2}$$

$39{,}24 < 48{,}6$ → Nije potrebna provjera izbočavanja hrpta na posmik.

Plastična posmična otpornost

$$V_{pl,Rd} = \frac{A_{V,z} \cdot (f_y/\sqrt{3})}{\gamma_{M0}}$$

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

$$A_{V,z} = 53{,}81 - 2 \cdot 15{,}00 \cdot 1{,}07 + (0{,}71 + 2 \cdot 1{,}05) \cdot 1{,}07 = 24{,}064\ cm^2$$

$$\eta \cdot h_w \cdot t_w = 1{,}20 \cdot 27{,}9 * 0{,}71 = 23{,}77\ cm^2$$

$$A_{V,z} = 24{,}064\ cm^2 \geq 23{,}77\ cm^2$$

$$V_{pl,z,Rd} = \frac{24{,}064 \cdot (35{,}50/\sqrt{3})}{1{,}00} = 493{,}21\ kN$$

Otpornost poprečnog presjeka na poprečnu silu

$$\frac{V_{z,Ed}}{V_{pl,Rd}} \leq 1{,}00 \qquad \frac{129{,}53}{493{,}21} < 1{,}00 \qquad 0{,}262 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 26,2%.

Otpornost na bočno torzijsko izvijanje

Gornja pojasnica čeličnog nosača je pridržana na dovoljnom broju mjesta, stoga provjera na bočno torzijsko izvijanje nije potrebna.

7.1.5. Granično stanje uporabljivosti

$$h_n = \frac{A_a \cdot (0,5 \cdot f_a + h_c) + \frac{b_{EFF}}{n} \cdot h_c \cdot \frac{h_c}{2}}{A_a + \frac{b_{EFF}}{n} \cdot h_c} = \frac{53,8 \cdot (0,5 \cdot 30 + 10) + \frac{250}{13,5} \cdot 10 \cdot 5}{53,8 + \frac{250}{13,5} \cdot 10} = 9,50 \text{ cm}$$

$$I_n = I_a + A_a \cdot z_a^2 + I_c + \frac{A_c}{n} \cdot z_c^2$$
$$= 8356 + 53,8 \cdot \left(\frac{30}{2} + 10 - 9,5\right)^2 + \frac{250}{13,5} \cdot \frac{10^2}{12} + \frac{250 \cdot 12}{13,5} \cdot (9,5 - 5)^2$$
$$= 25935,77\ cm^4$$

7.1.5.1. Stalno opterećenje

$$\delta_g = \frac{5}{384} \cdot \frac{g_{kl} \cdot L^4}{E_a \cdot I_a} + \frac{5}{384} \cdot \frac{g_{kl} \cdot L^4}{E_a \cdot I} = \frac{5}{384} \cdot \frac{0,0679 \cdot 250^4}{21000 \cdot 8356} + \frac{5}{384} \cdot \frac{0,055 \cdot 250^4}{21000 \cdot 25935,77}$$
$$= 2,4\ cm$$

7.1.5.2. Korisno opterećenje

$$\delta_p = \frac{5}{384} \cdot \frac{P_{kl} \cdot L^4}{E_a \cdot I} = \frac{5}{384} \cdot \frac{0,015 \cdot 250^4}{21000 \cdot 25935,77} = 0,14\ cm$$

Dokaz

$$\delta_{kon} \leq \frac{L}{300} = \frac{1168}{300} = 3,89\ cm > 2,4\ cm$$

$$\delta_{kon} \leq \frac{L}{250} = \frac{1168}{250} = 4,67\ cm > 2,54\ cm$$

7.2. Spregnuti nosač međukatne ploče

7.2.1. Ulazni podaci

Odabrani profil:	IPE 330
Tip poprečnog presjeka:	Toplo dogotovljeni
Površina poprečnog presjeka:	$A = 62{,}6\ cm^2$
Visina hrpta:	$h = 330\ mm$
Debljina hrpta:	$t_w = 7{,}5\ mm$
Širina pojasnice:	$b = 160\ mm$
Debljina pojasnice:	$t_f = 11{,}5\ mm$
Radijus:	$r = 18{,}0\ mm$
Klasa čelika:	S355
Marka betona:	C30/37

7.2.2. Opterećenja

e= 2.5 m

$g_c = h_c * e * \gamma_c = 0{,}11 * 2{,}5 * 25 = 6{,}88\ {}^{kN}/_{m'} \rightarrow beton$

$g_A = A * 10^{-2} = 62{,}6 * 10^{-2} = 0{,}626\ {}^{kN}/_{m'} \rightarrow nosač$

$g_k = 0{,}3 * 2{,}5 = 0{,}75\ {}^{kN}/_{m'} \rightarrow instalacije$

$g_{lim} = 0{,}13 * 2{,}5 = 0{,}325\ {}^{kN}/_{m'} \rightarrow lim$

$q = 2{,}0 * 2{,}5 = 5{,}0\ {}^{kN}/_{m'} \rightarrow uporabno$

$g_{dodatno} = 2{,}5 * 2{,}5 = 6{,}25\ {}^{kN}/_{m'} \rightarrow dodatno\ stalno$

$g_{ser} = 0{,}75 * 2{,}5 = 1{,}875\ {}^{kN}/_{m'} \rightarrow servisno\ opterećenje$

$$q_{ed,I} = 1{,}35 * (g_c + g_A + g_{lim}) + 1{,}5 * g_{ser}$$
$$= 1{,}35 * (6{,}88 + 0{,}626 + 0{,}325) + 1{,}5 * 1{,}875 = 13{,}38\ {}^{kN}/_{m'}$$
$$\rightarrow proračunsko\ opterećenje\ za\ prvu\ fazu$$

$$q_{ed,II} = 1{,}35 * (g_c + g_A + g_k + g_{lim} + g_{dodatno}) + 1{,}5 * q$$
$$= 1{,}35 * (6{,}88 + 0{,}626 + 0{,}75 + 0{,}325 + 6{,}25) + 1{,}5 * 5{,}0 = 27{,}52\ {}^{kN}/_{m'}$$
$$\rightarrow proračunsko\ opterećenje\ za\ drugu\ fazu$$

$$M_{ed,I} = \frac{q_{ed,I} * L^2}{8} = \frac{13{,}38 * 11{,}68^2}{8} = 228{,}17\ kNm$$
$$M_{ed,II} = \frac{q_{ed,II} * L^2}{8} = \frac{27{,}52 * 11{,}68^2}{8} = 469{,}29\ \ kNm$$

$$V_{ed,I} = \frac{q_{ed,I} * l}{2} = \frac{13{,}38 * 11{,}68}{2} = 78{,}14\ kN$$
$$V_{ed,II} = \frac{q_{ed,I} * l}{2} = \frac{27{,}52 * 11{,}68}{2} = 160{,}72\ kN$$

Sudjelujuća širina

$$b_{e1} = b_{e2} = \frac{L}{8} = \frac{11{,}68}{8} = 1{,}46$$
$$b_{eff} = 2 * b_{e1} = 2 * 1{,}46 = 2{,}92m > 2{,}5m$$
$$b_{eff} = 2{,}5\ m$$

7.2.3. Faza I

7.2.3.1. Teorija plastičnosti

$$W_{PL,y} = 804\ cm^3$$
$$M_{pl,y} = W_{PL,y} * f_{yd} = 28542\ kNcm = 285{,}42\ kNm$$
$$285{,}42\ kNm > 228{,}17\ kNm$$
$$\frac{228{,}17}{285{,}42} = 0{,}799\ \rightarrow iskorištenost\ profila\ u\ prvoj\ fazi\ je\ 80\%$$

7.2.3.2. Otpornost na bočno torzijsko izvijanje

Elastični kritični moment bočnog torzijskog izvijanja:

$$M_{cr} = C_1 \cdot \frac{\pi^2 \cdot E \cdot I_z}{L^2} \cdot \left[\sqrt{\frac{I_w}{I_z} + \frac{L^2 \cdot G \cdot I_t}{\pi^2 \cdot E \cdot I_z} + \left(C_2 \cdot z_g\right)^2} - C_2 \cdot z_g\right]$$

Modul elastičnosti	$E = 210000\ N/mm^2$
Modul posmika	$G = 80769{,}23\ N/mm^2$
Konstanta krivljenja	$I_w = 7{,}058 \cdot 10^{10}\ mm^6$
Moment tromosti	$I_z = 4200000\ mm^4$
Torzijska konstanta	$I_t = 160000\ mm^4$
Raspon	$L = 3750\ mm$

Vrijednost proračunatog M_{cr}:

$$M_{cr} = 125{,}15\ kNm$$

Bezdimenzionalna vitkost:

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}} = \sqrt{\frac{484{,}0 \cdot 23{,}5}{12515}} = 0{,}953$$

Faktor redukcije:

$$\frac{h}{b} = \frac{270}{135} = 2{,}00\ \rightarrow\ mjerodavna\ krivulja\ izvijanja\ \boldsymbol{a}\ \rightarrow\ \alpha_{LT} = 0{,}21$$

$$\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\overline{\lambda}_{LT} - 0{,}2\right) + \overline{\lambda}_{LT}^{2}\right] = 0{,}5 \cdot [1 + 0{,}21 \cdot (0{,}952 - 0{,}2) + 0{,}952^2]$$

$$\Phi_{LT} = 1{,}032$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}{}^2 - \overline{\lambda_{LT}}^2}} = \frac{1}{1{,}032 + \sqrt{1{,}032^2 - 0{,}952^2}} = 0{,}699 < 1$$

Računska otpornost:

$$M_{b,Rd} = \chi_{LT} \cdot \frac{W_{pl,y} \cdot f_y}{\gamma_{M1}} = 0{,}699 \cdot \frac{484{,}0 \cdot 23{,}5}{1{,}0} = 79{,}50\ kNm$$

$$M_{Ed,y} = 34{,}83\ kNm < M_{b,Rd} = 79{,}50\ kNm$$

$$\frac{M_{Ed,y}}{M_{b,Rd}} = \frac{34{,}83}{79{,}50} = 0{,}440 < 1{,}0\ \rightarrow Iskoristivost\ je\ 43{,}8\ \%$$

7.2.4. Faza II

7.2.4.1. Klasifikacija poprečnog presjeka

Hrbat

$$\frac{c}{t} = \frac{h - 2 \cdot t_f - 2 \cdot r}{t_w} = \frac{330{,}0 - 2 \cdot 11{,}5 - 2 \cdot 18{,}0}{7{,}5} = 36{,}13$$

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{355}} = 0{,}81$$

$$33 \cdot \varepsilon = 33 \cdot 0{,}81 = 26{,}73$$

$$36{,}13 > 26{,}73$$

$$72 \cdot \varepsilon = 72 \cdot 0{,}81 = 58{,}32$$

$$36{,}13 < 58{,}32$$

Hrbat je svrstan u klasu 2.

Pojasnica

$$\frac{c}{t} = \frac{\frac{b - t_w - 2 \cdot r}{2}}{t_f} = \frac{\frac{160{,}00 - 7{,}5 - 2 \cdot 18{,}0}{2}}{11{,}5} = 5{,}07$$

$$9 \cdot \varepsilon = 9 \cdot 0{,}81 = 7{,}29$$

$$5{,}07 < 7{,}29$$

Pojasnica je svrstana u klasu 1.

Poprečni presjek svrstan je u klasu 2.

7.2.4.2. Teorija plastičnosti

$$N_{CF} = b_{eff} * h_c * 0{,}85 * f_{cd} = 250 * 11 * 0{,}85 * 2 = 4\,675\ kN$$

$$N_A = A * f_{yd} = 62{,}6 * 35{,}5 = 2\,222{,}3\ kN$$

$$N_{CF} > N_A \rightarrow N.O.\, je\ u\ betonskoj\ ploči - CJELI\ NOSAČ\ JE\ U\ VLAKU$$

$$x_{pl} = \frac{A_a * f_{yd}}{0{,}85 * f_{cd} * b_{eff}} = \frac{62{,}6 * 35{,}5}{0{,}85 * 2 * 250} = 5{,}23\ cm$$

Otpornost na savijanje

$$M_{pl,Rd} = A_a * f_{yd} * \left(h_c + h - 0{,}5 * x_{pl}\right) = 62{,}6 * 35{,}5 * (11 + 16{,}5 - 0{,}5 * 5{,}23) = 553{,}01\ kNm$$

$$\frac{M_{ed}}{M_{pl,Rd}} = \frac{469{,}29}{553{,}01} = 0{,}8486 \rightarrow iskorištenost\ profila\ u\ drugoj\ fazi\ \ je\ 85\%$$

Otpornost na poprečnu silu

Provjera na izbočavanje hrpta na posmik

$$h_w = h - 2 \cdot t_f = 330{,}0 - 2 \cdot 11{,}5 = 307\ mm$$

$$\frac{h_w}{t_w} < \frac{72 \cdot \varepsilon}{\eta}$$

$$\frac{307}{7{,}5} < \frac{72 \cdot 0{,}81}{1{,}2}$$

$40{,}93 < 48{,}6$ → Nije potrebna provjera izbočavanja hrpta na posmik.

Plastična posmična otpornost

$$V_{pl,Rd} = \frac{A_{V,z} \cdot (f_y/\sqrt{3})}{\gamma_{M0}}$$

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

$$A_{V,z} = 62{,}61 - 2 \cdot 16{,}00 \cdot 1{,}15 + (0{,}72 + 2 \cdot 1{,}8) \cdot 1{,}15 = 30{,}778\ cm^2$$

$$\eta \cdot h_w \cdot t_w = 1{,}20 \cdot 30{,}7 \cdot 0{,}75 = 27{,}63\ cm^2$$

$$A_{V,z} = 30{,}778\ cm^2 \geq 27{,}63\ cm^2$$

$$V_{pl,z,Rd} = \frac{30{,}778 \cdot (35{,}50/\sqrt{3})}{1{,}00} = 630{,}82\ kN$$

Otpornost poprečnog presjeka na poprečnu silu

$$\frac{V_{z,Ed}}{V_{pl,Rd}} \leq 1{,}00 \qquad \frac{160{,}72}{630{,}82} < 1{,}00 \qquad 0{,}2548 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 25,48%.

Otpornost na bočno torzijsko izvijanje

Gornja pojasnica čeličnog nosača je pridržana na dovoljnom broju mjesta, stoga provjera na bočno torzijsko izvijanje nije potrebna.

7.2.5. Granično stanje uporabljivosti

$$h_n = \frac{A_a \cdot (0{,}5 \cdot f_a + h_c) + \frac{b_{EFF}}{n} \cdot h_c \cdot \frac{h_c}{2}}{A_a + \frac{b_{EFF}}{n} \cdot h_c} = \frac{62{,}61 \cdot (0{,}5 \cdot 33 + 11) + \frac{250}{13{,}5} \cdot 11 \cdot 5{,}5}{62{,}61 + \frac{250}{13{,}5} \cdot 11} = 10{,}67 \text{ cm}$$

$$I_n = I_a + A_a \cdot z_a^2 + I_c + \frac{A_c}{n} \cdot z_c^2 = 11770 + 62{,}61 \cdot \left(\frac{33}{2} + 11 - 10{,}67\right)^2 + \frac{250}{13{,}5} \cdot \frac{11^2}{12} + \frac{250 \cdot 12}{13{,}5} \cdot (10{,}67 - 5{,}5)^2 = 35\,630{,}70\ cm^4$$

7.2.5.1. Stalno opterećenje

$$\delta_g = \frac{5}{384} \cdot \frac{g_{kl} \cdot L^4}{E_a \cdot I_a} + \frac{5}{384} \cdot \frac{g_{kl} \cdot L^4}{E_a \cdot I} = \frac{5}{384} \cdot \frac{0{,}0751 \cdot 250^4}{21000 \cdot 11770} + \frac{5}{384} \cdot \frac{0{,}0625 \cdot 250^4}{21000 \cdot 35\,630{,}70} = 1{,}97\ cm$$

7.2.5.2. Korisno opterećenje

$$\delta_p = \frac{5}{384} \cdot \frac{P_{kl} \cdot L^4}{E_a \cdot I} = \frac{5}{384} \cdot \frac{0{,}05 \cdot 250^4}{21000 \cdot 35\,630{,}70} = 0{,}34\ cm$$

Dokaz

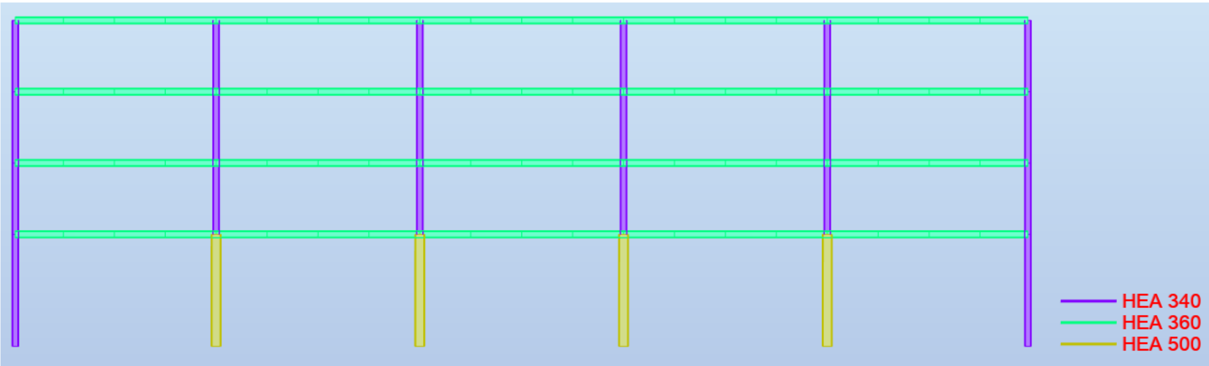
$$\delta_{kon} \leq \frac{L}{300} = \frac{1168}{300} = 3{,}89\ cm > 1{,}97\ cm$$

$$\delta_{kon} \leq \frac{L}{250} = \frac{1168}{250} = 4{,}67\ cm > 2{,}31\ cm$$

8 POMACI OKVIRA

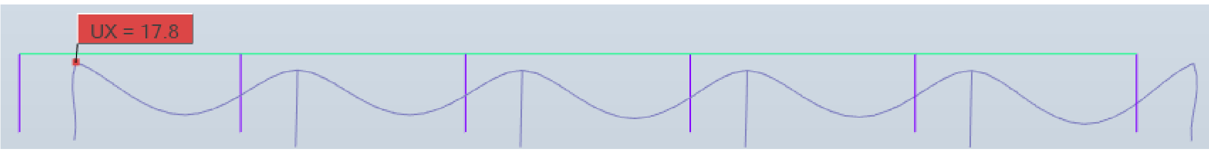
Okvir se sastoji od glavnih nosača i stupova. S obzirom na odabranu vrstu profila te opterećenja koja preuzima, okvire dijelimo u 2 grupe, vanjski i unutarnji okvir. U nastavku je prikaz sila, momenata i pomaka dijelova okvira. Sile su izražene u kN, momenti u kNm, a pomaci u mm. Pomaci su prikazani za referentnu kombinaciju graničnog stanja uporabljivosti.

8.1. Vanjski okvir

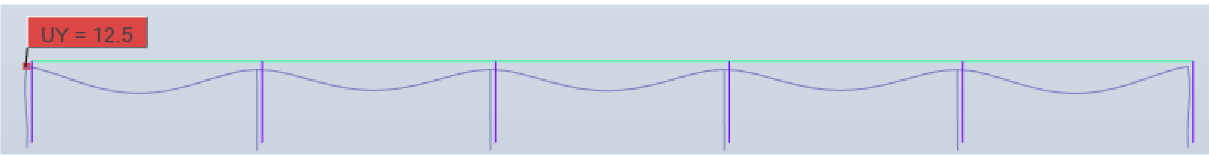


Slika 29. Prikaz vanjskog okvira

8.1.1. Treći kat



Slika 30. Pomak u smjeru x vanjskog okvira na dijelu trećeg kata



Slika 31. Pomak u smjeru y vanjskog okvira na dijelu trećeg kata

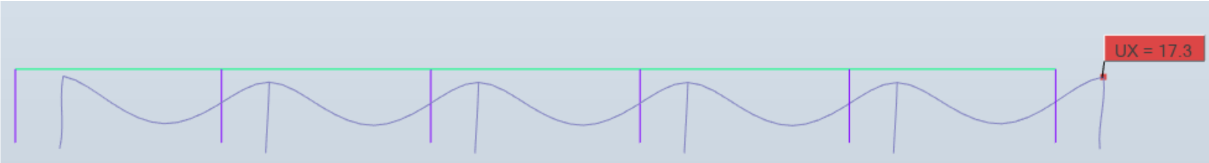
Horizontalni pomak kata:

$$u_x \leq \frac{H_i}{300}$$

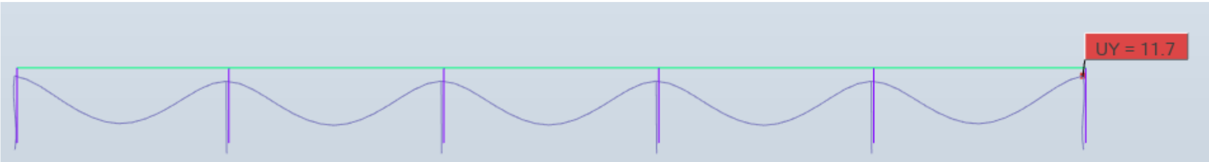
$$17{,}8 - 17{,}3 \leq \frac{3500}{300}$$

$$0{,}5\ mm \leq 11{,}67\ mm$$

8.1.2. Drugi kat



Slika 32. Pomak u smjeru x vanjskog okvira na dijelu drugog kata



Slika 33. Pomak vanjskog okvira u smjeru y na dijelu drugog kata

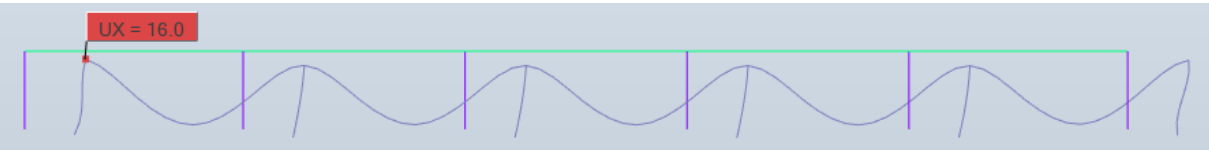
Horizontalni pomak kata:

$$u_x \leq \frac{H_i}{300}$$

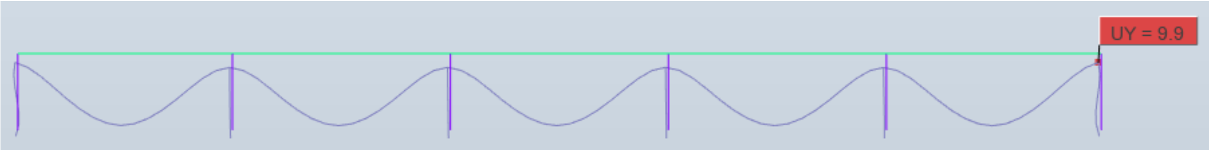
$$17{,}3 - 16{,}0 \leq \frac{3500}{300}$$

$$1{,}3\ mm \leq 11{,}67\ mm$$

8.1.3. Prvi kat



Slika 34. Pomak u smjeru x vanjskog okvira na dijelu prvog kata



Slika 35. Pomak u smjeru y vanjskog okvira na dijelu prvog kata

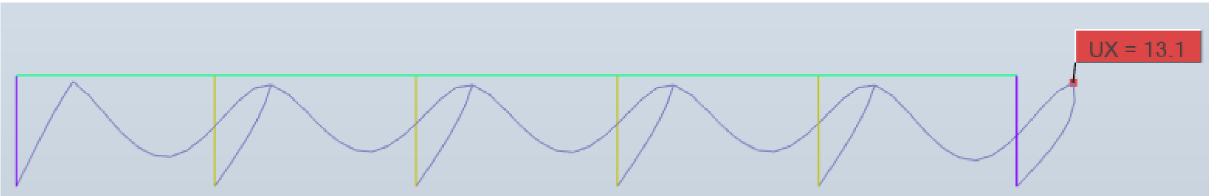
Horizontalni pomak kata:

$$u_x \leq \frac{H_i}{300} =$$

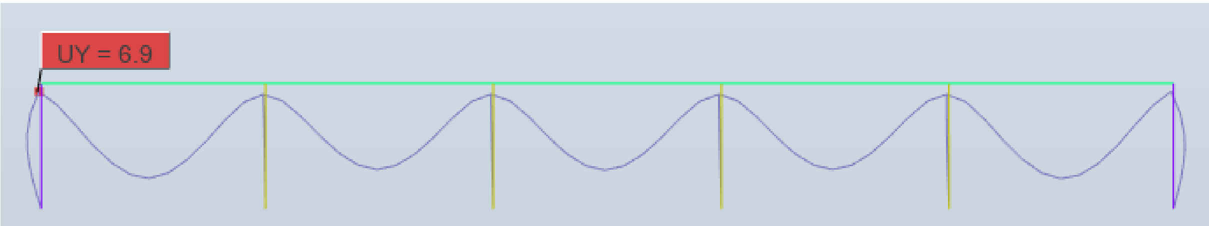
$$16 - 13{,}1 \leq \frac{5500}{300}$$

$$2{,}9\ mm \leq 18{,}3\ mm$$

8.1.4. Prizemlje



Slika 36. Pomak u smjeru x vanjskog okvira u prizemlju



Slika 37. Pomak u smjeru y vanjskog okvira u prizemlju

Horizontalni pomak kata:

$$u_x \leq \frac{H_i}{300} = \frac{5500}{300}$$

$$13{,}1\ mm \leq 18{,}33\ mm$$

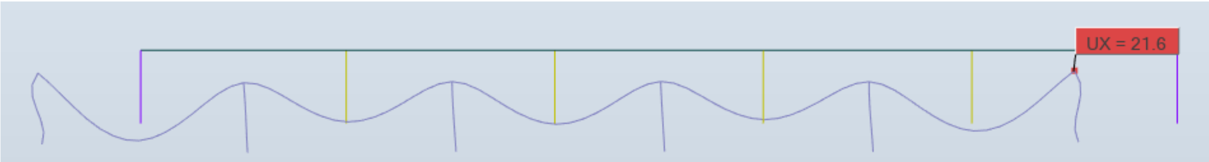
Ukupni pomak okvira:

$$u_x \leq \frac{H}{500} = \frac{18000}{500}$$

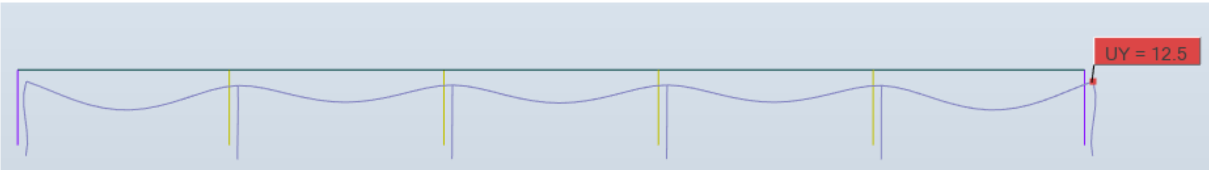
$$17{,}8\ mm \leq 36\ mm$$

8.2. Unutarnji okvir

8.2.1. Treći kat



Slika 38. Pomak u smjeru x unutarnjeg okvira na dijelu trećeg kata



Slika 39. . Pomak u smjeru y unutarnjeg okvira na dijelu trećeg kata

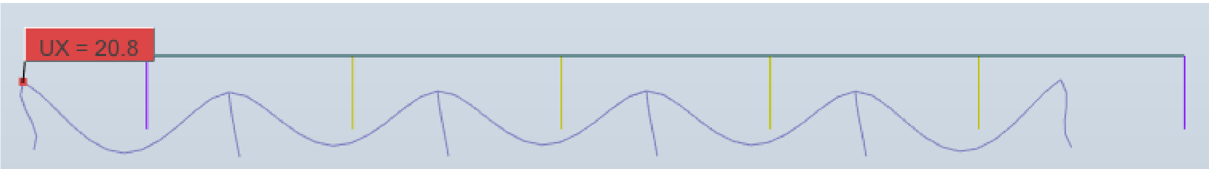
Horizontalni pomak kata:

$$u_x \leq \frac{H_i}{300}$$

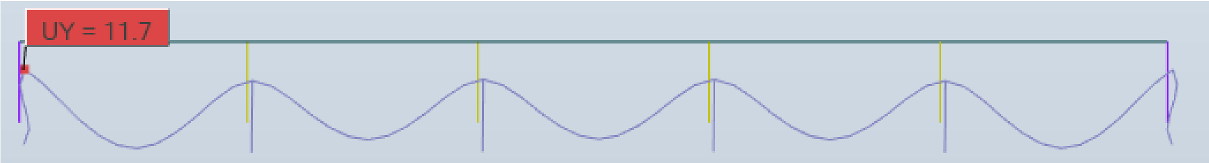
$$21{,}6 - 20{,}8 \leq \frac{3500}{300}$$

$$0{,}8\ mm \leq 11{,}67\ mm$$

8.2.2. Drugi kat



Slika 40. Pomak unutarnjeg okvira u smjeru x na dijelu drugog kata



Slika 41. Pomak unutarnjeg okvira u smjeru y na dijelu drugog kata

Horizontalni pomak kata:

$$u_x \leq \frac{H_i}{300}$$

$$20{,}8 - 19 \leq \frac{3500}{300}$$

$$1{,}8\ mm \leq 11{,}67\ mm$$

8.2.3. Prvi kat

Slika 42. Pomak u smjeru x unutarnjeg okvira na dijelu prvog kata

Slika 43. Pomak u smjeru y unutarnjeg okvira na dijelu prvog kata

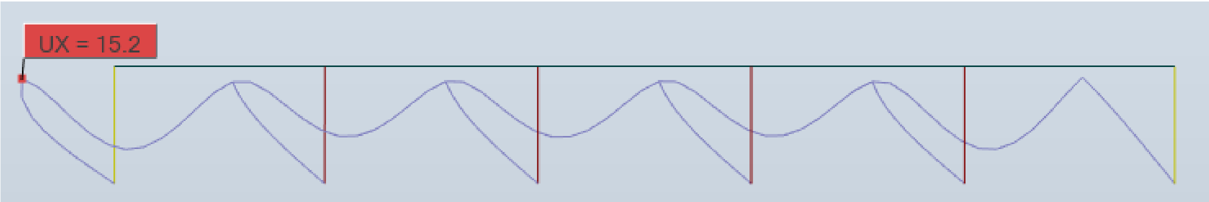
Horizontalni pomak kata:

$$u_x \leq \frac{H_i}{300}$$

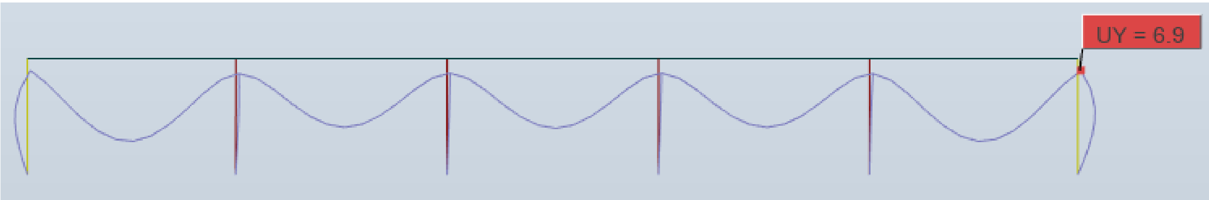
$$19 - 15{,}2 \leq \frac{5500}{300}$$

$$3{,}8\ mm \leq 18{,}33\ mm$$

8.2.4. Prizemlje



Slika 44. Pomak u smjeru x unutarnjeg okvira u prizemlju



Slika 45. Pomak u smjeru y unutarnjeg okvira u prizemlju

Horizontalni pomak kata:

$$u_x \leq \frac{H_i}{300} = \frac{5500}{300}$$

$$15{,}2\ mm \leq 18{,}3\ mm$$

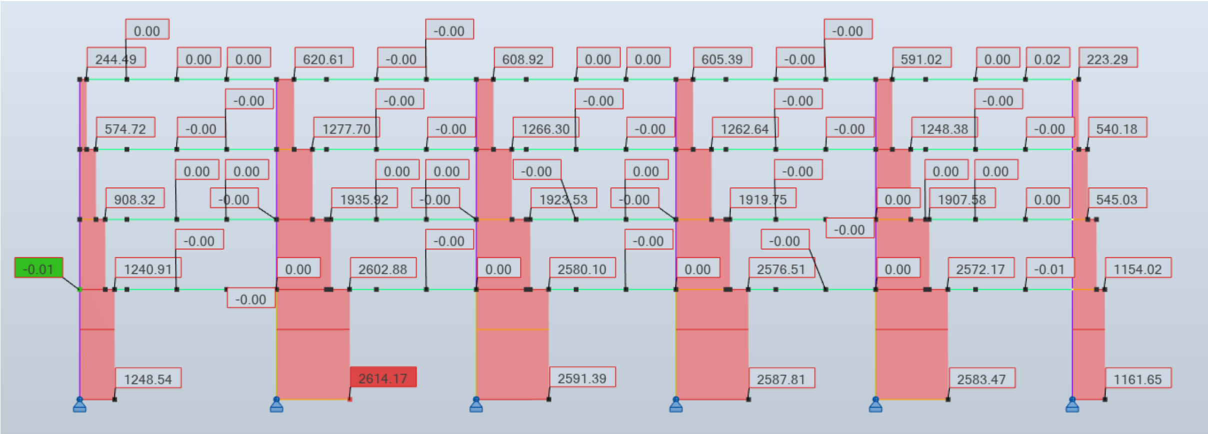
Ukupni pomak okvira:

$$u_x \leq \frac{H}{500} = \frac{18000}{500}$$

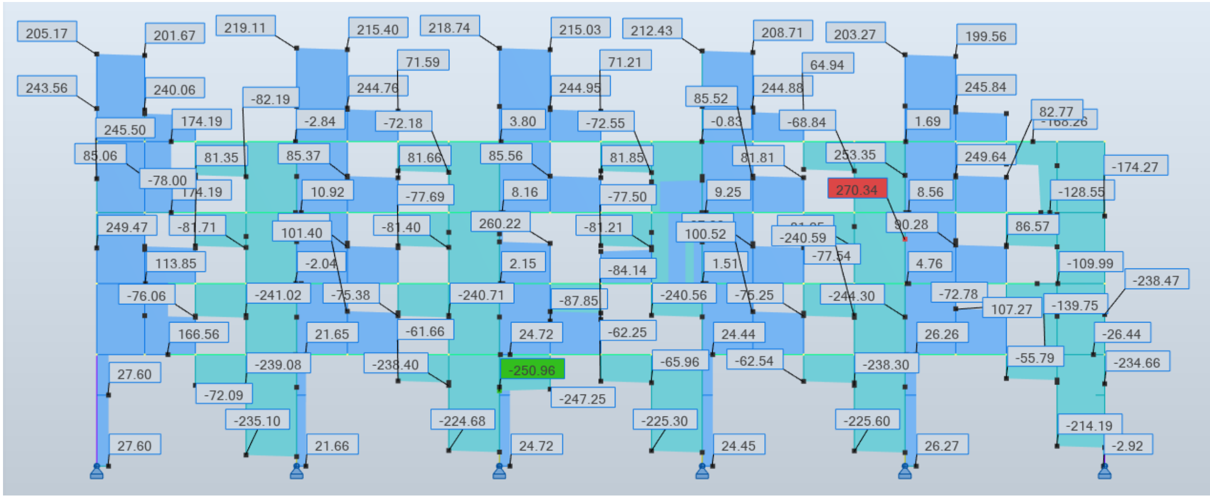
$$21{,}6\ mm \leq 36\ mm$$

9 KLASIFIKACIJA OKVIRA

9.1. Vanjski okvir



Slika 46. Uzdužne sile vanjskog okvira



Slika 47. Poprečne sile vanjskog okvira

Treći kat:

$$\alpha_{cr} = \frac{H_{Ed}}{V_{Ed}} \cdot \frac{h}{\delta_{h,Ed}} = \frac{352}{2983} \cdot \frac{3500}{17{,}8} = 23 > 10 \rightarrow dopuštena\ je\ analiza\ I.reda$$

Drugi kat:

$$\alpha_{cr} = \frac{H_{Ed}}{V_{Ed}} \cdot \frac{h}{\delta_{h,Ed}} = \frac{613}{6200} \cdot \frac{3500}{17{,}3} = 20 > 10 \rightarrow dopuštena\ je\ analiza\ I.reda$$

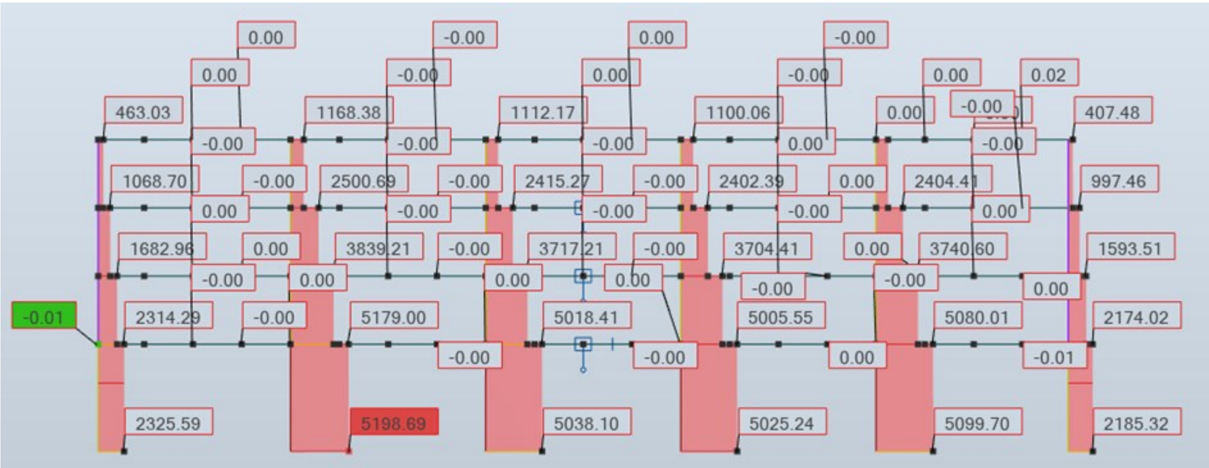
Prvi kat:

$$\alpha_{cr} = \frac{H_{Ed}}{V_{Ed}} \cdot \frac{h}{\delta_{h,Ed}} = \frac{9481}{949} \cdot \frac{5500}{16} = 34 > 10 \rightarrow dopuštena\ je\ analiza\ I.reda$$

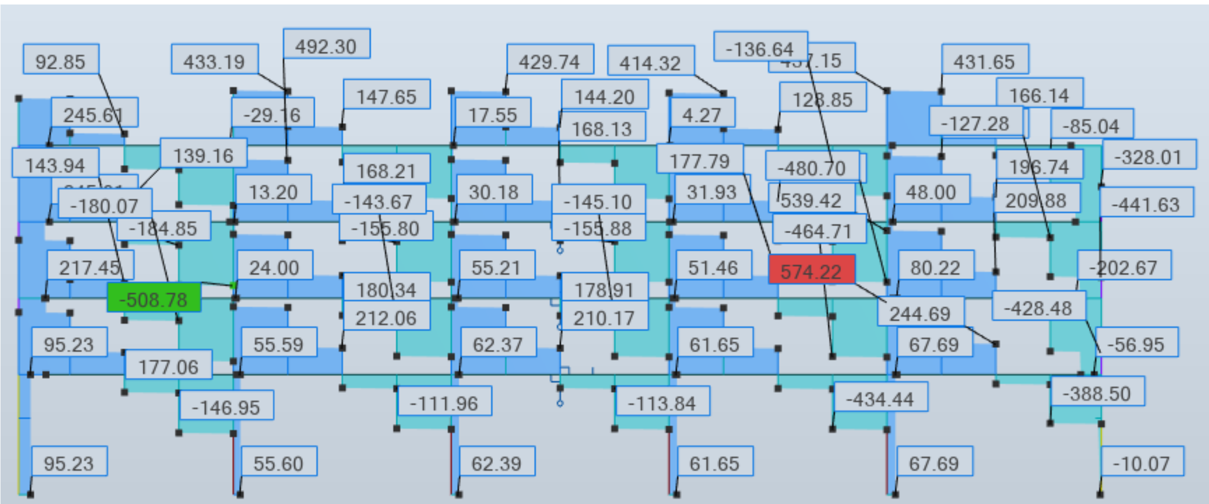
Prizemlje:

$$\alpha_{cr} = \frac{H_{Ed}}{V_{Ed}} \cdot \frac{h}{\delta_{h,Ed}} = \frac{1100}{12787} \cdot \frac{5500}{13,1} = 36 > 10 \rightarrow dopuštena\ je\ analiza\ I.reda$$

9.2. Unutarnji okvir



Slika 48. Uzdužne sile unutarnjeg okvira (GSN)



Slika 49. . Poprečne sile unutarnjeg okvira (GSN)

Treći kat:

$$\alpha_{cr} = \frac{H_{Ed}}{V_{Ed}} \cdot \frac{h}{\delta_{h,Ed}} = \frac{583}{5892} \cdot \frac{3500}{21{,}6} = 16 > 10 \rightarrow dopuštena\ je\ analiza\ I.reda$$

Drugi kat:

$$\alpha_{cr} = \frac{H_{Ed}}{V_{Ed}} \cdot \frac{h}{\delta_{h,Ed}} = \frac{1124}{12369} \cdot \frac{3500}{20{,}8} = 15 > 10 \rightarrow dopuštena\ je\ analiza\ I.reda$$

Prvi kat:

$$\alpha_{cr} = \frac{H_{Ed}}{V_{Ed}} \cdot \frac{h}{\delta_{h,Ed}} = \frac{1755}{18862} \cdot \frac{5500}{19} = 27 > 10 \rightarrow dopuštena\ je\ analiza\ I.reda$$

Prizemlje:

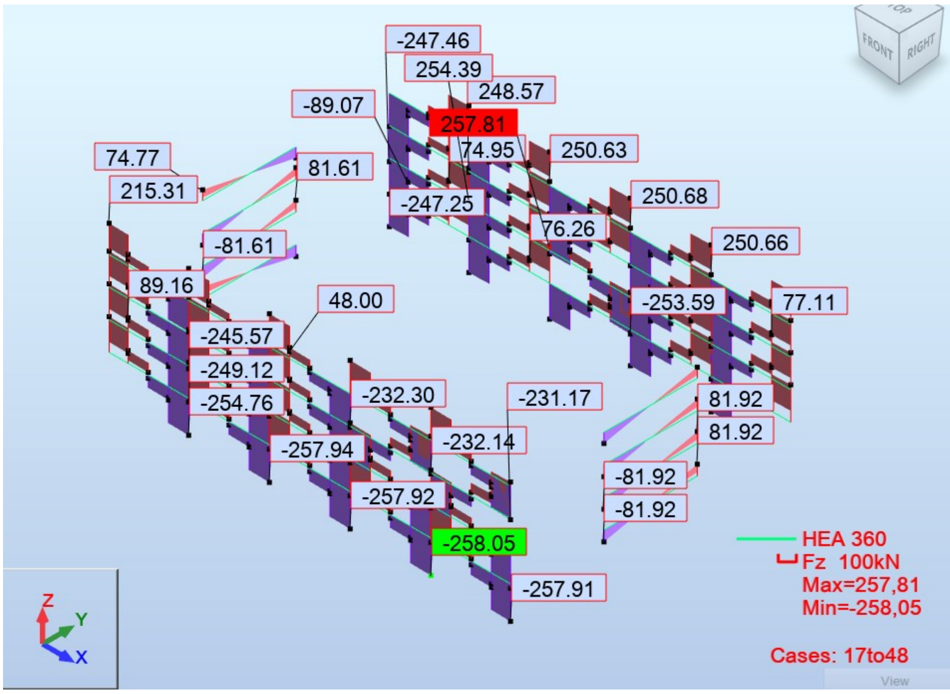
$$\alpha_{cr} = \frac{H_{Ed}}{V_{Ed}} \cdot \frac{h}{\delta_{h,Ed}} = \frac{1818}{25422} \cdot \frac{5500}{15{,}2} = 26 > 10 \rightarrow dopuštena\ je\ analiza\ I.reda$$

10 GLAVNI NOSAČ

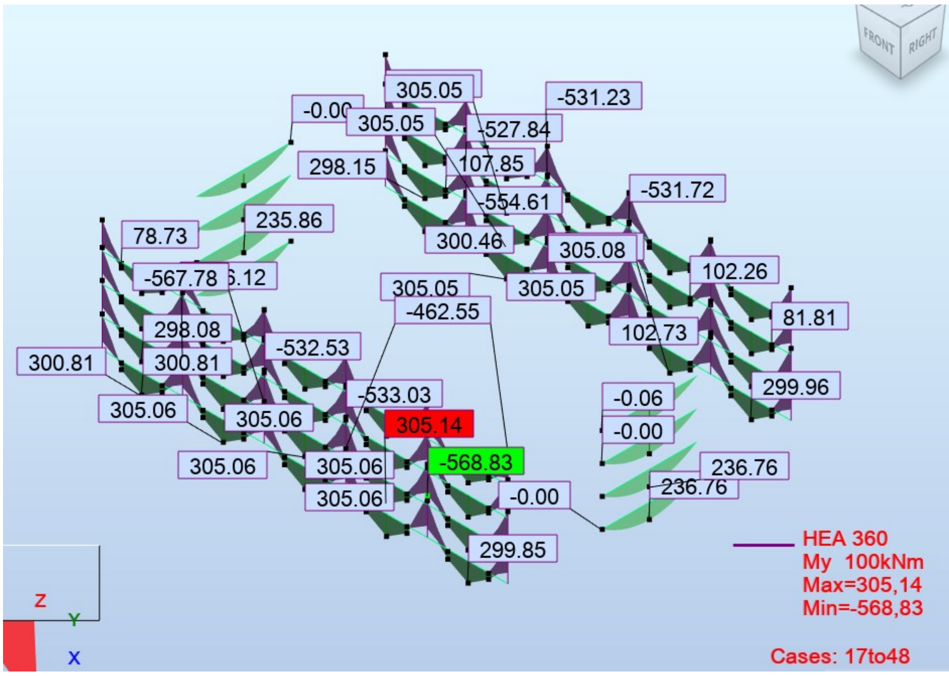
Glavne nosače dijelimo u tri grupe. Prvu grupu čine vanjski glavni nosači koji su položeni u smjeru okvira te nosači srednjeg raspona okomito na okvir. Drugu grupu čine vanjski rubni glavni nosači koji su usmjereni okomito na okvir. Treća grupa se sastoji od unutarnjih glavnih nosača.

10.1 Vanjski glavni nosači u smjeru okvira te središnji raspon okomit na okvir

10.1.1. Opterećenje

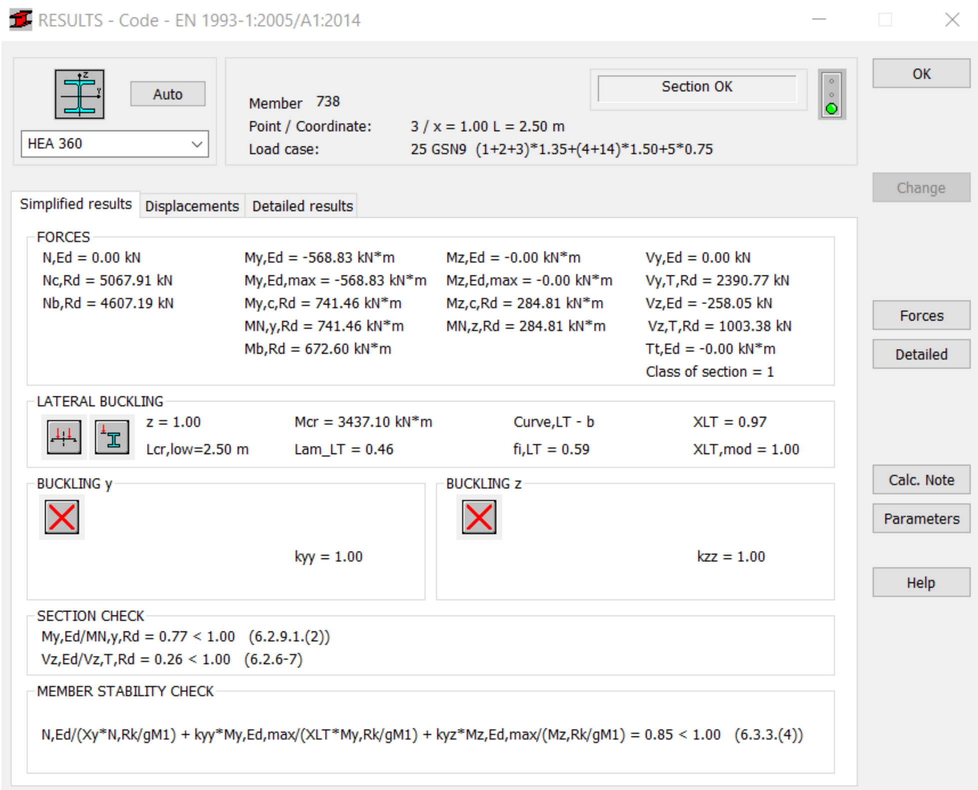


Slika 50. Poprečna sila grede HEA 360



Slika 51. Moment savijanja grede HEA 360

Najopterećeniji element je element 738.



Slika 52. Karakteristike najopterećenijeg elementa 738

10.1.2. Karakteristike odabranog profila

Odabrani profil:	HEA 360
Prostorna težina:	$G = 112{,}0\ kg/m$
Površina poprečnog presjeka:	$A = 142{,}8\ cm^2$
Visina presjeka:	$h = 350{,}0\ mm$
Širina pojasnice:	$b = 300{,}0\ mm$
Debljina hrpta:	$t_w = 10\ mm$
Debljina pojasnice:	$t_f = 17{,}5\ mm$
Radijus zaobljenja:	$r = 27\ mm$
Moment tromosti:	$I_y = 33090\ cm^4$
Moment tromosti:	$I_z = 7887\ cm^4$
Moment otpora:	$W_y = 1891\ cm^3$
Moment otpora:	$W_z = 525{,}8\ cm^3$
Moment plastičnosti:	$W_{pl,y} = 2088\ cm^4$
Moment plastičnosti:	$W_{pl,z} = 802{,}3\ cm^4$

10.1.3. Klasifikacija presjeka

Hrbat

$$\frac{c}{t} = \frac{h - 2\ \cdot\ t_f - 2\ \cdot r}{t_w} = \frac{350{,}00 - 2\ \cdot\ 17{,}5 - 2\ \cdot 27{,}0}{10{,}0} = 26{,}1$$

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{355}} = 0{,}81$$

$$72 \cdot\ \varepsilon = 72\ \cdot 0{,}81\ = 58{,}32$$

$$26{,}1 < 58{,}32$$

Hrbat je svrstan u klasu 1.

Pojasnica

$$\frac{c}{t} = \frac{\frac{b - t_w - 2\ \cdot r}{2}}{t_f} = \frac{\frac{300{,}00 - 10{,}0 - 2\ \cdot 27{,}0}{2}}{17{,}5} = 6{,}74$$

$$9\ \cdot\ \varepsilon = 9\ \cdot 0{,}81 = 7{,}29$$

$$6{,}74 < 7{,}29$$

Pojasnica je svrstana u klasu 1.

Poprečni presjek svrstan je u klasu 1.

10.1.4. Otpornost poprečnog presjeka na savijanje

Otpornost poprečnog presjeka na savijanje oko osi y-y

$$M_{pl,y} = \frac{W_{pl,Rd} \cdot f_y}{\gamma_{M0}} = \frac{2088 \cdot 35{,}5}{1{,}0} = 741{,}24\ kNm$$

$$M_{y,Ed} = 568{,}83\ kNm < M_{pl,y} = 741\ kNm$$

$$\frac{M_{y,Ed}}{M_{pl,y}} = \frac{568{,}83}{741} = 0{,}767 \ \rightarrow Iskoristivost\ je\ 77\ \%$$

10.1.5. Otpornost poprečnog presjeka na posmik

Otpornost poprečnog presjeka na posmik u smjeru osi z-z

Provjera izbočavanja hrpta na posmik

$$\frac{h_w}{t_w} > 72 \cdot \frac{\varepsilon}{\eta}$$

$$h_w = h - 2 \cdot t_f = 350 - 2 \cdot 17{,}5 = 315\ mm$$

$$\eta = 1{,}20$$

$$\frac{h_w}{t_w} = \frac{315}{10{,}0} = 31{,}5 < 72 \cdot \frac{\varepsilon}{\eta} = 72 \cdot \frac{0{,}81}{1{,}20} = 48{,}6$$

→ Nije potrebna provjera izbočavanja hrpta na posmik.

Plastična posmična otpornost:

$$V_{pl,z,Rd} = \frac{A_{v,z} \cdot (f_y/\sqrt{3})}{\gamma_{M0}}$$

Posmična površina:

$$A_{v,z} = A - 2 \cdot b \cdot t_f + t_f \cdot (t_w + 2 \cdot r) \geq \eta \cdot h_w \cdot t_w$$

$$A_{v,z} = 142{,}8 - 2 \cdot 30{,}0 \cdot 1{,}75 + 1{,}75 \cdot (1{,}0 + 2 \cdot 2{,}7) = 49\ cm^2$$

$$49\ cm^2 \geq 1{,}20 \cdot 31{,}5 \cdot 1{,}0 = 37{,}8\ cm^2$$

$$V_{pl,z,Rd} = \frac{49 \cdot (35{,}5/\sqrt{3})}{1{,}00} = 1004\ kN$$

$$V_{z,Ed} = 258\ kN < V_{pl,z,Rd} = 1004\ kN$$

$$\frac{V_{z,Ed}}{V_{pl,z,Rd}} = \frac{258}{1004} = 0{,}26\ \rightarrow Iskoristivost\ je\ 26\ \%$$

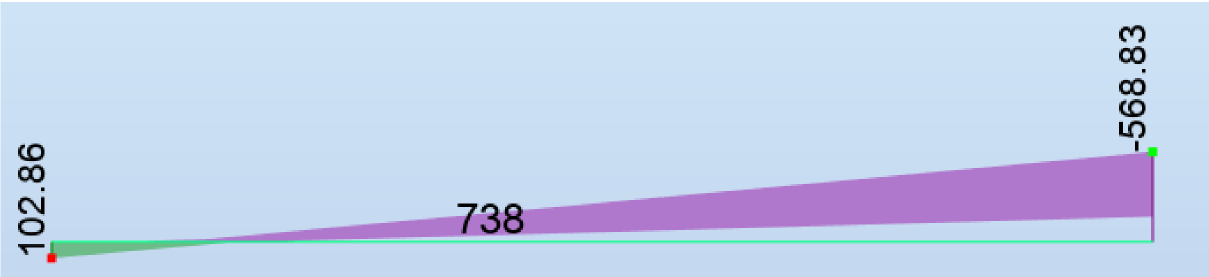
10.1.6. Otpornost poprečnog presjeka na interakciju savijanja i posmika

Otpornost poprečnog presjeka na interakciju savijanja i posmika u smjeru osi z-z

$$V_{z,Ed} \leq 0{,}50 \cdot V_{pl,z,Rd}$$

$258kN \leq 0{,}50 \cdot 1004 = 502\ kN$ → Nije potrebna redukcija otpornosti.

10.1.7. Otpornost elementa izloženog savijanju



Slika 53. Momentni dijagram elementa

ψ	C_1
+1,00	1,00
+0,75	1,14
+0,50	1,31
+0,25	1,52
0,00	1,77
-0,25	2,05
-0,50	2,33
-0,75	2,57
-1,00	2,55

Određivanje faktora C_1

$$\psi = -\frac{102,86}{568,83} = -0,181$$

Očitano:

$$C_1 = 1,97$$

Elastični kritični moment bočnog torzijskog izvijanja:

$$M_{cr} = C_1 \cdot \frac{\pi^2 \cdot E \cdot I_z}{L^2} \cdot \left[\sqrt{\frac{I_w}{I_z} + \frac{L^2 \cdot G \cdot I_t}{\pi^2 \cdot E \cdot I_z}}\right]$$

Modul elastičnosti $E = 210000\ N/mm^2$

Modul posmika $G = 80769,23\ N/mm^2$

Konstanta krivljenja $I_w = 33090\ mm^6$

Moment tromosti $I_z = 7887\ cm^4$

Torzijska konstanta $I_t = 148,8\ cm^4$

Raspon $L = 2500\ mm$

$$M_{cr} = 1,97 \cdot \frac{\pi^2 \cdot 21000 \cdot 7887}{250^2} \cdot \left[\sqrt{\frac{33090}{7887} + \frac{250^2 \cdot 8076,923 \cdot 148,8}{\pi^2 \cdot 21000 \cdot 7887}}\right]$$

$$M_{cr} = 36487\ kNm$$

Bezdimenzionalna vitkost:

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}} = \sqrt{\frac{2088 \cdot 35,5}{364807}} = 0,45$$

Faktor redukcije:

$$\frac{h}{b} = \frac{350}{300} = 1,16 < 2\ \rightarrow\ mjerodavna\ krivulja\ izvijanja\ \boldsymbol{b}\ \rightarrow\ \alpha_{LT} = 0,34$$

$$\Phi_{LT} = 0,5\left[1 + \alpha_{LT}\left(\overline{\lambda}_{LT} - 0,2\right) + \overline{\lambda}_{LT}^2\right]$$

$$\Phi_{LT} = 0,5 \cdot [1 + 0,34 \cdot (0,45 - 0,2) + 0,45^2] = 0,64$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{{\Phi_{LT}}^2 - \overline{\lambda_{LT}}^2}} = \frac{1}{0,64 + \sqrt{0,64^2 - 0,45^2}} = 0,91 \leq 1$$

Računska otpornost:

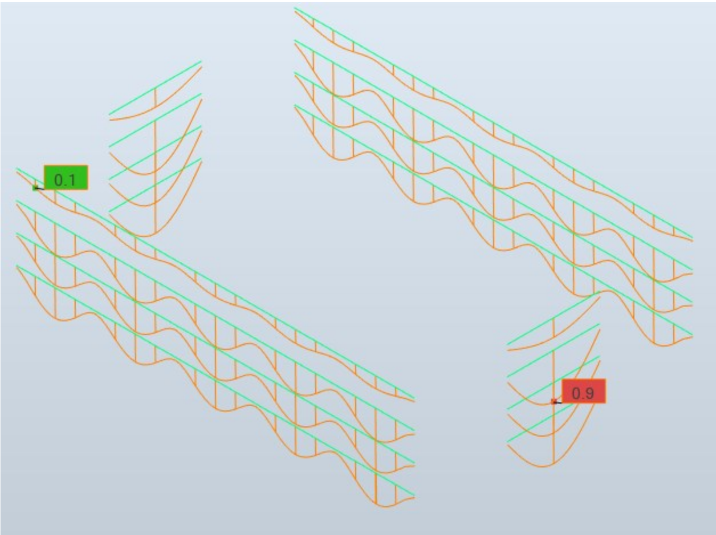
$$M_{b,Rd} = \chi_{LT} \frac{W_{pl,y} \cdot f_y}{\gamma_{M1}} = 0{,}91 \cdot \frac{2088 \cdot 35{,}5}{1{,}10} \cdot 10^{-2} = 613 \ kNm$$

$$M_{Ed,y} = 569 \ kNm < M_{b,Rd} = 613 \ kNm$$

$$\frac{M_{Ed,y}}{M_{b,Rd}} = \frac{569}{613} = 0{,}93 < 1{,}0$$

Presjek zadovoljava s iskoristivošću od 93 %.

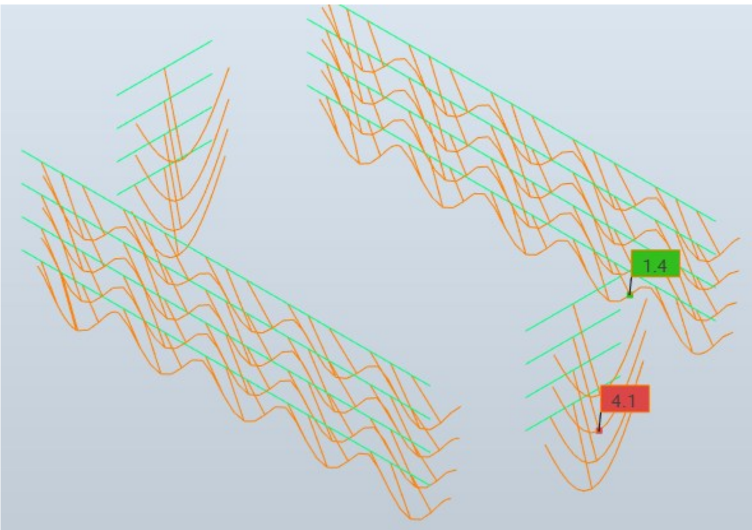
10.1.8.Granično stanje uporabljivosti



Slika 54. Progib grede HEA 360 pod utjecajem korisnoog opterećenja

Progib od koisnog opterećenja:

$$0{,}9 \ cm \leq \frac{L}{300} = \frac{1156}{300} = 3{,}85 \ cm$$



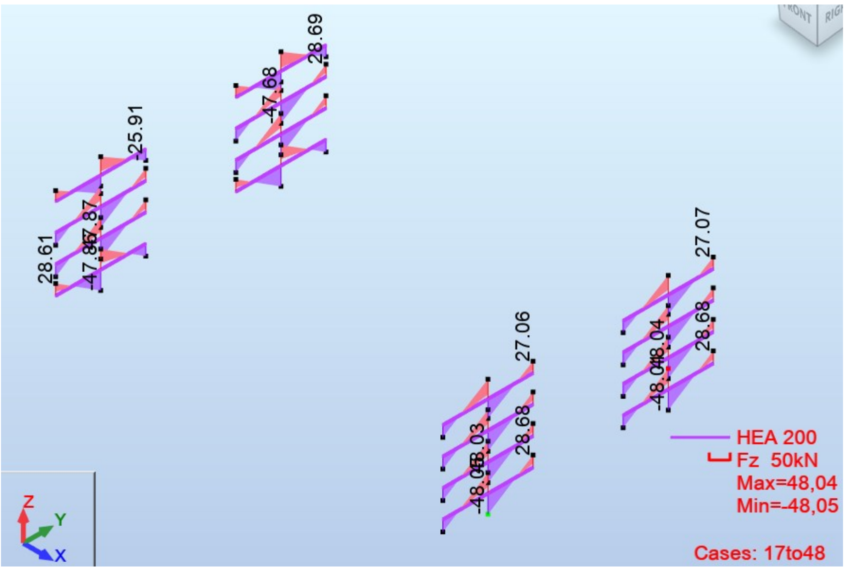
Slika 55. Ukupan progib grede HEA 360

Ukupan progib:

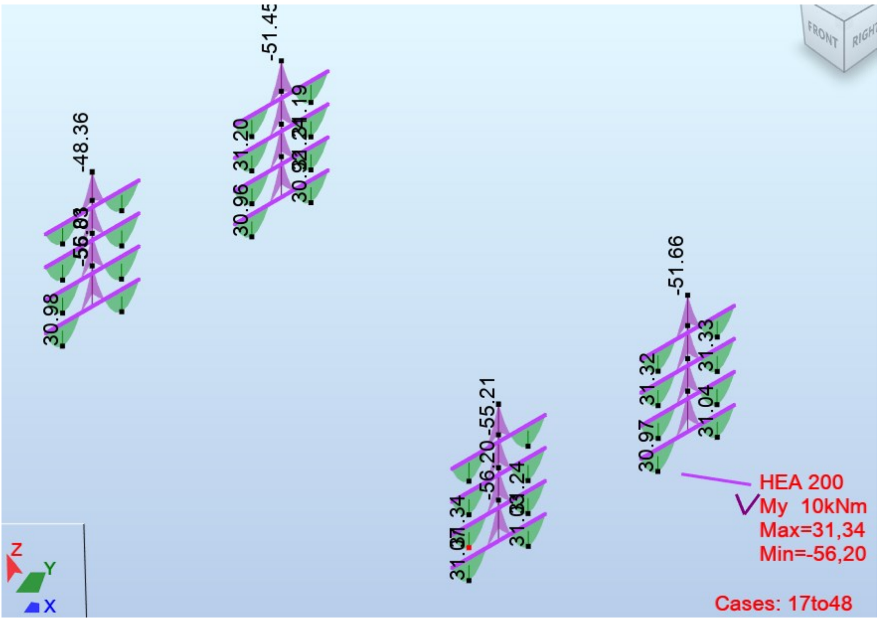
$$4{,}1\ cm \leq \frac{L}{250} = \frac{1156}{250} = 4{,}62\ cm$$

10.2. Vanjski rubni nosači okomiti na okvir

10.2.1. Opterećenje

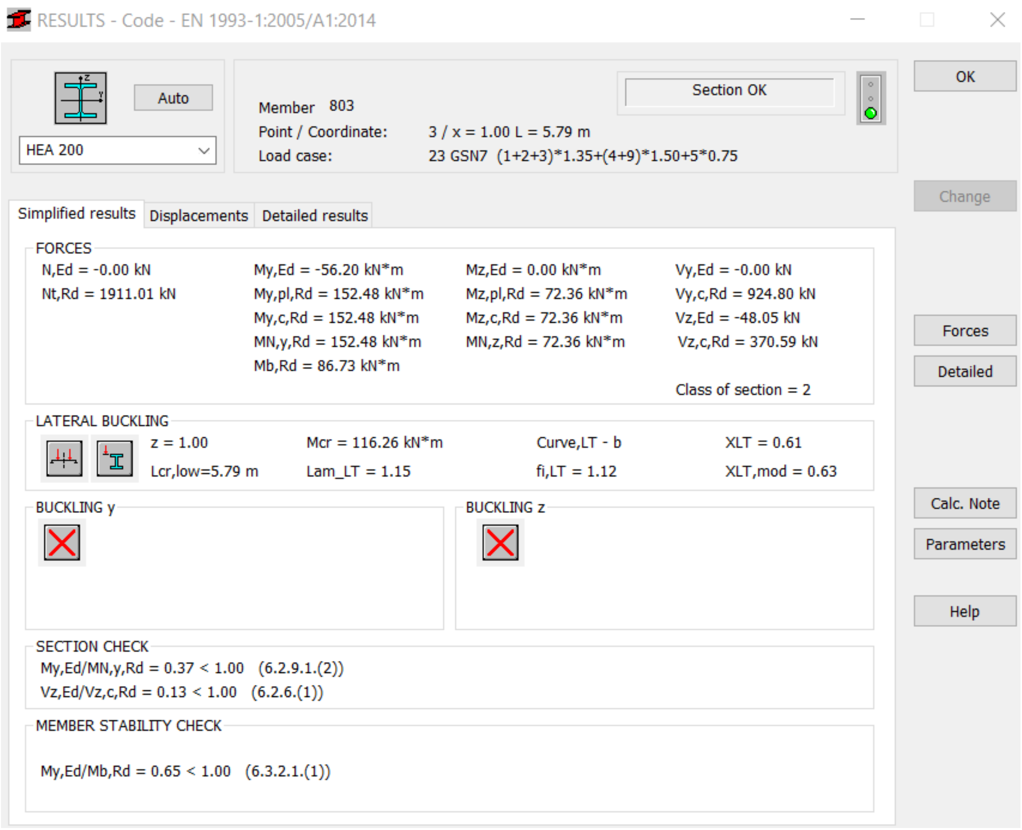


Slika 56.Poprečna sila grede HEA 200



Slika 57. Moment savijanje grede HEA 200

Najopterećeniji element je element 803.



Slika 58. Karakteristike najopterećenijeg elementa 803

10.2.2. Karakteristike odabranog profila

Odabrani profil:	HEA200
Prostorna težina:	$G = 42{,}3\ kg/m$
Površina poprečnog presjeka:	$A = 53{,}83\ cm^2$
Visina presjeka:	$h = 190{,}0\ mm$
Širina pojasnice:	$b = 200{,}0\ mm$
Debljina hrpta:	$t_w = 6{,}5\ mm$
Debljina pojasnice:	$t_f = 10{,}0\ mm$
Radijus zaobljenja:	$r = 18\ mm$
Moment tromosti:	$I_y = 3692\ cm^4$
Moment tromosti:	$I_z = 1336\ cm^4$
Moment otpora:	$W_y = 388{,}6\ cm^3$
Moment otpora:	$W_z = 133{,}6\ cm^3$
Moment plastičnosti:	$W_{pl,y} = 429{,}5\ cm^4$
Moment plastičnosti:	$W_{pl,z} = 203{,}8\ cm^4$

10.2.3. Klasifikacija presjeka

Hrbat

$$\frac{c}{t} = \frac{h - 2\ \cdot\ t_f - 2\ \cdot r}{t_w} = \frac{190{,}00 - 2\ \cdot\ 10 - 2\ \cdot 18{,}0}{6{,}5} = 20{,}62$$

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{355}} = 0{,}81$$

$$72 \cdot\ \varepsilon = 72\ \cdot 0{,}81\ = 58{,}32$$

$$20{,}62 < 58{,}32$$

Hrbat je svrstan u klasu 1.

Pojasnica

$$\frac{c}{t} = \frac{\frac{b - t_w - 2\ \cdot r}{2}}{t_f} = \frac{\frac{200{,}00 - 6{,}5 - 2\ \cdot 18{,}0}{2}}{10} = 7{,}88$$

$$9\ \cdot\ \varepsilon = 9\ \cdot 0{,}81 = 7{,}29$$

$$7{,}88\ > 7{,}29$$

Pojasnica je svrstana u klasu 2.

Poprečni presjek svrstan je u klasu 2.

10.2.4. Otpornost poprečnog presjeka na savijanje

Otpornost poprečnog presjeka na savijanje oko osi y-y

$$M_{pl,y} = \frac{W_{pl,Rd} \cdot f_y}{\gamma_{M0}} = \frac{429{,}5 \cdot 35{,}5}{1{,}0} = 153\ kNm$$

$$M_{y,Ed} = 56{,}2\ kNm < M_{pl,y} = 153\ kNm$$

$$\frac{M_{y,Ed}}{M_{pl,y}} = \frac{56{,}2}{153} = 0{,}37\ \rightarrow Iskoristivost\ je\ 37\ \%$$

10.2.5. Otpornost poprečnog presjeka na posmik

Otpornost poprečnog presjeka na posmik u smjeru osi z-z

Provjera izbočivanja hrpta na posmik

$$\frac{h_w}{t_w} > 72 \cdot \frac{\varepsilon}{\eta}$$

$$h_w = h - 2 \cdot t_f = 190 - 2 \cdot 10 = 170\ mm$$

$$\eta = 1{,}20$$

$$\frac{h_w}{t_w} = \frac{170}{6{,}5} = 26{,}2 < 72 \cdot \frac{\varepsilon}{\eta} = 72 \cdot \frac{0{,}81}{1{,}20} = 48{,}6$$

→ Nije potrebna provjera izbočavanja hrpta na posmik.

Plastična posmična otpornost:

$$V_{pl,z,Rd} = \frac{A_{v,z} \cdot (f_y/\sqrt{3})}{\gamma_{M0}}$$

Posmična površina:

$$A_{v,z} = A - 2 \cdot b \cdot t_f + t_f \cdot (t_w + 2 \cdot r) \geq \eta \cdot h_w \cdot t_w$$

$$A_{v,z} = 53{,}83 - 2 \cdot 20{,}0 \cdot 1{,}0 + 1{,}0 \cdot (0{,}65 + 2 \cdot 1{,}8) = 18{,}08\ cm^2$$

$$18{,}08\ cm^2 \geq 1{,}20 \cdot 17 \cdot 0{,}65 = 13{,}26\ cm^2$$

$$V_{pl,z,Rd} = \frac{18{,}08 \cdot (35{,}5/\sqrt{3})}{1{,}00} = 370\ kN$$

$$V_{z,Ed} = 48\ kN < V_{pl,z,Rd} = 370\ kN$$

$$\frac{V_{z,Ed}}{V_{pl,z,Rd}} = \frac{48}{370} = 0{,}13\ \rightarrow Iskoristivost\ je\ 13\ \%$$

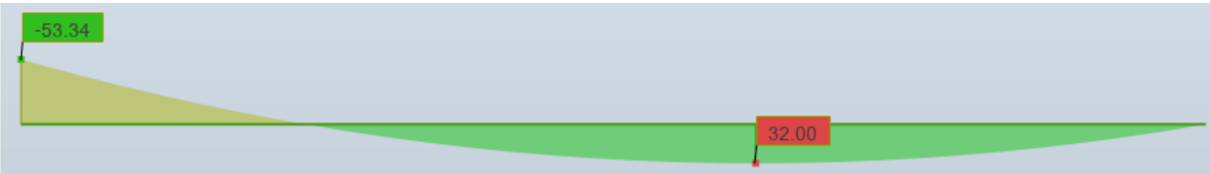
10.2.6. Otpornost poprečnog presjeka na interakciju savijanja i posmika

Otpornost poprečnog presjeka na interakciju savijanja i posmika u smjeru osi z-z

$$V_{z,Ed} \leq 0{,}50 \cdot V_{pl,z,Rd}$$

$48\ kN \leq 0{,}50 \cdot 370 = 185\ kN$ → Nije potrebna redukcija otpornosti.

10.2.7. Otpornost elementa izloženog savijanju



Slika 59. Momentni dijagram elementa

Očitan koeficijenti $c_1 = 1{,}13$ i $c_2 = 0{,}46$. *[6]*

Elastični kritični moment bočnog torzijskog izvijanja:

$$M_{cr} = C_1 \cdot \frac{\pi^2 \cdot E \cdot I_z}{L^2} \cdot \left[\sqrt{\frac{I_w}{I_z} + \frac{L^2 \cdot G \cdot I_t}{\pi^2 \cdot E \cdot I_z} + (C_2 z_g)^2} - C_2 z_g\right]$$

Modul elastičnosti	$E = 210000\ N/mm^2$
Modul posmika	$G = 8076{,}923\ N/mm^2$
Konstanta krivljenja	$I_w = 3692\ mm^6$
Moment tromosti	$I_z = 1336\ cm^4$

Torzijska konstanta $I_t = 20{,}98\ cm^4$

Raspon $L = 5790\ mm$

$$M_{cr} = 1{,}13 \cdot \frac{\pi^2 \cdot 21000 \cdot 1336}{579^2} \cdot \left[\sqrt{\frac{3692}{1336} + \frac{579^2 \cdot 8076{,}923 \cdot 20{,}98}{\pi^2 \cdot 21000 \cdot 1336}(0{,}46 \cdot 10)^2} - 0{,}46 \cdot 10\right]$$

$$M_{cr} = 846\ kNm$$

Bezdimenzionalna vitkost:

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}} = \sqrt{\frac{429{,}5 \cdot 35{,}5}{84618}} = 0{,}42$$

Faktor redukcije:

$$\frac{h}{b} = \frac{190}{200} = 0{,}95 < 2\ \rightarrow\ mjerodavna\ krivulja\ izvijanja\ \boldsymbol{b}\ \rightarrow\ \alpha_{LT} = 0{,}34$$

$$\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\overline{\lambda}_{LT} - 0{,}2\right) + \overline{\lambda}_{LT}^2\right]$$

$$\Phi_{LT} = 0{,}5 \cdot [1 + 0{,}34 \cdot (0{,}42 - 0{,}2) + 0{,}42^2] = 0{,}63$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{{\Phi_{LT}}^2 - \overline{\lambda_{LT}}^2}} = \frac{1}{0{,}63 + \sqrt{0{,}63^2 - 0{,}42^2}} = 0{,}91 \leq 1$$

Računska otpornost:

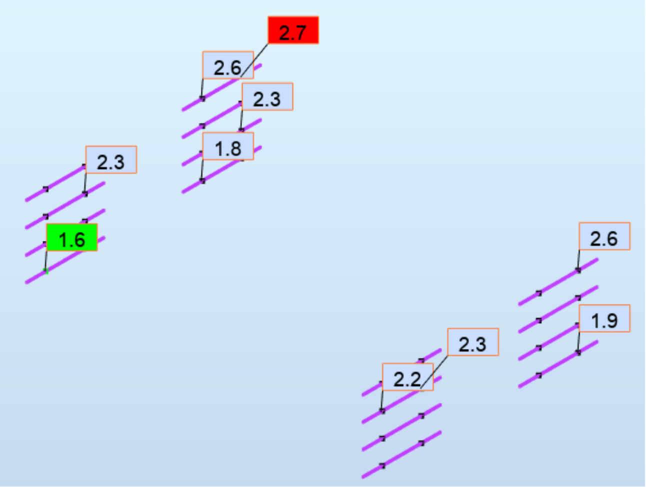
$$M_{b,Rd} = \chi_{LT}\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}} = 0{,}91 \cdot \frac{429{,}5 \cdot 35{,}5}{1{,}10} \cdot 10^{-2} = 126\ kNm$$

$$M_{Ed,y} = 56{,}20\ kNm < M_{b,Rd} = 126\ kNm$$

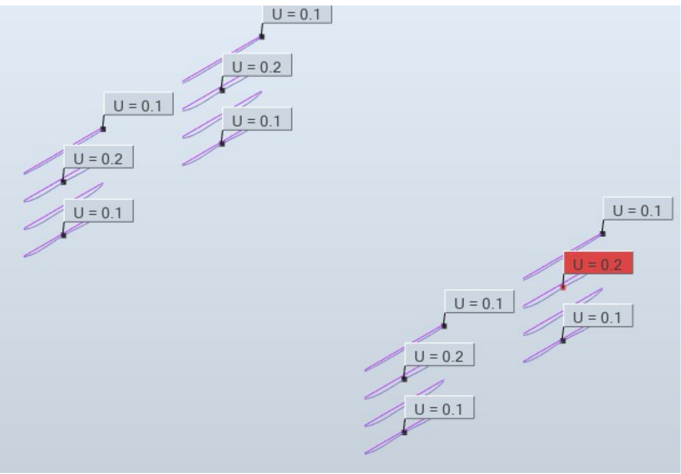
$$\frac{M_{Ed,y}}{M_{b,Rd}} = \frac{56{,}2}{126} = 0{,}45 < 1{,}0$$

Presjek zadovoljava s iskoristivošću od 45 %.

10.2.8. Granično stanje uporabljivosti



Slika 60. Prikaz progiba glavnog nosača poprečnog presjeka HEA 200



Slika 61. Progib od korisnog opterećenja

Progib od koisnog opterećenja:

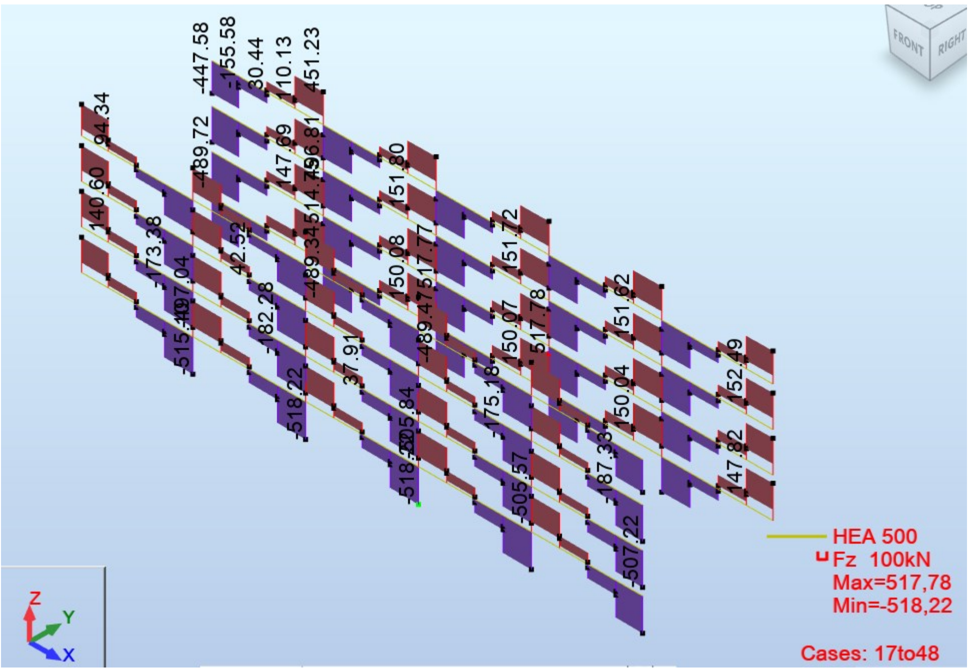
$$0{,}9\ cm \leq \frac{L}{300} = \frac{1156}{300} = 3{,}85\ cm$$

Ukupan progib:

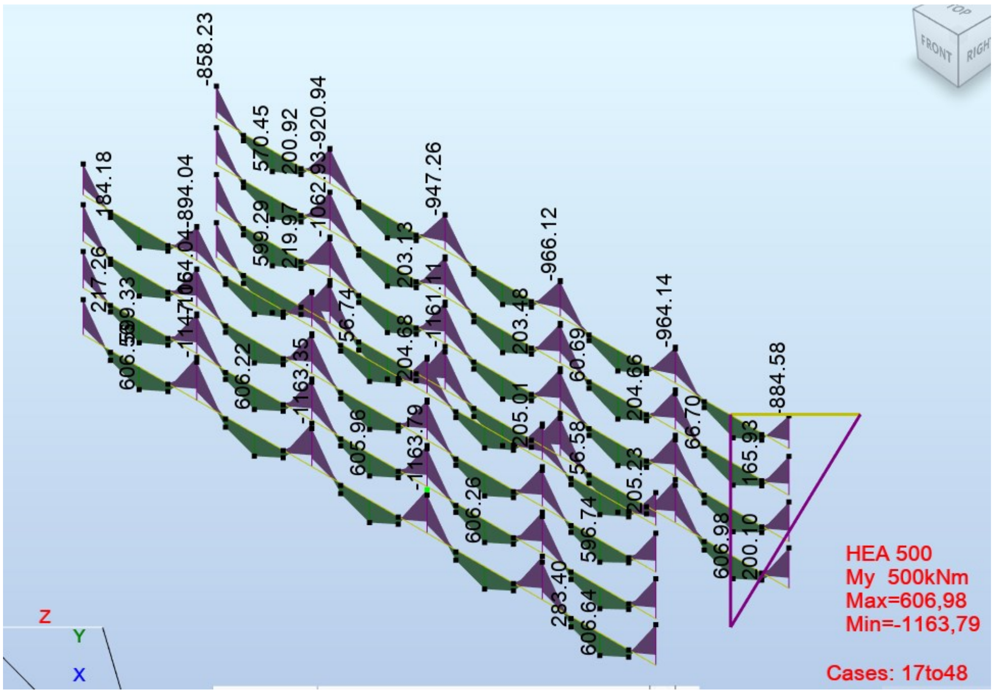
$$2{,}7\ cm \leq \frac{L}{250} = \frac{1156}{250} = 4{,}62\ cm$$

10.3. Unutarnji nosači u smjeru okvira

10.3.1.Opterećenje

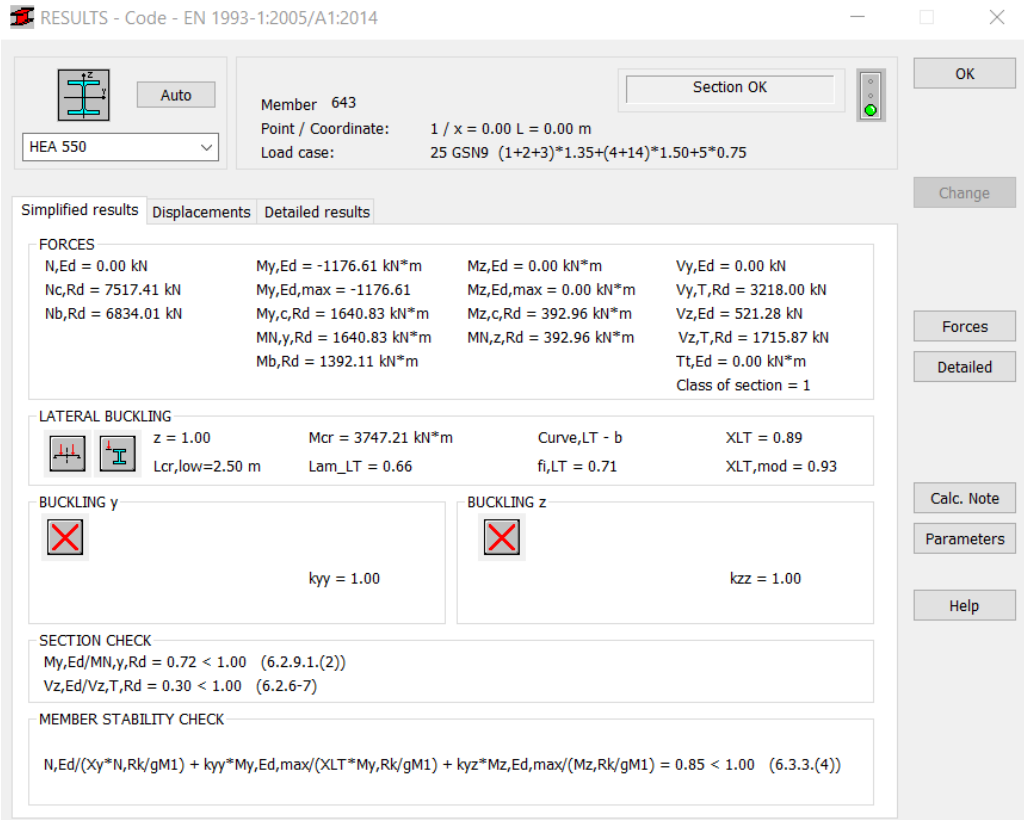


Slika 62. Poprečna sila grede HEA 500



Slika 63. Moment savijanja grede HEA 500

Najopterećeniji element je element broj 643.



Slika 64. Karakteristike elementa 643

10.3.2. Karakteristike odabranog profila

Odabrani profil:	HEA 550
Prostorna težina:	$G = 166\ kg/m$
Površina poprečnog presjeka:	$A = 211,8\ cm^2$
Visina presjeka:	$h = 540,0\ mm$
Širina pojasnice:	$b = 300,0\ mm$
Debljina hrpta:	$t_w = 12,5\ mm$
Debljina pojasnice:	$t_f = 24,0\ mm$
Radijus zaobljenja:	$r = 27\ mm$
Moment tromosti:	$I_y = 111900\ cm^4$
Moment tromosti:	$I_z = 10820\ cm^4$
Moment otpora:	$W_y = 4146\ cm^3$

Moment otpora: $W_z = 721{,}3\ cm^3$

Moment plastičnosti: $W_{pl,y} = 4622\ cm^4$

Moment plastičnosti: $W_{pl,z} = 1107\ cm^4$

10.3.3.Klasifikacija presjeka

Hrbat

$$\frac{c}{t} = \frac{h - 2\ \cdot\ t_f - 2\ \cdot r}{t_w} = \frac{540{,}00 - 2\ \cdot\ 24 - 2\ \cdot 27{,}0}{12{,}5} = 35{,}04$$

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{355}} = 0{,}81$$

$$72 \cdot\ \varepsilon = 72\ \cdot 0{,}81\ = 58{,}32$$

$$35{,}04 < 58{,}32$$

Hrbat je svrstan u klasu 1.

Pojasnica

$$\frac{c}{t} = \frac{\frac{b - t_w - 2\ \cdot r}{2}}{t_f} = \frac{\frac{300{,}00 - 12{,}5 - 2\ \cdot 27{,}0}{2}}{24} = 4{,}86$$

$$9\ \cdot\ \varepsilon = 9\ \cdot 0{,}81 = 7{,}29$$

$$4{,}86\ < 7{,}29$$

Pojasnica je svrstana u klasu 1.

Poprečni presjek svrstan je u klasu 1.

10.3.4.Otpornost poprečnog presjeka na savijanje

Otpornost poprečnog presjeka na savijanje oko osi y-y

$$M_{pl,y} = \frac{W_{pl,Rd} \cdot f_y}{\gamma_{M0}} = \frac{4622 \cdot 35{,}5}{1{,}0} = 164081\ kNm$$

$$M_{y,Ed} = 1083\ kNm < M_{pl,y} = 1640\ kNm$$

$$\frac{M_{y,Ed}}{M_{pl,y}} = \frac{1177}{1640} = 0{,}72\ \rightarrow Iskoristivost\ je\ 72\ \%$$

10.3.5. Otpornost poprečnog presjeka na posmik

Otpornost poprečnog presjeka na posmik u smjeru osi z-z

Provjera izbočivanja hrpta na posmik

$$\frac{h_w}{t_w} > 72 \cdot \frac{\varepsilon}{\eta}$$

$$h_w = h - 2 \cdot t_f = 540 - 2 \cdot 24 = 492\ mm$$

$$\eta = 1{,}20$$

$$\frac{h_w}{t_w} = \frac{492}{12{,}5} = 39{,}36 < 72 \cdot \frac{\varepsilon}{\eta} = 72 \cdot \frac{0{,}81}{1{,}20} = 48{,}6$$

→ Nije potrebna provjera izbočavanja hrpta na posmik.

Plastična posmična otpornost:

$$V_{pl,z,Rd} = \frac{A_{v,z} \cdot (f_y/\sqrt{3})}{\gamma_{M0}}$$

Posmična površina:

$$A_{v,z} = A - 2 \cdot b \cdot t_f + t_f \cdot (t_w + 2 \cdot r) \geq \eta \cdot h_w \cdot t_w$$

$$A_{v,z} = 211{,}8 - 2 \cdot 30{,}0 \cdot 2{,}4 + 2{,}4 \cdot (1{,}25 + 2 \cdot 2{,}8) = 84{,}24\ cm^2$$

$$84{,}24\ cm^2 \geq 1{,}20 \cdot 49{,}2 \cdot 1{,}25 = 73{,}8\ cm^2$$

$$V_{pl,z,Rd} = \frac{84{,}24 \cdot (35{,}5/\sqrt{3})}{1{,}00} = 1727\ kN$$

$$V_{z,Ed} = 521\ kN < V_{pl,z,Rd} = 1727\ kN$$

$$\frac{V_{z,Ed}}{V_{pl,z,Rd}} = \frac{521}{1727} = 0{,}30\ \rightarrow Iskoristivost\ je\ 30\ \%$$

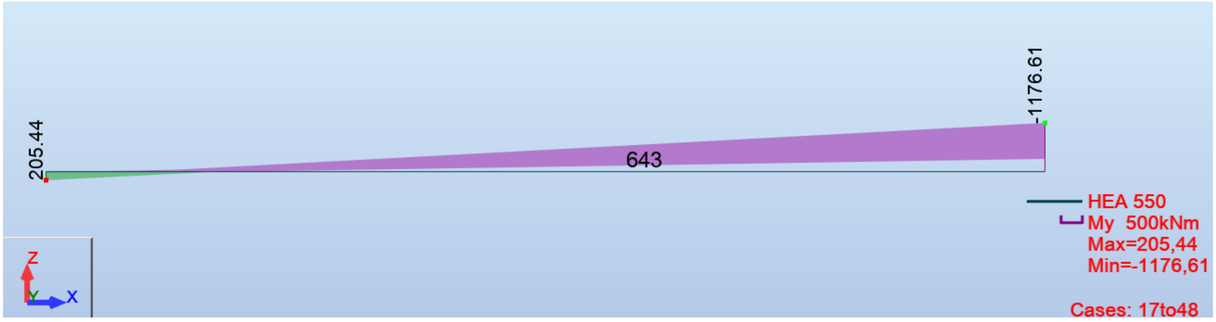
10.3.6. Otpornost poprečnog presjeka na interakciju savijanja i posmika

Otpornost poprečnog presjeka na interakciju savijanja i posmika u smjeru osi z-z

$$V_{z,Ed} \leq 0{,}50 \cdot V_{pl,z,Rd}$$

$521\ kN \leq 0{,}50 \cdot 1727 = 864\ kN$ → Nije potrebna redukcija otpornosti.

10.3.7.Otpornost elementa izloženog savijanju



Slika 65. Momentni dijagram elementa 643

Određivanje faktora C_1

ψ	C_1
+1,00	1,00
+0,75	1,14
+0,50	1,31
+0,25	1,52
0,00	1,77
-0,25	2,05
-0,50	2,33
-0,75	2,57
-1,00	2,55

$$\psi = -\frac{205{,}44}{1176{,}61} = -0{,}175$$

Očitano:

$$C_1 = 1{,}97$$

Elastični kritični moment bočnog torzijskog izvijanja:

$$M_{cr} = C_1 \cdot \frac{\pi^2 \cdot E \cdot I_z}{L^2} \cdot \left[\sqrt{\frac{I_w}{I_z} + \frac{L^2 \cdot G \cdot I_t}{\pi^2 \cdot E \cdot I_z}}\right]$$

Modul elastičnosti $E = 210000\ N/mm^2$

Modul posmika $G = 80769{,}23\ N/mm^2$

Konstanta krivljenja $I_w = 111900\ mm^6$

Moment tromosti $I_z = 10820\ cm^4$

Torzijska konstanta $I_t = 351{,}5\ cm^4$

Raspon $L = 2500\ mm$

$$M_{cr} = 1{,}97 \cdot \frac{\pi^2 \cdot 21000 \cdot 10820}{250^2} \cdot \left[\sqrt{\frac{111900}{10820} + \frac{250^2 \cdot 8076{,}923 \cdot 351{,}5}{\pi^2 \cdot 21000 \cdot 10820}}\right]$$

$$M_{cr} = 67742\ kNm$$

Bezdimenzionalna vitkost:

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}} = \sqrt{\frac{3949 \cdot 35{,}5}{6774200}} = 0{,}14$$

Faktor redukcije:

$$\frac{h}{b} = \frac{490}{300} = 1{,}63 < 2 \ \rightarrow \ mjerodavna\ krivulja\ izvijanja\ \boldsymbol{b} \ \rightarrow \ \alpha_{LT} = 0{,}34$$

$$\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\overline{\lambda}_{LT} - 0{,}2\right) + \overline{\lambda}_{LT}^{2}\right]$$

$$\Phi_{LT} = 0{,}5 \cdot [1 + 0{,}34 \cdot (0{,}14 - 0{,}2) + 0{,}14^2] = 0{,}5$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{{\Phi_{LT}}^2 - \overline{\lambda_{LT}}^2}} = \frac{1}{0{,}5 + \sqrt{0{,}5^2 - 0{,}14^2}} = 1{,}02 \geq 1$$

Računska otpornost:

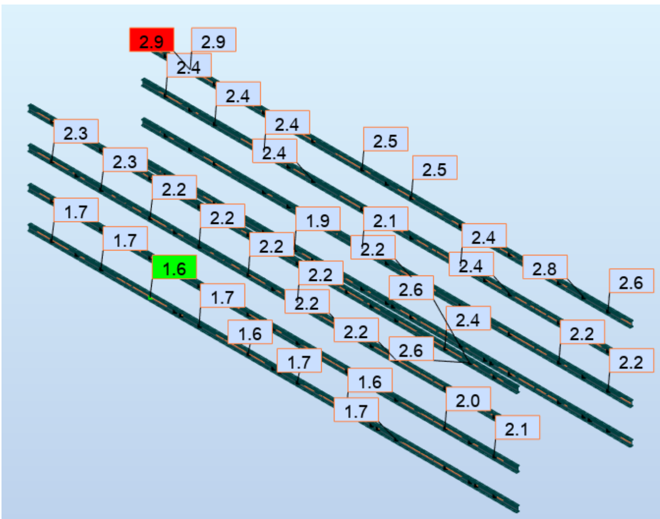
$$M_{b,Rd} = \chi_{LT}\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}} = 1 \cdot \frac{3949 \cdot 35{,}5}{1{,}10} \cdot 10^{-2} = 1274\ kNm$$

$$M_{Ed,y} = 1083\ kNm < M_{b,Rd} = 1274\ kNm$$

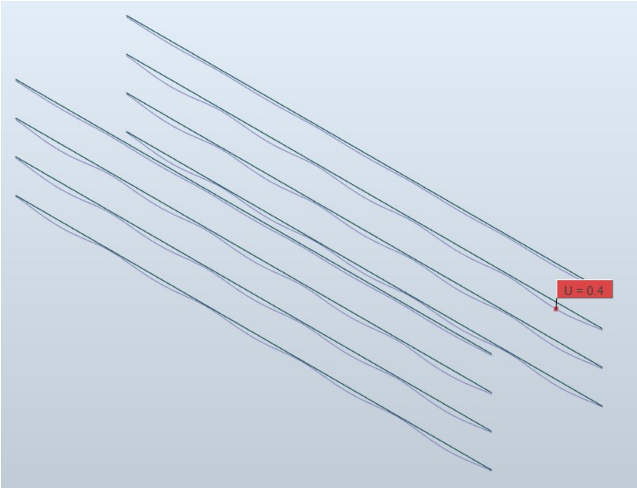
$$\frac{M_{Ed,y}}{M_{b,Rd}} = \frac{1083}{1274} = 0{,}85 < 1{,}0$$

Presjek zadovoljava s iskoristivošću od 85 %.

10.3.8.Granično stanje uporabljivosti



Slika 66. Prikaz progiba glavnog nosača poprečnog presjeka HEA 550



Slika 67. Progib od korisnog opterećenja

Progib od korisnog opterećenja:

$$0{,}4\ cm \leq \frac{L}{300} = \frac{1000}{300} = 3{,}33\ cm$$

Ukupan progib:

$$2{,}9\ cm \leq \frac{L}{250} = \frac{1000}{250} = 4{,}00\ cm$$

11. STUPOVI

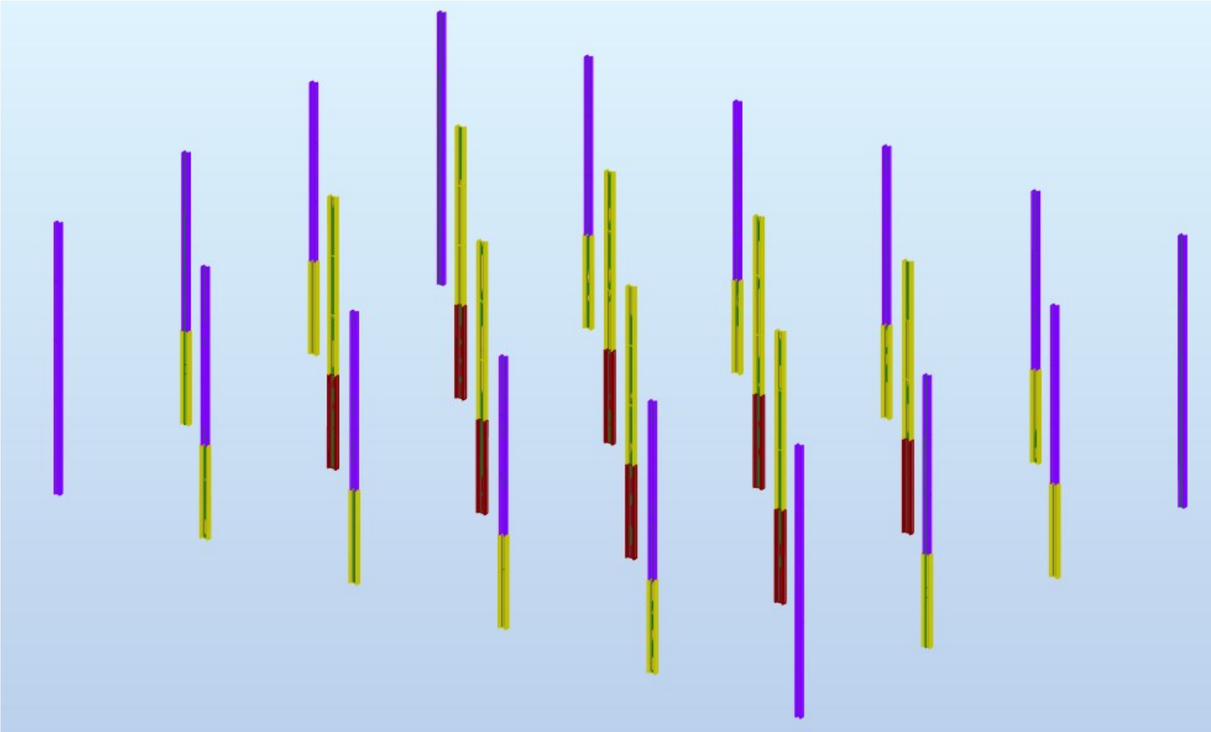
Koriste se tri različita poprečna presjeka stupa, HEA 340, HEA 500, te HEM 500.

Kako je građevina visoka 18 metara, a maksimalna moguća duljina profila 12 metara, svi stupovi će se izvesti od dva dijela.

Stupovi oznake S1 su poprečnog presjeka HEA 340. Tu skupinu čine stupovi u kutovima građevine punom svojim visinom te gornji stupovi obruba građevine. Na slici niže su S1 stupovi označeni ljubičastom bojom.

Stupovi oznake S2 su poprečnog presjeka HEA 500. Tu skupinu čine donji stupovi obruba građevine te gornji dijelovi unutarnjih stupova. Na slici niže su S2 stupovi označeni žutom bojom.

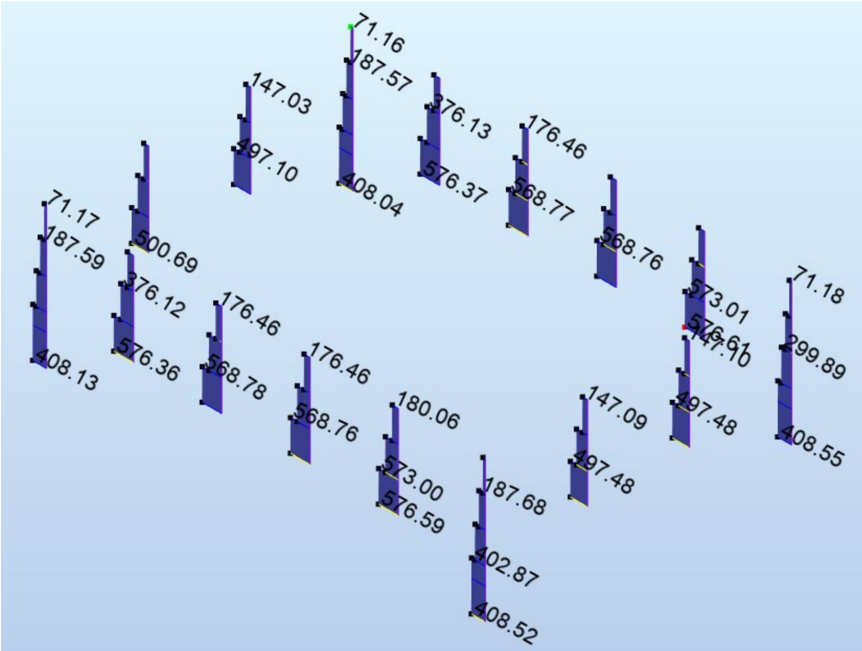
Stupovi oznake S3 su poprečnog presjeka HEM 500. Tu skupinu čine donji unutarnji stupovi. Na slici niže su S3 stupovi označeni tamno crvenom bojom.



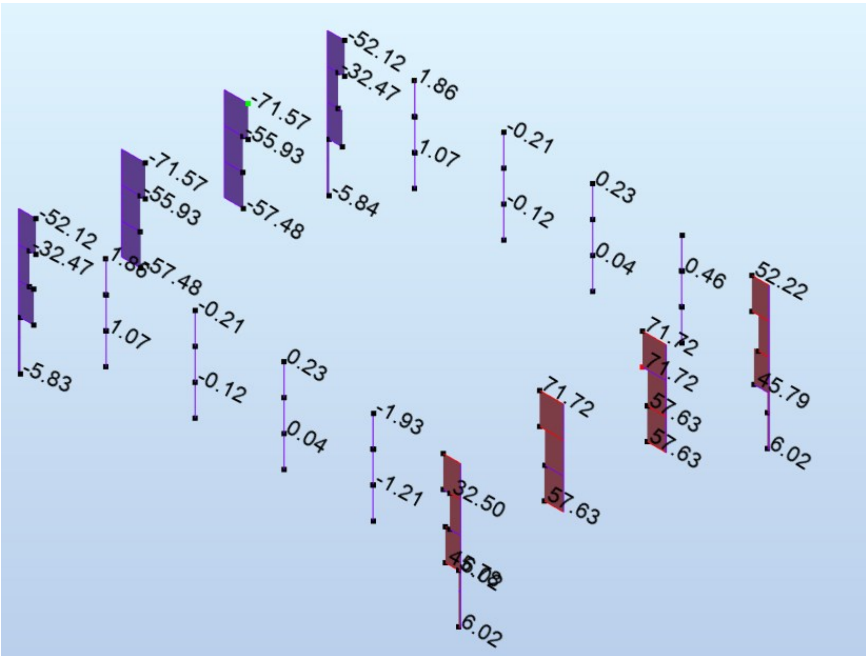
Slika 68. Stupovi

11.1. Stupovi S1

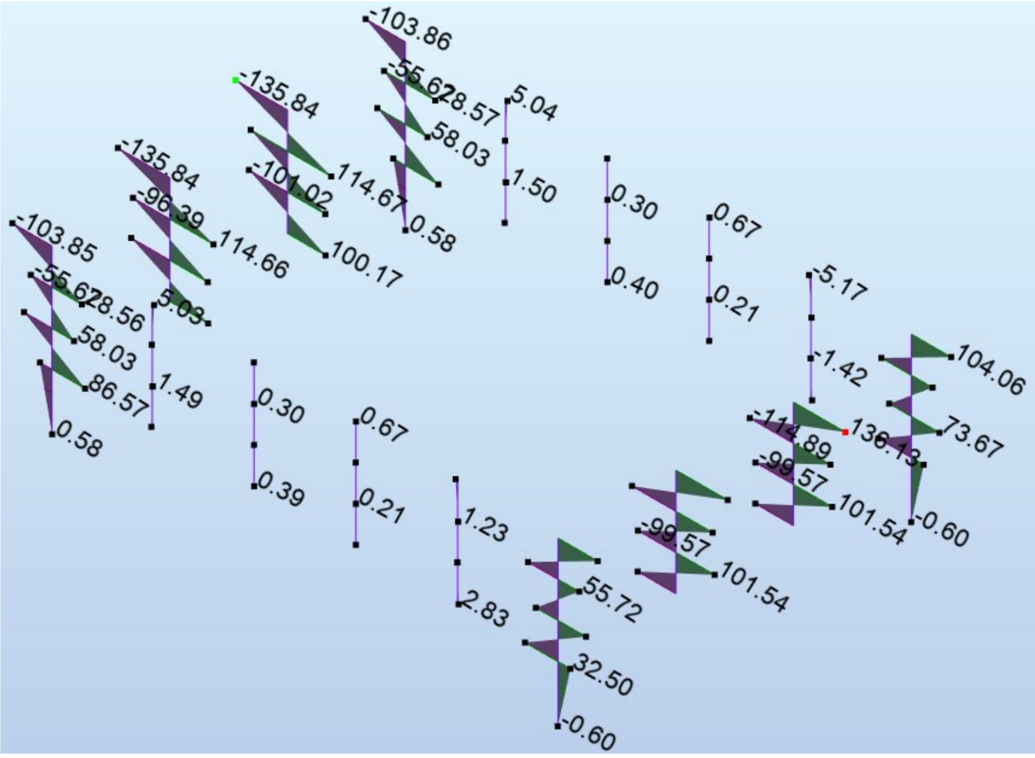
11.1.1. Opterećenja



Slika 69. Uzdužna sila u stupovima HEA 340

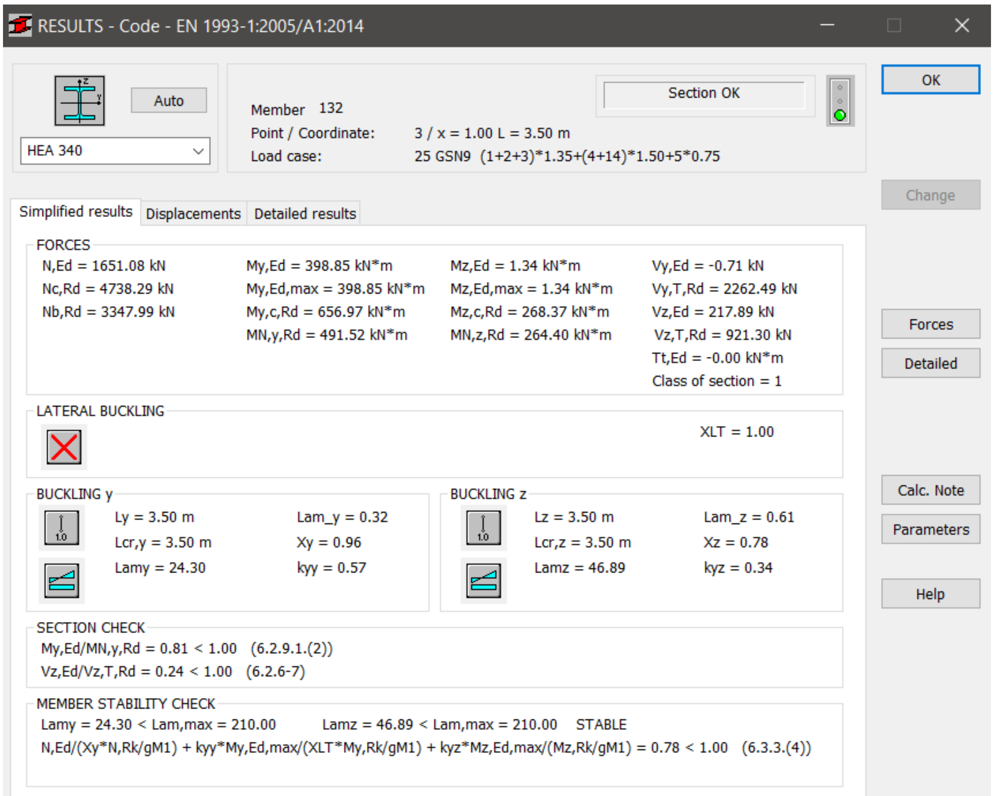


Slika 70. Poprečna sila u stupovima HEA 340



Slika 71.Moment savijanja u stupovima HEA 340

Najopterećeniji element je element broj 132.



Slika 72. Karakteristike elementa 132

11.1.2.Karakteristike odabranog profila

Odabrani profil:	HEA 340
Tip poprečnog presjeka:	Toplo dogotovljeni
Površina poprečnog presjeka:	$A = 133{,}5\ cm^2$
Visina hrpta:	$h = 330\ mm$
Debljina hrpta:	$t_w = 9{,}5\ mm$
Širina pojasnice:	$b = 300\ mm$
Debljina pojasnice:	$t_f = 16{,}5\ mm$
Radijus:	$r = 27\ mm$
Osnovni materijal:	$S355\ ;\ t \leq 40mm$
Granica popuštanja:	$f_y = 355\ N/mm^2$
Modul elastičnosti:	$E = 210\ 000\ N/mm^2$
Parcijalni koeficijent za presjek:	$\gamma_{M0} = 1{,}00$
Parcijalni koeficijent za element:	$\gamma_{M1} = 1{,}10$

11.1.3. Klasifikacija profila

Hrbat

$$\frac{c}{t} = \frac{h - 2\ \cdot\ t_f - 2\ \cdot r}{t_w} = \frac{330 - 2\ \cdot\ 16{,}5 - 2\ \cdot 27{,}0}{9{,}5} = 25{,}6$$

$$\varepsilon = 0{,}81$$

$$33\ \cdot\ \varepsilon = 33\ \cdot 0{,}81\ = 26{,}73$$

Hrbat je svrstan u klasu 1.

Pojasnica

$$\frac{c}{t} = \frac{\frac{b - t_w - 2\ \cdot r}{2}}{t_f} = \frac{\frac{300 - 9{,}5 - 2\ \cdot 27{,}0}{2}}{16{,}5} = 7{,}2$$

$$9 \cdot \varepsilon = 9 \cdot 0{,}81 = 7{,}29$$

Pojasnica je svrstana u klasu 1.

Poprečni presjek svrstan je u klasu 1.

11.1.4. Otpornost poprečnog presjeka na tlaku

$$N_{c,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{133{,}5 \cdot 35{,}5}{1{,}00} = 4739\ kN > 1651\ kN$$

Otpornost poprečnog presjeka na tlak

$$\frac{N_{Ed}}{N_{c,Rd}} < 1{,}00$$

$$\frac{1651}{4739} = 0{,}35 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 35%.

11.1.5. Otpornost poprečnog presjeka na moment savijanja

$$M_{pl,y,Rd} = \frac{W_{el,y} \cdot f_y}{\gamma_{M0}} = \frac{1850 \cdot 35{,}5}{1{,}0} \cdot 10^{-2} = 657\ kNm$$

Otpornost presjeka na moment savijanja

$$\frac{M_{y,Ed}}{M_{c,Rd}} \leq 1{,}00$$

$$\frac{399}{657} = 0{,}61 \leq 1{,}0$$

Presjek zadovoljava s iskoristivošću od 61%.

11.1.6. Otpornost poprečnog presjeka na poprečnu silu

Provjera na izbočivanje hrpta na posmik

$$h_w = h - 2 \cdot t_f = 330{,}0 - 2 \cdot 16{,}5 = 297\ mm$$

$$\frac{h_w}{t_w} < \frac{72 \cdot \varepsilon}{\eta}$$

$$\frac{297}{9{,}5} < \frac{72 \cdot 0{,}81}{1{,}2}$$

$31{,}26 < 48{,}6$ → Nije potrebna provjera izbočivanja hrpta na posmik.

Plastična posmična otpornost

$$V_{pl,Rd} = \frac{A_{V,z} \cdot (f_y/\sqrt{3})}{\gamma_{M0}}$$

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

$$A_{V,z} = 133{,}5\ \ - 2 \cdot 30{,}00\ \ \cdot\ 1{,}65\ \ + (0{,}95 + 2\ \cdot 2{,}7) \cdot 1{,}65 = 44{,}98\ cm^2$$

$$\eta\ \cdot h_w \cdot t_w = 1{,}20 \cdot 29{,}7\ \cdot 0{,}95 = 33{,}9\ cm^2$$

$$A_{V,z} = 45\ cm^2 \geq\ 34\ cm^2$$

$$V_{pl,z,Rd} = \frac{45 \cdot (35{,}50/\sqrt{3})}{1{,}00} = 922\ kN$$

Otpornost poprečnog presjeka na poprečnu silu

$$\frac{V_{z,Ed}}{V_{pl,Rd}} \leq 1{,}00 \qquad \frac{218}{922} < 1{,}00 \qquad 0{,}24 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 24%.

11.1.7. Otpornost poprečnog presjeka na interakciju momenta savijanja, uzdužne sile i poprečne sile

$$V_{z,Ed} < 0{,}5 \cdot V_{z,Rd}$$

$$218\ kN <\ 0{,}5 \cdot 922\ \ = 461\ kN$$

$$\frac{218}{461} = 0{,}47\ \ < 1{,}0$$

$$N_{Ed} < 0{,}25 \cdot N_{c,Rd}$$

$$1\ 651\ kN < 0{,}25 \cdot 4739 = 1184{,}75\ kN$$

$$\frac{1\ 651}{1184} = 1{,}39 > 1{,}0$$

Potrebna je redukcija otpornosti poprečnog presjeka na savijanje.

$$M_{N,V,y,Rd} = M_{pl,y,Rd} \cdot \frac{1-n}{1-0{,}5 \cdot a} = 657 \cdot \frac{1-0{,}35}{1-0{,}5 \cdot 0{,}26} = 491\ kNm$$

$$n = \frac{N_{Ed}}{N_{pl,Rd}} = \frac{1651}{4739} = 0{,}35$$

$$a = \frac{A - 2 \cdot b \cdot t_f}{A} \leq 0{,}5$$

$$a = \frac{133{,}5 - 2 \cdot 30 \cdot 1{,}65}{133{,}5} = 0{,}26$$

$M_{N,V,y,Rd} = M_{el,y,Rd} = 491\ kNm$

$M_{N,V,y,Rd} > M_{y,Ed}$

$491\ kNm > 399\ kNm$

$N_{Ed} < 0{,}50 \cdot h_w \cdot t_w \cdot f_y$

$1651\ kN < 0{,}50 \cdot 29{,}70 \cdot 0{,}95 \cdot 35{,}5 = 501\ kN$

$\frac{1651}{501} = 3{,}3 > 1{,}0$

Potrebna je redukcija otpornosti poprečnog presjeka na savijanje.

11.1.8. Otpornost elementa na izvijanje

Moment tromosti prečke i stupa

$I_{prečke} = 33090\ cm^4$

$I_{stupa} = 27690\ cm^4$

Krutost prečke i stupa okvira

$K_{prečke} = K_{11} = \frac{I_{prečke}}{L} = \frac{33090}{1156} = 28{,}62\ cm^3$

$K_{stupa} = K_c = \frac{I_{stupa}}{h} = \frac{86970}{550} = 158{,}13\ cm^3$

Koeficijenti η

$\eta_1 = \frac{K_c}{K_c + K_{11}} = \frac{158{,}13}{158{,}13 + 28{,}62} = 0{,}85$

$\eta_2 = 1{,}0\ \ (stup\ je\ zglobno\ oslonjen)$

Koeficijent k za bočno nepomičan mod

$k = 0{,}5 + 0{,}14 \cdot (\eta_1 + \eta_2) + 0{,}055 \cdot (\eta_1 + \eta_2)^2$

$k = 0{,}5 + 0{,}14 \cdot (0{,}85 + 1{,}0) + 0{,}055 \cdot (0{,}85 + 1{,}0)^2 = 0{,}95$

Efektivne duljine izvijanja

$L_{i,y} = k \cdot L = 0{,}95 \cdot 550 = 522{,}5\ cm$

Duljine izvijanja

$$L_{cr,y} = 3{,}5\ m \qquad\qquad L_{cr,z} = 3{,}5\ m$$

Elastična kritična sila

$$N_{cr,y} = \frac{\pi^2 \cdot E \cdot I_y}{L_{cr,y}^2} = \frac{\pi^2 \cdot 21000 \cdot 27690}{350^2} = 46850\ kN$$

$$N_{cr,z} = \frac{\pi^2 \cdot E \cdot I_z}{L_{cr,z}^2} = \frac{\pi^2 \cdot 21000 \cdot 7436}{350^2} = 12581\ kN$$

Bezdimenzijska svedena vitkost

$$\lambda_y = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{133{,}5 \cdot 35{,}50}{46850}} = 0{,}32 \qquad \lambda_z = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{133{,}5 \cdot 35{,}50}{12581}} = 0{,}61$$

Faktor redukcije

$$\Phi = 0{,}5 \cdot [1 + \alpha \cdot (\lambda - 0{,}2) + \lambda^2]$$

Toplo dogotovljeni profil s krivuljom izvijanja a i faktorom imperfekcije $\alpha = 0{,}21$.

$$\Phi_y = 0{,}5 \cdot [1 + 0{,}21 \cdot (0{,}32 - 0{,}2) + 0{,}32^2] = 0{,}56$$

$$\chi_y = \frac{1}{\Phi_y + \sqrt{{\Phi_y}^2 - {\lambda_y}^2}} = \frac{1}{0{,}56 + \sqrt{0{,}56^2 - 0{,}32^2}} = 0{,}98$$

Toplo dogotovljeni profil s krivuljom izvijanja b i faktorom imperfekcije $\alpha = 0{,}34$.

$$\Phi_z = 0{,}5 \cdot [1 + 0{,}34 \cdot (0{,}61 - 0{,}2) + 0{,}61^2] = 0{,}76$$

$$\chi_z = \frac{1}{\Phi_z + \sqrt{{\Phi_z}^2 - {\lambda_z}^2}} = \frac{1}{0{,}76 + \sqrt{0{,}76^2 - 0{,}61^2}} = 0{,}82$$

Računska otpornost elementa na izvijanje

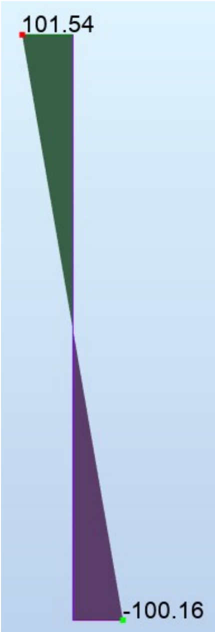
$$N_{b,Rd} = \chi_{min} \cdot \frac{A \cdot f_y}{\gamma_{M1}} = 0{,}82 \cdot \frac{133{,}5 \cdot 35{,}50}{1{,}10} = 3\ 533\ kN$$

Otpornost elementa na izvijanje

$$\frac{N_{Ed}}{N_{b,Rd}} < 1{,}00 \quad \frac{1651}{3533} < 1{,}00 \quad 0{,}47 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 47%.

11.1.9. Otpornost elementa na savijanje



Slika73. Momentni dijagram stupa

ψ	C_1
+1,00	1,00
+0,75	1,14
+0,50	1,31
+0,25	1,52
0,00	1,77
-0,25	2,05
-0,50	2,33
-0,75	2,57
-1,00	2,55

Određivanje faktora C_1 i C_2

$$-1 \leq \psi \leq 1$$

$$\psi = -\frac{100{,}16}{101{,}54} \cong -1$$

Očitano:

$$C_1 = 2{,}55$$

$$C_2 = 0{,}00$$

Elastični kritični moment bočnog torzijskog izvijanja:

$$M_{cr} = C_1 \cdot \frac{\pi^2 \cdot E \cdot I_z}{L^2} \cdot \left[\sqrt{\frac{I_w}{I_z} + \frac{L^2 \cdot G \cdot I_t}{\pi^2 \cdot E \cdot I_z}}\right]$$

Modul elastičnosti	$E = 210000\ N/mm^2$
Modul posmika	$G = 80769{,}23\ N/mm^2$
Konstanta krivljenja	$I_w = 2177\ mm^6$
Moment tromosti	$I_z = 7436\ cm^4$
Torzijska konstanta	$I_t = 127{,}2\ cm^4$
Raspon	$L = 3500\ mm$

$$M_{cr} = 2{,}55 \cdot \frac{\pi^2 \cdot 21000 \cdot 7436}{350^2} \cdot \left[\sqrt{\frac{2177000}{7436} + \frac{350^2 \cdot 8076{,}923 \cdot 127{,}5}{\pi^2 \cdot 21000 \cdot 7436}}\right] \cdot 10^{-2}$$

$$M_{cr} = 6209{,}50\ kNm$$

Bezdimenzionalna vitkost:

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}} = \sqrt{\frac{1850 \cdot 35{,}5}{620950}} = 0{,}33$$

Faktor redukcije:

$$\frac{h}{b}=\frac{330}{300}=1{,}1<2\ \rightarrow\ mjerodavna\ krivulja\ izvijanja\ \boldsymbol{b}\ \rightarrow\ \alpha_{LT}=0{,}34$$

$$\Phi_{LT}=0{,}5\left[1+\alpha_{LT}\left(\bar{\lambda}_{LT}-0{,}2\right)+\bar{\lambda}_{LT}^{2}\right]$$

$$\Phi_{LT}=0{,}5\cdot[1+0{,}34\cdot(0{,}33-0{,}2)+0{,}33^{2}]=0{,}58$$

$$\chi_{LT}=\frac{1}{\Phi_{LT}+\sqrt{\Phi_{LT}{}^{2}-\overline{\lambda_{LT}}^{2}}}=\frac{1}{0{,}58+\sqrt{0{,}58^{2}-0{,}33^{2}}}=0{,}95\leq 1$$

Računska otpornost:

$$M_{b,Rd}=\chi_{LT}\frac{W_{pl,y}\cdot f_{y}}{\gamma_{M1}}=0{,}95\cdot\frac{1850\cdot 35{,}5}{1{,}10}\cdot 10^{-2}=567\ kNm$$

$$M_{Ed,y}=399\ kNm<M_{b,Rd}=567\ kNm$$

$$\frac{M_{Ed,y}}{M_{b,Rd}}=\frac{399}{567}=0{,}71<1{,}0$$

Presjek zadovoljava s iskoristivošću od 71 %.

11.1.10. Otpornost elementa na interakciju savijanja i uzdužne sile

$$\frac{\mathrm{N_{Ed}}}{\chi_{y}\cdot\frac{\mathrm{N_{rk}}}{\gamma_{M1}}}+\frac{\mathrm{k}_{yy}\cdot\mathrm{M}_{y.Ed}}{\chi_{LT}\cdot\frac{\mathrm{M_{y,Rky}}}{\gamma_{M1}}}\leq 1$$

$$\frac{\mathrm{N_{Ed}}}{\chi_{z}\cdot\frac{\mathrm{N_{rk}}}{\gamma_{M1}}}+\frac{\mathrm{k}_{zy}\cdot\mathrm{M}_{y.Ed}}{\chi_{LT}\cdot\frac{\mathrm{M_{y,Rky}}}{\gamma_{M1}}}\leq 1$$

Određivanje interakcijskih faktora $\mathrm{k_{ij}}$

$$\mathrm{C_{my}}=0{,}6+0{,}4\cdot\psi\ \geq 0{,}40$$

$$\mathrm{C_{my}}=0{,}6+0{,}4\cdot(-1)=0{,}2\geq 0{,}40\rightarrow\mathrm{C_{my}}=0{,}4$$

$$\mathrm{k}_{yy}=C_{my}\left[1+0{,}6\cdot\bar{\lambda}_{y}\cdot\frac{\mathrm{N_{Ed}}}{\chi_{y}\cdot{}^{\mathrm{N_{rk}}}/_{\gamma_{M1}}}\right]\leq C_{my}\left[1+0{,}6\cdot\frac{\mathrm{N_{Ed}}}{\chi_{y}\cdot{}^{\mathrm{N_{rk}}}/_{\gamma_{M1}}}\right]$$

$$\mathrm{k}_{yy}=0{,}4\cdot\left[1+0{,}6\cdot 0{,}32\cdot\frac{1651}{0{,}98\cdot 3533}\right]\leq 0{,}4\cdot\left[1+0{,}6\cdot\frac{1651}{0{,}98\cdot 3533}\right]$$

$$k_{yy} = 0{,}44 < 0{,}52$$

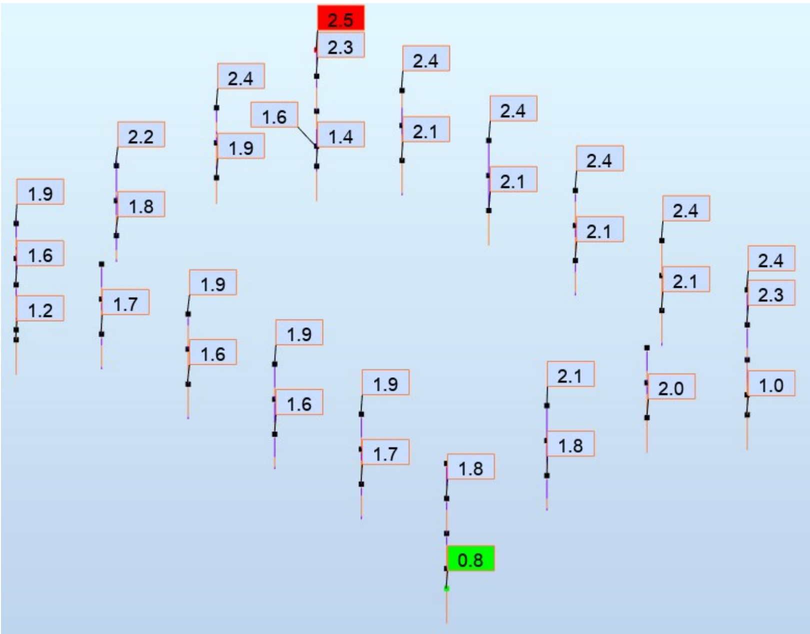
$$k_{zy} = 0{,}8 \cdot k_{yy} = 0{,}8 \cdot 0{,}52 = 0{,}35$$

Otpornost elementa na interakciju savijanja i uzdužne sile

$$\frac{1651}{0{,}98 \cdot 3533} + \frac{0{,}44 \cdot 399}{0{,}95 \cdot 567} = 0{,}81 < 1$$

$$\frac{1651}{0{,}82 \cdot 3533} + \frac{0{,}35 \cdot 399}{0{,}95 \cdot 567} = 0{,}83 < 1 \rightarrow mjerodavna\ iskoristivost\ stupa$$

11.1.11. Granično stanje uporabljivosti



Slika 74. Prikaz progiba stupova poprečnog presjeka HEA 340

Maksimalni pomak:

$$\delta_{max} = 25{,}0\ mm$$

Dopušteni pomak:

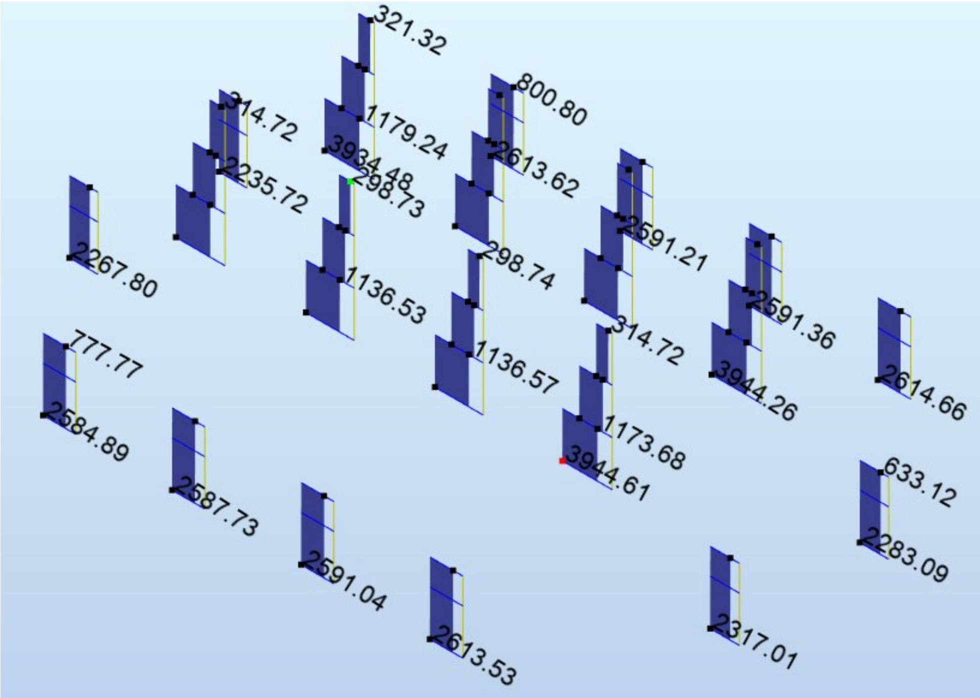
$$\delta_{dop} = \frac{L}{250} = \frac{3500}{150} = 24\ mm$$

Iskoristivost:

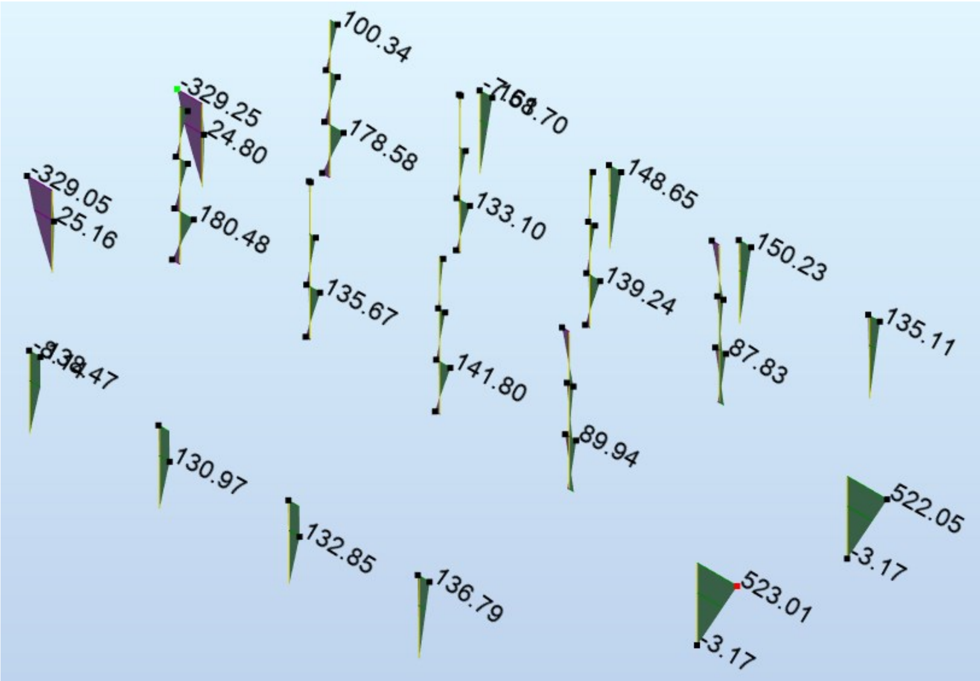
$$\frac{\delta_{max}}{\delta_{dop}} = \frac{25}{42} = 0{,}60\ \rightarrow Iskoristivost\ 60\ \%$$

11.2. Stupovi S2

11.2.1. Opterećenja

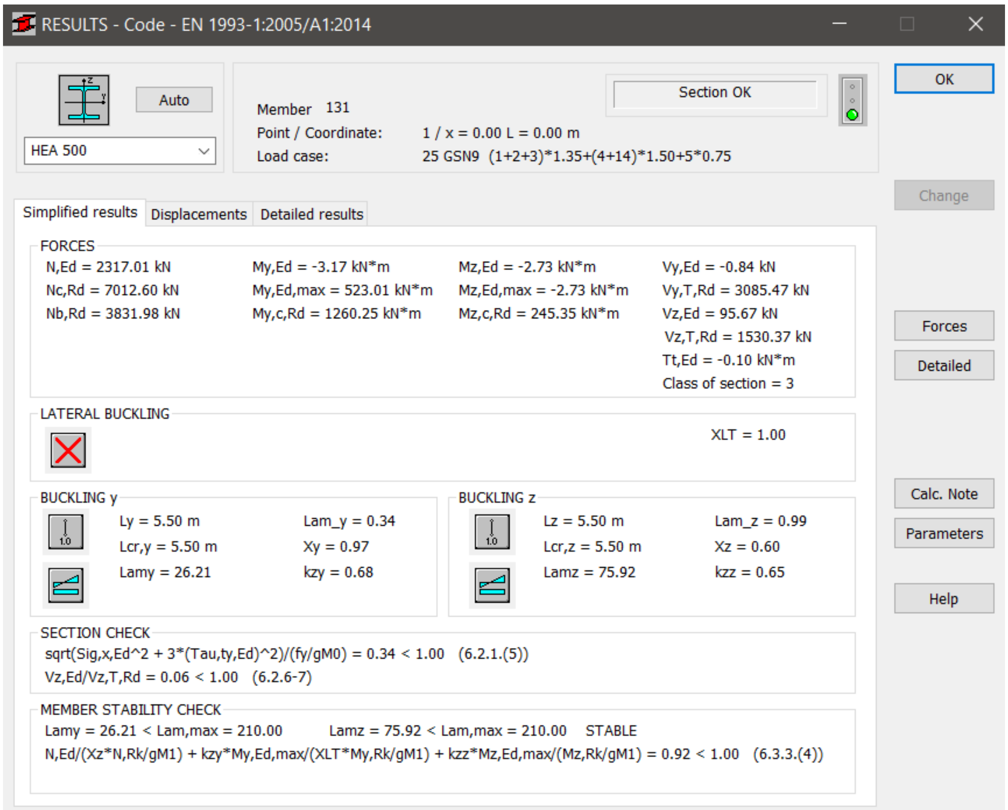


Slika 75. Uzdužna sila stupova HEA 500



Slika 76.Moment savijanja stupova HEA 500

Najopterećeniji element je element broj 131.



Slika 77. Karakteristike elementa 131

11.2.2. Karakteristike odabranog profila

Odabrani profil:	HEA 500
Tip poprečnog presjeka:	Toplo dogotovljeni
Površina poprečnog presjeka:	$A = 197{,}5\ cm^2$
Visina hrpta:	$h = 490\ mm$
Debljina hrpta:	$t_w = 12{,}0\ mm$
Širina pojasnice:	$b = 300\ mm$
Debljina pojasnice:	$t_f = 24\ mm$
Radijus:	$r = 27\ mm$

Osnovni materijal: $S355\ ;\ t \leq 40mm$

Granica popuštanja: $f_y = 355\ N/mm^2$

Modul elastičnosti: $E = 210\ 000\ N/mm^2$

Parcijalni koeficijent za presjek: $\gamma_{M0} = 1{,}00$

Parcijalni koeficijent za element: $\gamma_{M1} = 1{,}10$

11.2.3. Klasifikacija profila

Hrbat

$$\frac{c}{t} = \frac{h - 2\ \cdot\ t_f - 2\ \cdot r}{t_w} = \frac{490 - 2\ \cdot\ 24 - 2\ \cdot 27{,}0}{12{,}5} = 31{,}04$$

$$\varepsilon = 0{,}81$$

$$33\ \cdot\ \varepsilon = 33\ \cdot 0{,}81\ = 26{,}73$$

$$38 \cdot\ \varepsilon = 38\ \cdot 0{,}81\ = 30{,}78$$

Hrbat je svrstan u klasu 3.

Pojasnica

$$\frac{c}{t} = \frac{\frac{b - t_w - 2\ \cdot r}{2}}{t_f} = \frac{\frac{490 - 12 - 2\ \cdot 27{,}0}{2}}{23} = 9{,}21$$

$$9\ \cdot\ \varepsilon = 9\ \cdot 0{,}81 = 7{,}29$$

$$10\ \cdot\ \varepsilon = 10\ \cdot 0{,}81\ = 8{,}1$$

Pojasnica je svrstana u klasu 3.

Poprečni presjek svrstan je u klasu 3.

11.2.4. Otpornost poprečnog presjeka na tlaku

$$N_{c,Rd} = \frac{A\ \cdot\ f_y}{\gamma_{M0}} = \frac{197{,}5\ \cdot 35{,}5}{1{,}00} = 7011\ kN > 2317\ kN$$

Otpornost poprečnog presjeka na tlak

$$\frac{N_{Ed}}{N_{c,Rd}} < 1{,}00$$

$$\frac{2317}{7011} = 0{,}33 \ < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 33%.

11.2.5. Otpornost poprečnog presjeka na moment savijanja

$$M_{pl,y,Rd} = \frac{W_{el,y} \cdot f_y}{\gamma_{M0}} = \frac{3949 \cdot 35{,}5}{1{,}0} \cdot 10^{-2} = 1260\ kNm$$

Otpornost presjeka na moment savijanja

$$\frac{M_{y,Ed}}{M_{c,Rd}} \ \leq 1{,}00$$

$$\frac{523}{1260} = 0{,}42 \ \leq 1{,}0$$

Presjek zadovoljava s iskoristivošću od 42%.

11.2.6. Otpornost poprečnog presjeka na poprečnu silu

Provjera na izbočivanje hrpta na posmik

$$h_w = h - 2 \ \cdot \ t_f = \ 490{,}0 - 2 \ \cdot \ 23 = 444\ mm$$

$$\frac{h_w}{t_w} < \frac{72 \ \cdot \ \varepsilon}{\eta}$$

$$\frac{444}{12{,}0} < \frac{72 \ \cdot \ 0{,}81}{1{,}2}$$

$37 < \ 48{,}6$ → Nije potrebna provjera izbočivanja hrpta na posmik.

Plastična posmična otpornost

$$V_{pl,Rd} = \frac{A_{V,z} \cdot (f_y/\sqrt{3})}{\gamma_{M0}}$$

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

$$A_{V,z} = 197{,}5 \ - 2 \cdot 30{,}00 \ \ \cdot 2{,}3 \ + (1{,}2 + 2 \ \cdot 2{,}7) \cdot 2{,}3 = 74{,}68\ cm^2$$

$$\eta \ \cdot h_w \cdot t_w = 1{,}20 \cdot 44{,}4 \ \cdot 1{,}2 = 63{,}94\ cm^2$$

$$A_{V,z} = 74{,}68\ cm^2 \geq \ 63{,}94\ cm^2$$

$$V_{pl,z,Rd} = \frac{74{,}68 \cdot (35{,}50/\sqrt{3})}{1{,}00} = 1531\ kN$$

Otpornost poprečnog presjeka na poprečnu silu

$$\frac{V_{z,Ed}}{V_{pl,Rd}} \ \leq 1{,}00 \qquad \frac{95{,}7}{1531} \ < 1{,}00 \qquad 0{,}06 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 6%.

11.2.7. Otpornost poprečnog presjeka na interakciju momenta savijanja, uzdužne sile i poprečne sile

$V_{z,Ed} < 0{,}5 \cdot V_{z,Rd}$

$95{,}7\ kN < \ 0{,}5 \cdot 1531 \ = 766\ kN$

$\frac{95{,}7}{766} = 0{,}12 \ < 1{,}0$

$N_{Ed} < 0{,}25 \cdot N_{c,Rd}$

$2317\ kN < 0{,}25 \cdot 7011 = 1753\ kN$

$\frac{2317}{1753} = 1{,}32 > 1{,}0$

Potrebna je redukcija otpornosti poprečnog presjeka na savijanje.

$$M_{N,V,y,Rd} = M_{pl,y,Rd} \cdot \frac{1 - n}{1 - 0{,}5 \cdot a} = 1260 \cdot \frac{1 - 0{,}33}{1 - 0{,}5 \cdot 0{,}30} = 933\ kNm$$

$$n = \frac{N_{Ed}}{N_{pl,Rd}} = \frac{2317}{7011} = 0{,}33$$

$$a = \frac{A - 2 \cdot b \cdot t_f}{A} \leq 0{,}5$$

$$a = \frac{197{,}5 - 2 \cdot 30 \cdot 2{,}3}{197{,}5} = 0{,}30$$

$M_{N,V,y,Rd} = M_{el,y,Rd} = 933\ kNm$

$M_{N,V,y,Rd} > \ M_{y,Ed}$

$933\ kNm > \ 523\ kNm$

$N_{Ed} < 0{,}50 \cdot h_w \cdot t_w \cdot f_y$

$2317\ kN < 0{,}50 \cdot 44{,}4 \cdot 1{,}2 \cdot 35{,}5 = 946\ kN$

$\frac{2317}{946} = 2{,}5 > 1{,}0$

Potrebna je redukcija otpornosti poprečnog presjeka na savijanje.

11.2.8. Otpornost elementa na izvijanje

Moment tromosti prečke i stupa

$$I_{prečke} = 33090\ cm^4$$

$$I_{stupa} = 86970\ cm^4$$

Krutost prečke i stupa okvira

$$K_{prečke} = K_{11} = \frac{I_{prečke}}{L} = \frac{33090}{1156} = 28{,}62\ cm^3$$

$$K_{stupa} = K_c = \frac{I_{stupa}}{h} = \frac{86970}{550} = 158{,}13\ cm^3$$

Koeficijenti η

$$\eta_1 = \frac{K_c}{K_c + K_{11}} = \frac{158{,}13}{158{,}13 + 28{,}62} = 0{,}85$$

$$\eta_2 = 1{,}0\ \ (stup\ je\ zglobno\ oslonjen)$$

Koeficijent k za bočno nepomičan mod

$$k = 0{,}5 + 0{,}14 \cdot (\eta_1 + \eta_2) + 0{,}055 \cdot (\eta_1 + \eta_2)^2$$

$$k = 0{,}5 + 0{,}14 \cdot (0{,}85 + 1{,}0) + 0{,}055 \cdot (0{,}85 + 1{,}0)^2 = 0{,}95$$

Efektivne duljine izvijanja

$$L_{i,y} = k \cdot L = 0{,}95 \cdot 550 = 522{,}5\ cm$$

Duljine izvijanja

$$L_{cr,y} = 5{,}5\ m \qquad\qquad L_{cr,z} = 5{,}5\ m$$

Elastična kritična sila

$$N_{cr,y} = \frac{\pi^2 \cdot E \cdot I_y}{L_{cr,y}^2} = \frac{\pi^2 \cdot 21000 \cdot 86970}{550^2} = 59589\ kN$$

$$N_{cr,z} = \frac{\pi^2 \cdot E \cdot I_z}{L_{cr,z}^2} = \frac{\pi^2 \cdot 21000 \cdot 10370}{550^2} = 7105\ kN$$

Bezdimenzijska svedena vitkost

$$\lambda_y = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{197{,}5 \cdot 35{,}50}{59589}} = 0{,}34 \qquad \lambda_z = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{197{,}5 \cdot 35{,}50}{7105}} = 0{,}99$$

Faktor redukcije

$$\Phi = 0{,}5 \cdot [1 + \alpha \cdot (\lambda - 0{,}2) + \lambda^2]$$

Toplo dogotovljeni profil s krivuljom izvijanja a i faktorom imperfekcije $\alpha = 0{,}21$.

$$\Phi_y = 0{,}5 \cdot [1 + 0{,}21 \cdot (0{,}34 - 0{,}2) + 0{,}34^2] = 0{,}58$$

$$\chi_y = \frac{1}{\Phi_y + \sqrt{{\Phi_y}^2 - {\lambda_y}^2}} = \frac{1}{0{,}58 + \sqrt{0{,}58^2 - 0{,}34^2}} = 0{,}95$$

Toplo dogotovljeni profil s krivuljom izvijanja b i faktorom imperfekcije $\alpha = 0{,}34$.

$$\Phi_z = 0{,}5 \cdot [1 + 0{,}34 \cdot (0{,}99 - 0{,}2) + 0{,}99^2] = 1{,}12$$

$$\chi_z = \frac{1}{\Phi_z + \sqrt{{\Phi_z}^2 - {\lambda_z}^2}} = \frac{1}{1{,}12 + \sqrt{1{,}12^2 - 0{,}99^2}} = 0{,}61$$

Računska otpornost elementa na izvijanje

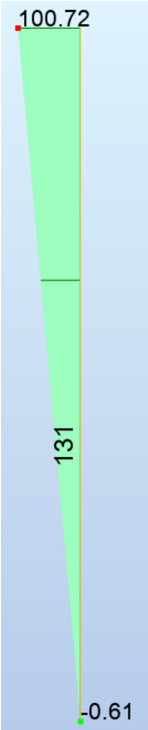
$$N_{b,Rd} = \chi_{min} \cdot \frac{A \cdot f_y}{\gamma_{M1}} = 0{,}61 \cdot \frac{197{,}5 \cdot 35{,}50}{1{,}10} = 3888\ kN$$

Otpornost elementa na izvijanje

$$\frac{N_{Ed}}{N_{b,Rd}} < 1{,}00 \quad \frac{2317}{3888} < 1{,}00 \quad 0{,}60 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 60%.

11.2.9. Otpornost elementa na savijanje



Slika78. Momentni dijagram stupa

ψ	C_1
+1,00	1,00
+0,75	1,14
+0,50	1,31
+0,25	1,52
0,00	1,77
-0,25	2,05
-0,50	2,33
-0,75	2,57
-1,00	2,55

Određivanje faktora C_1 i C_2

$$-1 \leq \psi \leq 1$$

$$\psi = -\frac{0{,}61}{100{,}72} \cong 0$$

Očitano:

$$C_1 = 1{,}77$$

$$C_2 = 0{,}00$$

Elastični kritični moment bočnog torzijskog izvijanja:

$$M_{cr} = C_1 \cdot \frac{\pi^2 \cdot E \cdot I_z}{L^2} \cdot \left[\sqrt{\frac{I_w}{I_z} + \frac{L^2 \cdot G \cdot I_t}{\pi^2 \cdot E \cdot I_z}}\right]$$

Modul elastičnosti	$E = 210000\ N/mm^2$
Modul posmika	$G = 80769{,}23\ N/mm^2$
Konstanta krivljenja	$I_w = 5643\ mm^6$
Moment tromosti	$I_z = 10370\ cm^4$
Torzijska konstanta	$I_t = 309{,}3\ cm^4$
Raspon	$L = 5500\ mm$

$$M_{cr} = 1{,}77 \cdot \frac{\pi^2 \cdot 21000 \cdot 10370}{550^2} \cdot \left[\sqrt{\frac{5643000}{10370} + \frac{550^2 \cdot 8076{,}923 \cdot 309{,}3}{\pi^2 \cdot 21000 \cdot 10370}}\right] \cdot 10^{-2}$$

$$M_{cr} = 3763{,}95\ kNm$$

Bezdimenzionalna vitkost:

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}} = \sqrt{\frac{3949 \cdot 35{,}5}{376395}} = 0{,}61$$

Faktor redukcije:

$$\frac{h}{b} = \frac{490}{300} = 1{,}63 < 2 \ \rightarrow \ mjerodavna\ krivulja\ izvijanja\ \boldsymbol{b} \ \rightarrow \ \alpha_{LT} = 0{,}34$$

$$\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0{,}2\right) + \bar{\lambda}_{LT}^{2}\right]$$

$$\Phi_{LT} = 0{,}5 \cdot [1 + 0{,}34 \cdot (0{,}61 - 0{,}2) + 0{,}61^2] = 0{,}76$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^{\ 2} - \bar{\lambda}_{LT}^{2}}} = \frac{1}{0{,}76 + \sqrt{0{,}76^2 - 0{,}61^2}} = 0{,}82 \leq 1$$

Računska otpornost:

$$M_{b,Rd} = \chi_{LT}\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}} = 0{,}82 \cdot \frac{3949 \cdot 35{,}5}{1{,}10} \cdot 10^{-2} = 1045\ kNm$$

$$M_{Ed,y} = 523\ kNm < M_{b,Rd} = 1045\ kNm$$

$$\frac{M_{Ed,y}}{M_{b,Rd}} = \frac{523}{1045} = 0{,}50 < 1{,0}$$

Presjek zadovoljava s iskoristivošću od 50 %.

11.2.10. Otpornost elementa na interakciju savijanja i uzdužne sile

$$\frac{\mathrm{N_{Ed}}}{\chi_\mathrm{y} \cdot \frac{\mathrm{N_{rk}}}{\gamma_\mathrm{M1}}} + \frac{\mathrm{k}_{yy} \cdot \mathrm{M}_{y.Ed}}{\chi_\mathrm{LT} \cdot \frac{\mathrm{M_{y,Rky}}}{\gamma_\mathrm{M1}}} \leq 1$$

$$\frac{\mathrm{N_{Ed}}}{\chi_\mathrm{z} \cdot \frac{\mathrm{N_{rk}}}{\gamma_\mathrm{M1}}} + \frac{\mathrm{k}_{zy} \cdot \mathrm{M}_{y.Ed}}{\chi_\mathrm{LT} \cdot \frac{\mathrm{M_{y,Rky}}}{\gamma_\mathrm{M1}}} \leq 1$$

Određivanje interakcijskih faktora $\mathrm{k_{ij}}$

$$\mathrm{C_{my}} = 0{,}6 + 0{,}4 \cdot \psi \ \geq 0{,}40$$

$$\mathrm{C_{my}} = 0{,}6 + 0{,}4 \cdot (0) = 0{,}6 \geq 0{,}40$$

$$\mathrm{k}_{yy} = C_{my}\left[1 + 0{,}6 \cdot \bar{\lambda}_\mathrm{y} \cdot \frac{\mathrm{N_{Ed}}}{\chi_\mathrm{y} \cdot \mathrm{N_{rk}}/\gamma_\mathrm{M1}}\right] \leq C_{my}\left[1 + 0{,}6 \cdot \frac{\mathrm{N_{Ed}}}{\chi_\mathrm{y} \cdot \mathrm{N_{rk}}/\gamma_\mathrm{M1}}\right]$$

$$\mathrm{k}_{yy} = 0{,}6 \cdot \left[1 + 0{,}6 \cdot 0{,}34 \cdot \frac{2317}{0{,}95 \cdot 7011}\right] \leq 0{,}6 \cdot \left[1 + 0{,}6 \cdot \frac{2317}{0{,}98 \cdot 7011}\right]$$

$$\mathrm{k}_{yy} = 0{,}64 < 0{,}73$$

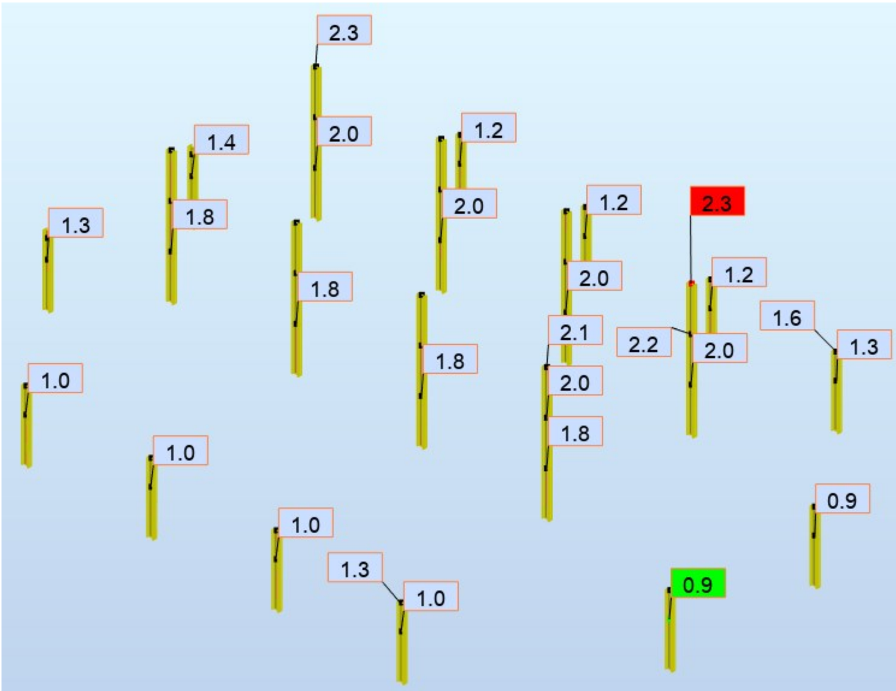
$$k_{zy} = 0{,}8 \cdot k_{yy} = 0{,}8 \cdot 0{,}73 = 0{,}58$$

Otpornost elementa na interakciju savijanja i uzdužne sile

$$\frac{2317}{0{,}95 \cdot 7011} + \frac{0{,}73 \cdot 523}{0{,}82 \cdot 1045} = 0{,}79 < 1$$

$$\frac{2317}{0{,}61 \cdot 7011} + \frac{0{,}58 \cdot 523}{0{,}82 \cdot 1045} = 0{,}90 < 1 \rightarrow mjerodavna\ iskoristivost\ stupa$$

11.2.11. Granično stanje uporabljivosti



Slika 79. Progib stupova HEA 500

Maksimalni pomak:

$$\delta_{max} = 23{,}0\ mm$$

Dopušteni pomak:

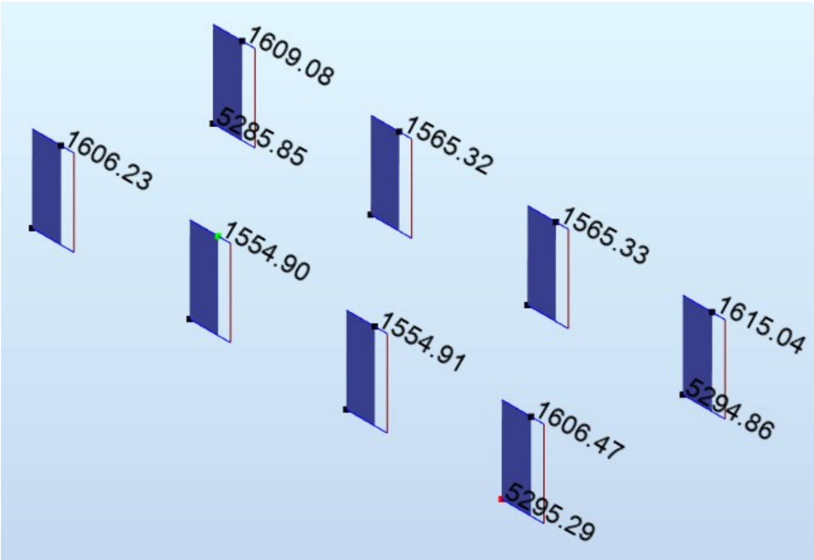
$$\delta_{dop} = \frac{L}{150} = \frac{3500}{150} = 24\ mm$$

Iskoristivost:

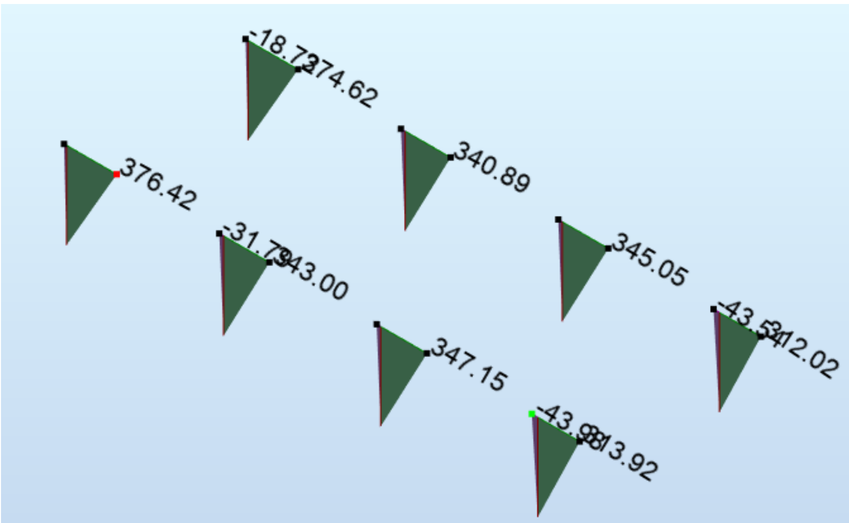
$$\frac{\delta_{max}}{\delta_{dop}} = \frac{23}{24} = 0{,}99\ \rightarrow Iskoristivost\ 99\ \%$$

11.3. Stupovi S3

11.3.1. Opterećenja

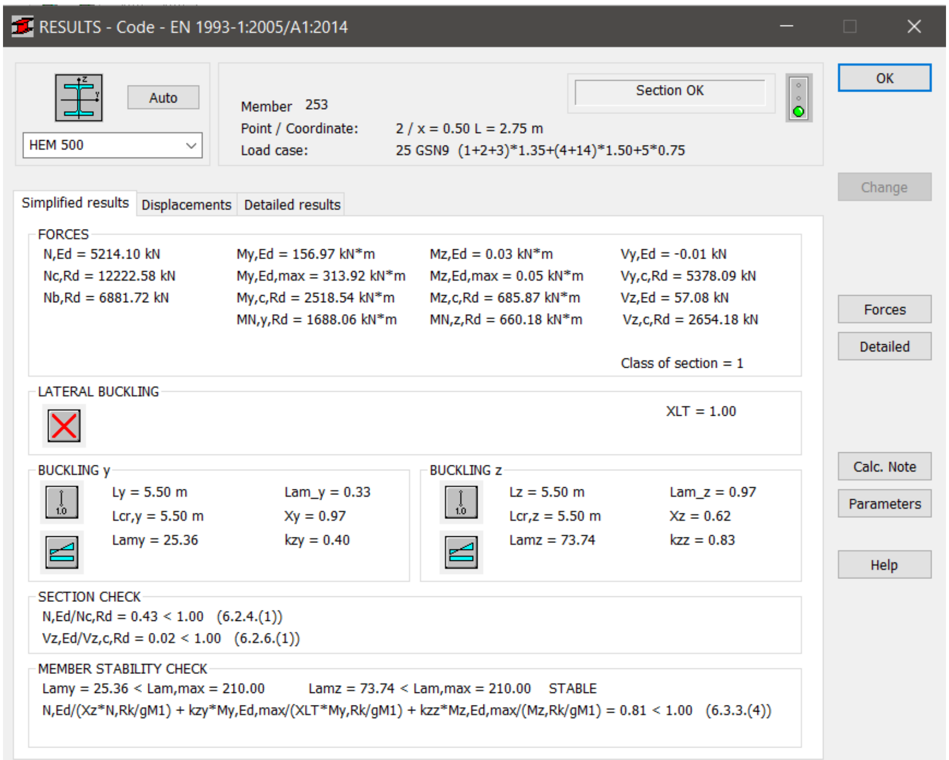


Slika 80. Uzdužna sila stupova HEM 500



Slika 81. Moment savijanja stupova HEM 500

Najopterećeniji element je element broj 253.



Slika 82. Karakteristike elementa 253

11.3.2. Karakteristike odabranog profila

Odabrani profil:	HEM 500
Tip poprečnog presjeka:	Toplo dogotovljeni
Površina poprečnog presjeka:	$A = 344{,}3\ cm^2$
Visina hrpta:	$h = 524\ mm$
Debljina hrpta:	$t_w = 21\ mm$
Širina pojasnice:	$b = 306\ mm$
Debljina pojasnice:	$t_f = 40\ mm$
Radijus:	$r = 27\ mm$
Osnovni materijal:	$S355\ ;\ t \leq 40mm$
Granica popuštanja:	$f_y = 355\ N/mm^2$
Modul elastičnosti:	$E = 210\ 000\ N/mm^2$
Parcijalni koeficijent za presjek:	$\gamma_{M0} = 1{,}00$
Parcijalni koeficijent za element:	$\gamma_{M1} = 1{,}10$

11.3.3. Klasifikacija profila

Hrbat

$$\frac{c}{t} = \frac{h - 2 \cdot t_f - 2 \cdot r}{t_w} = \frac{524 - 2 \cdot 40 - 2 \cdot 27,0}{21} = 20,5$$

$$\varepsilon = 0,81$$

$$33 \cdot \varepsilon = 33 \cdot 0,81 = 26,73$$

Hrbat je svrstan u klasu 1.

Pojasnica

$$\frac{c}{t} = \frac{\frac{b - t_w - 2 \cdot r}{2}}{t_f} = \frac{\frac{306 - 21 - 2 \cdot 27,0}{2}}{40} = 2,9$$

$$9 \cdot \varepsilon = 9 \cdot 0,81 = 7,29$$

Pojasnica je svrstana u klasu 1.

Poprečni presjek je svrstan u klasu 1.

11.3.4. Otpornost poprečnog presjeka na tlaku

$$N_{c,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{344,3 \cdot 35,5}{1,00} = 12222\ kN > 5214\ kN$$

Otpornost poprečnog presjeka na tlak

$$\frac{N_{Ed}}{N_{c,Rd}} < 1,00$$

$$\frac{5214}{12222} = 0,43 < 1,00$$

Presjek zadovoljava s iskoristivošću od 43%.

11.3.5. Otpornost poprečnog presjeka na moment savijanja

$$M_{pl,y,Rd} = \frac{W_{el,y} \cdot f_y}{\gamma_{M0}} = \frac{6280 \cdot 35,5}{1,0} \cdot 10^{-2} = 2194\ kNm$$

Otpornost presjeka na moment savijanja

$$\frac{M_{y,Ed}}{M_{c,Rd}} \leq 1{,}00$$

$$\frac{314}{2194} = 0{,}14 \leq 1{,}0$$

Presjek zadovoljava s iskoristivošću od 14%.

11.3.6. Otpornost poprečnog presjeka na poprečnu silu

Provjera na izbočivanje hrpta na posmik

$$h_w = h - 2 \cdot t_f = 524{,}0 - 2 \cdot 40 = 444\ mm$$

$$\frac{h_w}{t_w} < \frac{72 \cdot \varepsilon}{\eta}$$

$$\frac{444}{21} < \frac{72 \cdot 0{,}81}{1{,}2}$$

$21{,}14 < 48{,}6$ → Nije potrebna provjera izbočavanja hrpta na posmik.

Plastična posmična otpornost

$$V_{pl,Rd} = \frac{A_{V,z} \cdot (f_y/\sqrt{3})}{\gamma_{M0}}$$

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

$$A_{V,z} = 344{,}3 - 2 \cdot 30{,}60 \cdot 4 + (2{,}1 + 2 \cdot 2{,}7) \cdot 4 = 129{,}5\ cm^2$$

$$\eta \cdot h_w \cdot t_w = 1{,}20 \cdot 44{,}4 \cdot 2{,}1 = 110{,}88\ cm^2$$

$$A_{V,z} = 129{,}5\ cm^2 \geq 110{,}88\ cm^2$$

$$V_{pl,z,Rd} = \frac{129{,}5 \cdot (35{,}50/\sqrt{3})}{1{,}00} = 2654\ kN$$

Otpornost poprečnog presjeka na poprečnu silu

$$\frac{V_{z,Ed}}{V_{pl,Rd}} \leq 1{,}00 \qquad \frac{57{,}03}{2654} < 1{,}00 \qquad 0{,}02 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 2%.

11.3.7. Otpornost poprečnog presjeka na interakciju momenta savijanja, uzdužne sile i poprečne sile

$$V_{z,Ed} < 0{,}5 \cdot V_{z,Rd}$$

$$57{,}03\ kN < 0{,}5 \cdot 2654 = 1327\ kN$$

$$\frac{57{,}03}{1327} = 0{,}04 < 1{,}0$$

$$N_{Ed} < 0{,}25 \cdot N_{c,Rd}$$

$$5214\ kN < 0{,}25 \cdot 12222 = 3056\ kN$$

$$\frac{5214}{3056} = 1{,}7 > 1{,}0$$

Potrebna je redukcija otpornosti poprečnog presjeka na savijanje.

$$M_{N,V,y,Rd} = M_{pl,y,Rd} \cdot \frac{1-n}{1-0{,}5\cdot a} = 2194 \cdot \frac{1-0{,}43}{1-0{,}5\cdot 0{,}29} = 1463\ kNm$$

$$n = \frac{N_{Ed}}{N_{pl,Rd}} = \frac{5214}{12222} = 0{,}43$$

$$a = \frac{A - 2\cdot b\cdot t_f}{A} \leq 0{,}5$$

$$a = \frac{344{,}3 - 2\cdot 30{,}6\cdot 4}{344{,}3} = 0{,}29$$

$$M_{N,V,y,Rd} = M_{el,y,Rd} = 1463\ kNm$$

$$M_{N,V,y,Rd} > M_{y,Ed}$$

$$1463\ kNm > 314\ kNm$$

$$N_{Ed} < 0{,}50 \cdot h_w \cdot t_w \cdot f_y$$

$$5214\ kN < 0{,}50 \cdot 52{,}4 \cdot 2{,}1 \cdot 35{,}5 = 1953\ kN$$

$$\frac{5214}{1953} = 2{,}7 > 1{,}0$$

Potrebna je redukcija otpornosti poprečnog presjeka na savijanje.

11.3.8. Otpornost elementa na izvijanje

Moment tromosti prečke i stupa

$$I_{prečke} = 33090\ cm^4$$

$$I_{stupa} = 161900\ cm^4$$

Krutost prečke i stupa okvira

$$K_{prečke} = K_{11} = \frac{I_{prečke}}{L} = \frac{33090}{1156} = 28{,}62\ cm^3$$

$$K_{stupa} = K_c = \frac{I_{stupa}}{h} = \frac{161900}{550} = 294\ cm^3$$

Koeficijenti η

$$\eta_1 = \frac{K_c}{K_c + K_{11}} = \frac{294}{294 + 28{,}62} = 0{,}91$$

$$\eta_2 = 1{,}0\ \ (stup\ je\ zglobno\ oslonjen)$$

Koeficijent k za bočno nepomičan mod

$$k = 0{,}5 + 0{,}14 \cdot (\eta_1 + \eta_2) + 0{,}055 \cdot (\eta_1 + \eta_2)^2$$

$$k = 0{,}5 + 0{,}14 \cdot (0{,}91 + 1{,}0) + 0{,}055 \cdot (0{,}91 + 1{,}0)^2 = 0{,}97$$

Efektivne duljine izvijanja

$$L_{i,y} = k \cdot L = 0{,}97 \cdot 550 = 533{,}5\ cm$$

Duljine izvijanja

$$L_{cr,y} = \ 5{,}5\ m \qquad\qquad L_{cr,z} = \ 5{,}5\ m$$

Elastična kritična sila

$$N_{cr,y} = \frac{\pi^2 \cdot E \cdot I_y}{L_{cr,y}^2} = \frac{\pi^2 \cdot 21000 \cdot 161900}{550^2} = 110927\ kN$$

$$N_{cr,z} = \frac{\pi^2 \cdot E \cdot I_z}{L_{cr,z}^2} = \frac{\pi^2 \cdot 21000 \cdot 19150}{550^2} = 13120\ kN$$

Bezdimenzijska svedena vitkost

$$\lambda_y = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{344{,}3 \cdot 35{,}50}{110927}} = 0{,}33 \qquad \lambda_z = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{344{,}3 \cdot 35{,}50}{13120}} = 0{,}97$$

Faktor redukcije

$$\Phi\ =\ 0{,}5 \cdot [1 + \alpha \cdot (\lambda - 0{,}2) + \lambda^2]$$

Toplo dogotovljeni profil s krivuljom izvijanja a i faktorom imperfekcije $\alpha = 0{,}21$.

$$\Phi_y\ =\ 0{,}5 \cdot [1 + 0{,}21 \cdot (0{,}33 - 0{,}2) + 0{,}33^2]\ = 0{,}57$$

$$\chi_y = \frac{1}{\Phi_y + \sqrt{{\Phi_y}^2 - {\lambda_y}^2}} = \frac{1}{0{,}57 + \sqrt{0{,}57^2 - 0{,}33^2}} = 0{,}97$$

Toplo dogotovljeni profil s krivuljom izvijanja b i faktorom imperfekcije $\alpha = 0{,}34$.

$$\Phi_z = 0{,}5 \cdot [1 + 0{,}34 \cdot (0{,}97 - 0{,}2) + 0{,}97^2] = 1{,}1$$

$$\chi_z = \frac{1}{\Phi_z + \sqrt{{\Phi_z}^2 - {\lambda_z}^2}} = \frac{1}{1{,}1 + \sqrt{1{,}1^2 - 0{,}97^2}} = 0{,}62$$

Računska otpornost elementa na izvijanje

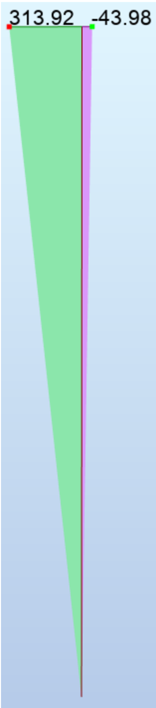
$$N_{b,Rd} = \chi_{min} \cdot \frac{A \cdot f_y}{\gamma_{M1}} = 0{,}62 \cdot \frac{344{,}3 \cdot 35{,}50}{1{,}10} = 6889\ kN$$

Otpornost elementa na izvijanje

$$\frac{N_{Ed}}{N_{b,Rd}} < 1{,}00 \quad \frac{5214}{6889} < 1{,}00 \quad 0{,}76 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 76%.

11.3.9. Otpornost elementa na savijanje



Slika 83. Momentni dijagram stupa

Određivanje faktora C_1 i C_2

ψ	C_1
+1,00	1,00
+0,75	1,14
+0,50	1,31
+0,25	1,52
0,00	1,77
-0,25	2,05
-0,50	2,33
-0,75	2,57
-1,00	2,55

$$-1 \leq \psi \leq 1$$

$$\psi = -\frac{0}{313} \cong 0$$

Očitano:

$$C_1 = 1{,}77$$

$$C_2 = 0{,}00$$

Elastični kritični moment bočnog torzijskog izvijanja:

$$M_{cr} = C_1 \cdot \frac{\pi^2 \cdot E \cdot I_z}{L^2} \cdot \left[\sqrt{\frac{I_w}{I_z} + \frac{L^2 \cdot G \cdot I_t}{\pi^2 \cdot E \cdot I_z}}\right]$$

Modul elastičnosti $E = 210000\ N/mm^2$

Modul posmika $G = 80769{,}23\ N/mm^2$

Konstanta krivljenja $I_w = 11190\ mm^6$

Moment tromosti $I_z = 19150\ cm^4$

Torzijska konstanta $I_t = 1539\ cm^4$

Raspon $L = 35500\ mm$

$$M_{cr} = 1{,}77 \cdot \frac{\pi^2 \cdot 21000 \cdot 19150}{550^2} \cdot \left[\sqrt{\frac{11190000}{19150} + \frac{550^2 \cdot 8076{,}923 \cdot 1539}{\pi^2 \cdot 21000 \cdot 19150}}\right] \cdot 10^{-2}$$

$$M_{cr} = \ 9089{,}19\ kNm$$

Bezdimenzionalna vitkost:

$$\overline{\lambda_{LT}} = \sqrt{\frac{W_{pl,y} \cdot f_y}{M_{cr}}} = \sqrt{\frac{7094 \cdot 35{,}5}{908919}} = 0{,}53$$

Faktor redukcije:

$$\frac{h}{b} = \frac{330}{300} = 1{,}1 < 2 \ \rightarrow \ mjerodavna\ krivulja\ izvijanja\ \boldsymbol{b} \ \rightarrow \ \alpha_{LT} = 0{,}34$$

$$\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\overline{\lambda}_{LT} - 0{,}2\right) + \overline{\lambda}_{LT}^{2}\right]$$

$$\Phi_{LT} = 0{,}5 \cdot [1 + 0{,}34 \cdot (0{,}53 - 0{,}2) + 0{,}53^2] = 0{,}70$$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{{\Phi_{LT}}^2 - \overline{\lambda_{LT}}^2}} = \frac{1}{0{,}70 + \sqrt{0{,}70^2 - 0{,}53^2}} = 0{,}86 \leq 1$$

Računska otpornost:

$$M_{b,Rd} = \chi_{LT}\frac{W_{pl,y} \cdot f_y}{\gamma_{M1}} = 0{,}86 \cdot \frac{7094 \cdot 35{,}5}{1{,}10} \cdot 10^{-2} = 1969\ kNm$$

$$M_{Ed,y} = 314\ kNm < M_{b,Rd} = 1969\ kNm$$

$$\frac{M_{Ed,y}}{M_{b,Rd}} = \frac{314}{1969} = 0{,}16 < 1{,}0$$

Presjek zadovoljava s iskoristivošću od 16 %.

11.3.10. Otpornost elementa na interakciju savijanja i uzdužne sile

$$\frac{N_{Ed}}{\chi_y \cdot \frac{N_{rk}}{\gamma_{M1}}} + \frac{k_{yy} \cdot M_{y.Ed}}{\chi_{LT} \cdot \frac{M_{y,Rky}}{\gamma_{M1}}} \leq 1$$

$$\frac{N_{Ed}}{\chi_z \cdot \frac{N_{rk}}{\gamma_{M1}}} + \frac{k_{zy} \cdot M_{y.Ed}}{\chi_{LT} \cdot \frac{M_{y,Rky}}{\gamma_{M1}}} \leq 1$$

Određivanje interakcijskih faktora k_{ij}

$$C_{my} = 0,6 + 0,4 \cdot \psi \geq 0,40$$

$$C_{my} = 0,6 + 0,4 \cdot (0) = 0,6 \geq 0,40$$

$$k_{yy} = C_{my}\left[1 + 0,6 \cdot \bar{\lambda}_y \cdot \frac{N_{Ed}}{\chi_y \cdot {N_{rk}}/{\gamma_{M1}}}\right] \leq C_{my}\left[1 + 0,6 \cdot \frac{N_{Ed}}{\chi_y \cdot {N_{rk}}/{\gamma_{M1}}}\right]$$

$$k_{yy} = 0,6 \cdot \left[1 + 0,6 \cdot 0,33 \cdot \frac{5214}{0,97 \cdot 12222}\right] \leq 0,6 \cdot \left[1 + 0,6 \cdot \frac{5214}{0,98 \cdot 12222}\right]$$

$$k_{yy} = 0,65 < 0,76$$

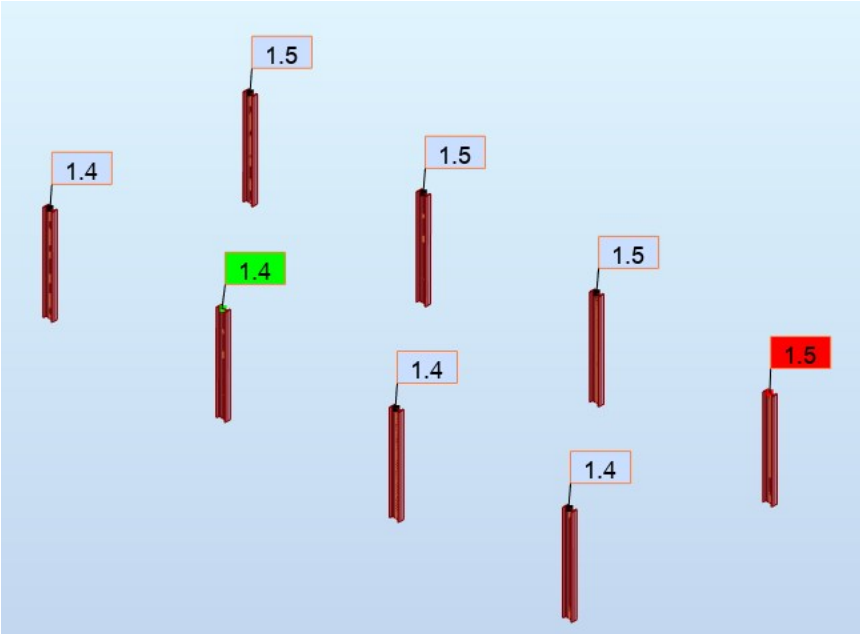
$$k_{zy} = 0,8 \cdot k_{yy} = 0,8 \cdot 0,76 = 0,61$$

Otpornost elementa na interakciju savijanja i uzdužne sile

$$\frac{5214}{0,97 \cdot 12222} + \frac{0,76 \cdot 314}{0,86 \cdot 1969} = 0,58 < 1$$

$$\frac{5214}{0,82 \cdot 12222} + \frac{0,35 \cdot 314}{0,86 \cdot 1969} = 0,59 < 1$$

11.3.11. Granično stanje uporabljivosti



Slika 84. Prikaz progiba stupova poprečnog presjeka HEM 500

Maksimalni pomak:

$$\delta_{max} = 15,0\ mm$$

Dopušteni progib:

$$\delta_{dop} = \frac{L}{150} = \frac{5500}{150} = 36\ mm$$

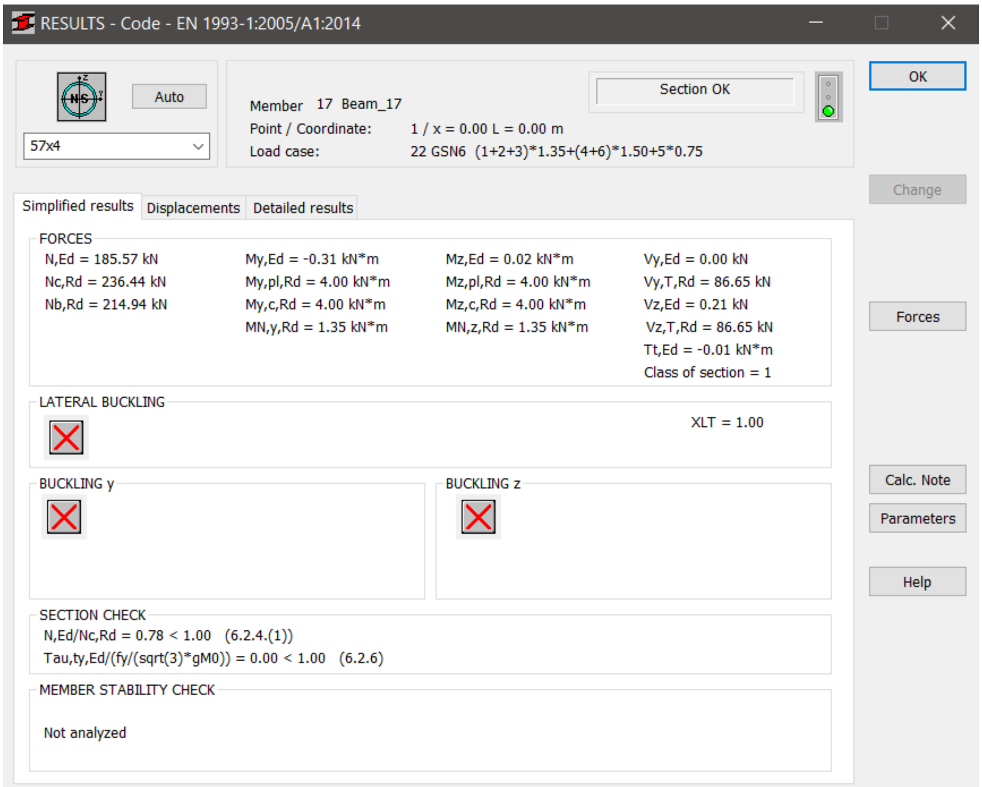
Iskoristivost:

$$\frac{\delta_{max}}{\delta_{dop}} = \frac{15}{22} = 0,68\ \rightarrow Iskoristivost\ 68\ \%$$

12. VERTIKALNA STABILIZACIJA

12.1. Opterećenja

Najopterećeniji element je element 17.



Slika 85. Karakteristike elementa 17

12.2. Karakteristike odabranog profila

Odabrani profil:	$57\ x\ 4{,}0$
Tip poprečnog presjeka:	Toplo dogotovljeni
Površina poprečnog presjeka:	$A = 6{,}66\ cm^2$
Promjer presjeka:	$D = 57\ mm$
Debljina stijenke:	$t = 4{,}0\ mm$
Osnovni materijal:	$S235\ ;\ t \leq 40mm$
Granica popuštanja:	$f_y = 235\ N/mm^2$
Modul elastičnosti:	$E = 210\ 000\ N/mm^2$
Parcijalni koeficijent za presjek:	$\gamma_{M0} = 1{,}00$
Parcijalni koeficijent za element:	$\gamma_{M1} = 1{,}10$

12.3. Klasifikacija profila

$$\frac{c}{t} = \frac{D - 2\ \cdot\ t}{t} = \frac{57 - 2\ \cdot\ 4}{4} = 12{,}25$$

$$33\ \cdot\ \varepsilon = 33\ \cdot 0{,}81\ = 26{,}73$$

$$12{,}25 < 26{,}73$$

Poprečni presjek je svrstan u klasu 1.

12.4. Otpornost poprečnog presjeka na vlak

$$N_{t,Rd} = \frac{A\ \cdot\ f_y}{\gamma_{M0}} = \frac{6{,}66\ \cdot 35{,}50}{1{,}00} = 236{,}43\ kN > 186\ kN$$

Otpornost poprečnog presjeka na vlak

$$\frac{N_{Ed}}{N_{t,Rd}} < 1{,}00$$

$$\frac{186}{236} < 1{,}00$$

$$0{,}79 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 79%.

12.5. Otpornost elementa na izvijanje

Duljine izvijanja

$$L_{cr,y} = L_{cr,z} = L_{cr} = 7{,}98\ m$$

Elastična kritična sila

$$N_{cr} = \frac{\pi^2 \cdot E \cdot I}{L_{cr}^2} = \frac{\pi^2 \cdot 21000 \cdot 23{,}52}{798^2} = 7{,}7\ kN$$

Bezdimenzijska svedena vitkost

$$\lambda = \sqrt{\frac{A \cdot f_y}{N_{cr}}} = \sqrt{\frac{6{,}66 \cdot 35{,}50}{765}} = 0{,}56$$

Faktor redukcije

$$\Phi = 0{,}5 \cdot [1 + \alpha \cdot (\lambda - 0{,}2) + \lambda^2]$$

Toplo dogotovljeni profil s krivuljom izvijanja a i faktorom imperfekcije $\alpha = 0{,}21$.

$$\Phi = 0{,}5 \cdot [1 + 0{,}21 \cdot (0{,}56 - 0{,}2) + 0{,}56^2] = 0{,}69$$

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda^2}} = \frac{1}{0{,}69 + \sqrt{0{,}69^2 - 0{,}56^2}} = 0{,}91$$

Računska otpornost elementa na izvijanje

$$N_{b,Rd} = \chi \cdot \frac{A \cdot f_y}{\gamma_{M1}} = 0{,}91 \cdot \frac{6{,}66 \cdot 35{,}50}{1{,}10} = 196\ kN$$

Otpornost elementa na izvijanje

$$\frac{N_{Ed}}{N_{b,Rd}} < 1{,}00$$

$$\frac{186}{196} < 1{,}00$$

$$0{,}95 < 1{,}00$$

Presjek zadovoljava s iskoristivošću od 95%.

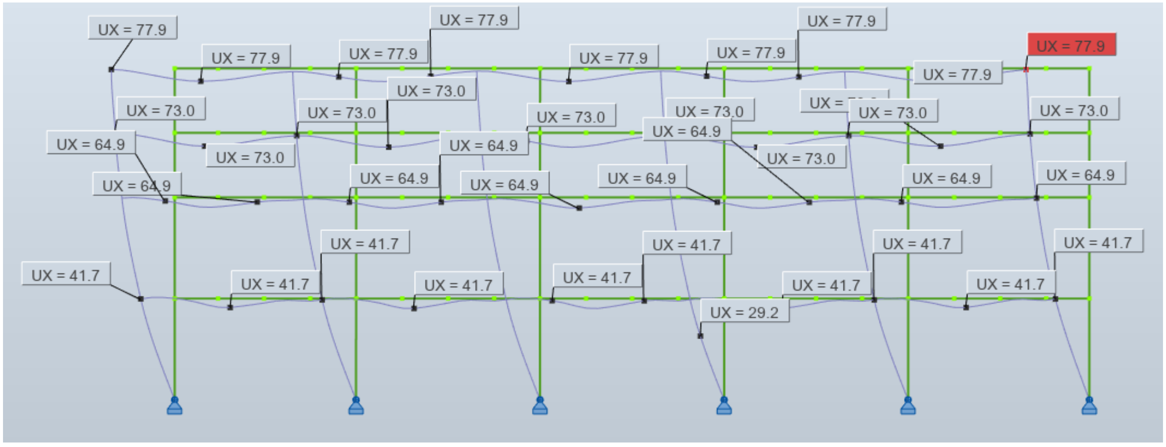
13. POTRES

Prilikom proračuna konstrukcije na potres, došlo je do promijene profila. Profili koji zadovoljavaju na granično stanje uporabljivosti i granično stanje nosivosti, nisu zadovoljavali na potres. Zbog toga su se profili povećali. S obzirom na to da su profili jači, nema potrebe provjeravati nove profile na granično stanje uporabljivosti i granično stanje nosivosti.

13.1. Zahtijev ograničenog oštećenja

13.1.1 Vanjska ravnina

13.1.1.1. Vezni sustav u x smjeru



Slika 86. Pomaci vanjskog okvira u smjeru x

$$d_r \cdot v \leq 0{,}01 \cdot h$$

Prizemlje:

$$41{,}7 \leq 0{,}01 \cdot 5500$$

$$41{,}7\ mm \leq 55\ mm$$

Prvi kat:

$$(64{,}9 - 41{,}7) \cdot 1 \leq 0{,}01 \cdot 5500$$

$$23{,}2\ mm \leq 55\ mm$$

Drugi kat:

$$(73 - 64{,}9) \cdot 1 \leq 0{,}01 \cdot 3500$$

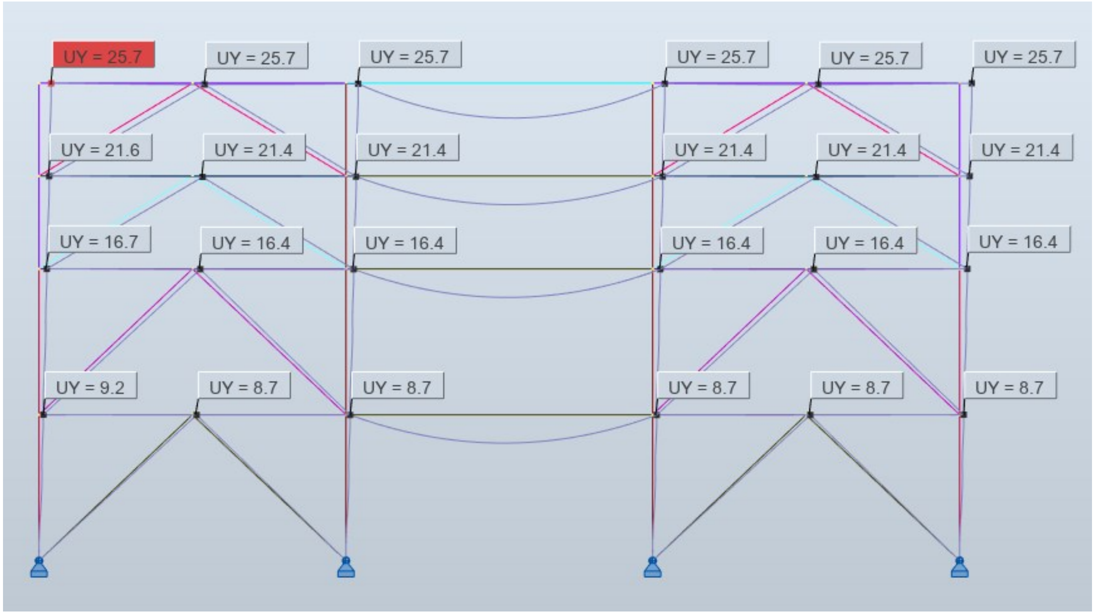
$$5{,}1\ mm \leq 35\ mm$$

Treći kat:

$$(77{,}9 - 73) \cdot 1 \leq 0{,}01 \cdot 3500$$

$$4{,}9\ mm \leq 35\ mm$$

13.1.1.2. Vezni sustav u y smjeru



Slika 87. Pomaci vanjskog okvira u smjeru y

Prizemlje:

$$9{,}2 \leq 0{,}01 \cdot 5500$$

$$9{,}2\ mm \leq 55\ mm$$

Prvi kat:

$$(16{,}7 - 9{,}2) \cdot 1 \leq 0{,}01 \cdot 5500$$

$$7{,}5\ mm \leq 55\ mm$$

Drugi kat:

$$(21{,}6 - 16{,}7) \cdot 1 \leq 0{,}01 \cdot 3500$$

$$4{,}9\ mm \leq 35\ mm$$

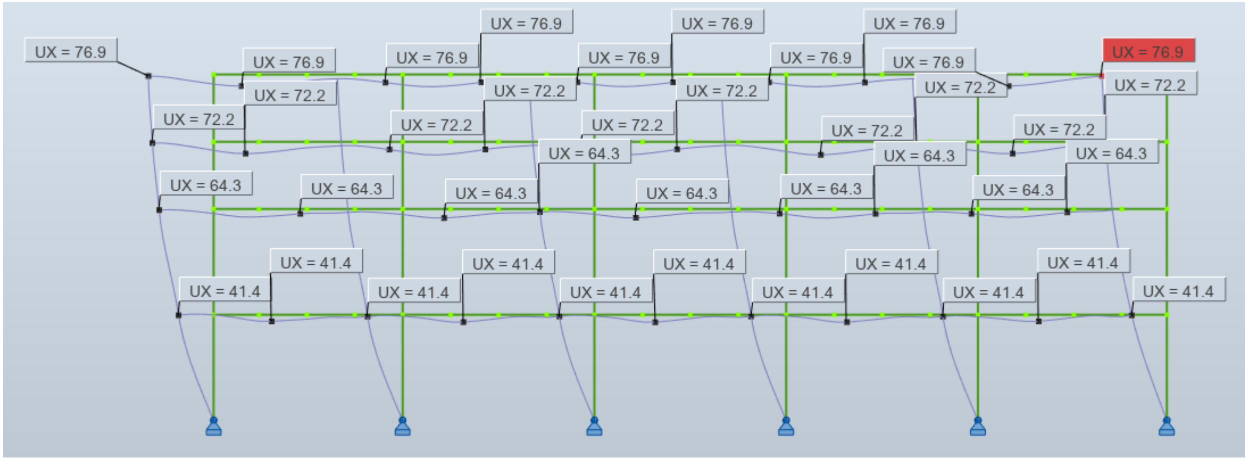
Treći kat:

$$(25{,}7 - 21{,}6) \cdot 1 \leq 0{,}01 \cdot 3500$$

$$4{,}1\ mm \leq 35\ mm$$

13.1.2. Unutarnja ravnina

13.1.2.1 Vezni sustav u x smjeru



Slika 88. Pomaci unutarnjeg okvira u smjeru x

Prizemlje:

$$41{,}4 \cdot 1 \leq 0{,}01 \cdot 5500$$

$$41{,}4\ mm \leq 55\ mm$$

Prvi kat:

$$(64{,}3 - 41{,}4) \cdot 1 \leq 0{,}01 \cdot 5500$$

$$22{,}9\ mm \leq 55\ mm$$

Drugi kat:

$$(72{,}2 - 64{,}3) \cdot 1 \leq 0{,}01 \cdot 3500$$

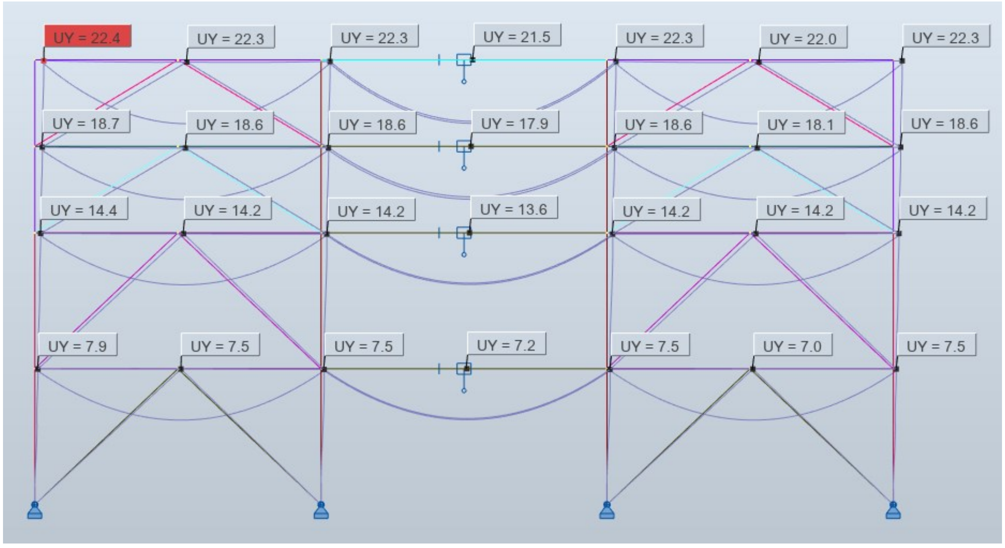
$$7{,}9\ mm \leq 35\ mm$$

Treći kat:

$$(76{,}9 - 72{,}2) \cdot 1 \leq 0{,}01 \cdot 3500$$

$$4{,}7\ mm \leq 35\ mm$$

13.1.2.2 Vezni sustav u y smjeru



Slika 89. Pomoci unutarnjeg okvira u smjeru y

Prizemlje:

$$7{,}9 \cdot 1 \leq 0{,}01 \cdot 5500$$

$$7{,}9\ mm \leq 55\ mm$$

Prvi kat:

$$(14{,}4 - 7{,}9) \cdot 1 \leq 0{,}01 \cdot 5500$$

$$6{,}5\ mm \leq 55\ mm$$

Drugi kat:

$$(18{,}7 - 14{,}4) \cdot 1 \leq 0{,}01 \cdot 3500$$

$$4{,}3\ mm \leq 35\ mm$$

Treći kat:

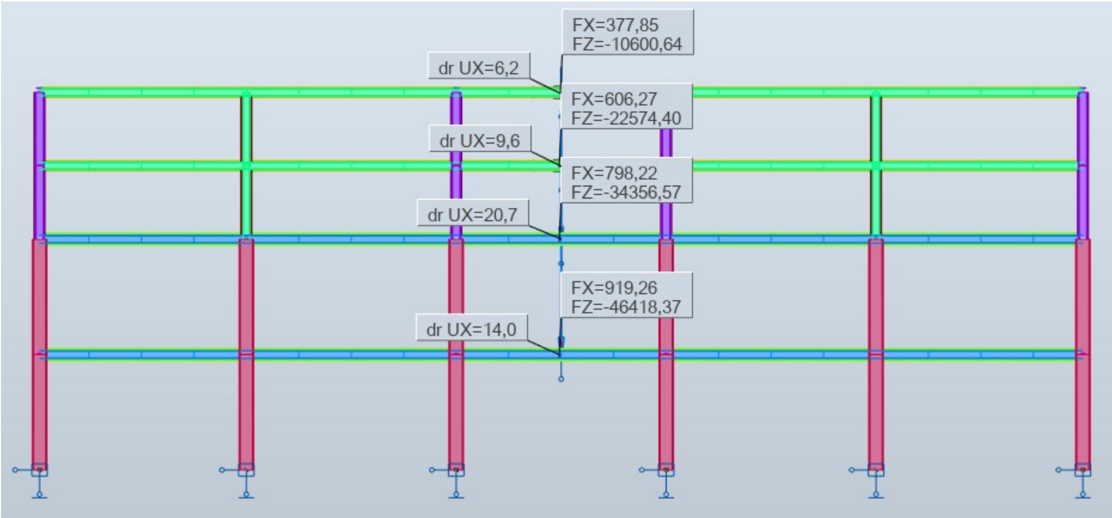
$$(22{,}3 - 18{,}7) \cdot 1 \leq 0{,}01 \cdot 3500$$

$$3{,}6\ mm \leq 35\ mm$$

13.2. Klasifikacija veznog sustava

Ako je na svim katovima zadovoljen uvjet $\theta = \frac{P_{tot} \cdot d_r}{V_{tot} \cdot h} < 0{,}1$, tada nije potrebno uzimati $P - \Delta$ učinke u obzir.

13.2.1. U smjeru X



Slika 90. Opterećenja i pomak u smjeru X

Treći kat:

$$\theta = \frac{10601 \cdot 6{,}2}{378 \cdot 3500} = 0{,}049 < 0{,}1$$

Drugi kat:

$$\theta = \frac{22574 \cdot 9{,}6}{606 \cdot 3500} = 0{,}102 < 0{,}1$$

Prvi kat:

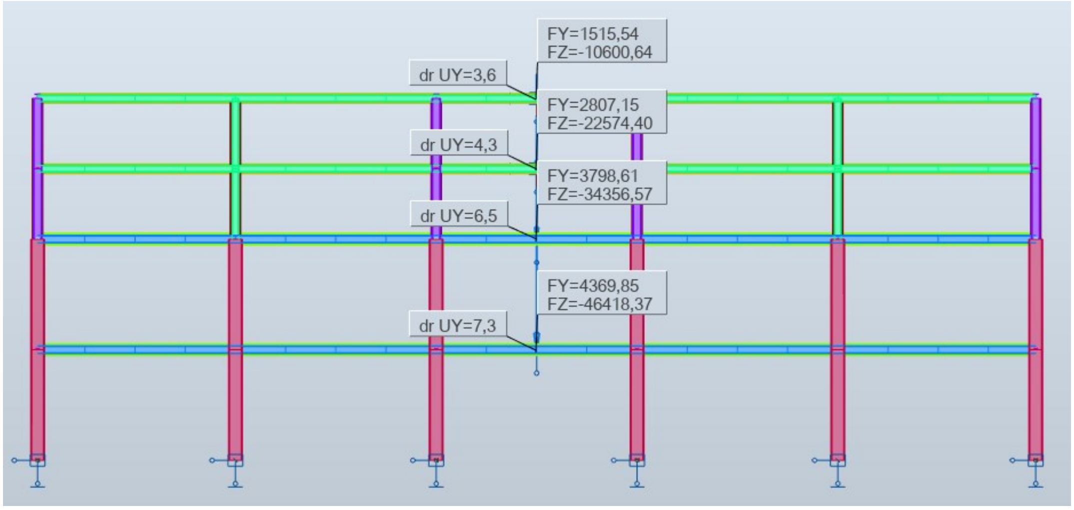
$$\theta = \frac{34357 \cdot 20{,}7}{798 \cdot 5500} = 0{,}162 < 0{,}1$$

Prizemlje:

$$\theta = \frac{46418 \cdot 14}{919 \cdot 5500} = 0{,}129 < 0{,}1$$

Uvjet za zanemarivanje uzimati $P - \Delta$ učinka nije zadovoljen na razini prizemlja i prvog kata. Uvijet za pojednostavljenu metodu je zadovoljen. Stoga se računa faktor za povećanje unutarnjih unutarnjih sila i momenata zbog učinka drugog reda primjenom najvećeg koeficijenta osjetljivosti međukatnog pomakačija vrijednost iznosi e= 1,19. Ta se vrijednost dobiva od $\frac{1}{1-\theta} = \frac{1}{1-0{,}162} = 1{,}19$.

13.2.1. U smjeru Y



Slika 91. Opterećenja i pomak u smjeru Y

Treći kat:

$$\theta = \frac{10601 \cdot 3{,}6}{1516 \cdot 3500} = 0{,}007 < 0{,}1$$

Drugi kat:

$$\theta = \frac{22575 \cdot 4{,}3}{2807 \cdot 3500} = 0{,}010 < 0{,}1$$

Prvi kat:

$$\theta = \frac{34357 \cdot 6{,}5}{3799 \cdot 5500} = 0{,}011 < 0{,}1$$

Prizemlje:

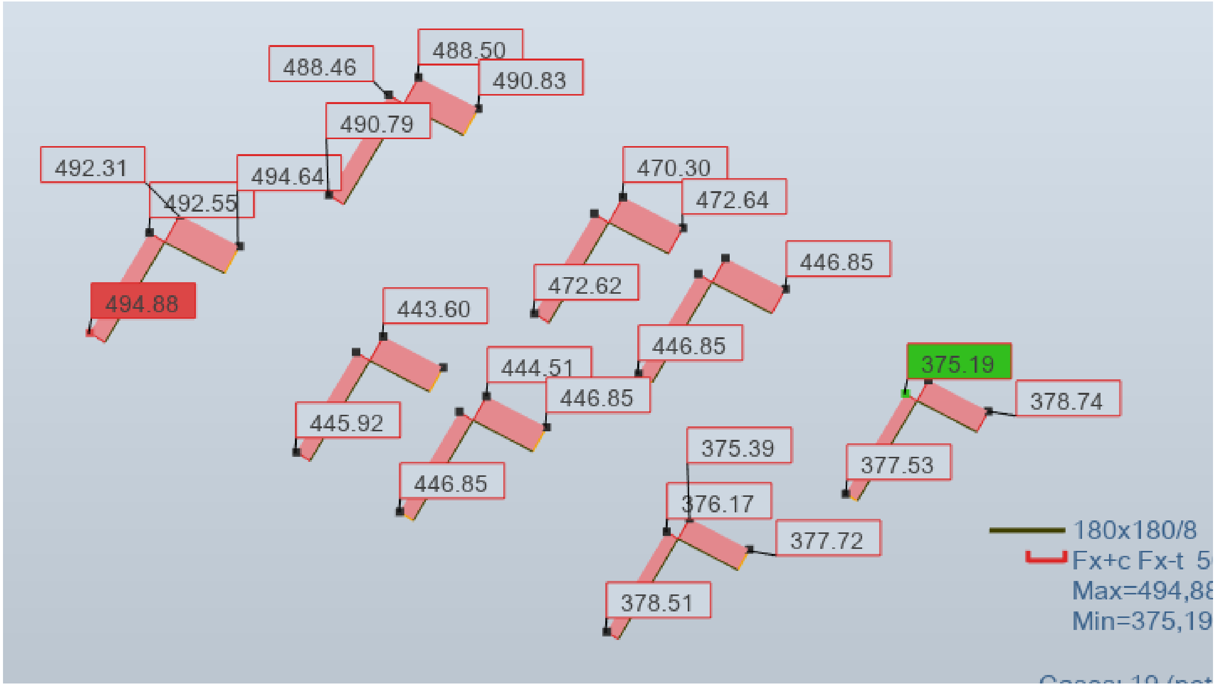
$$\theta = \frac{46418 \cdot 7{,}3}{46418 \cdot 5500} = 0{,}001 < 0{,}1$$

13.3. Proračun dijagonala

Tablica 20. Dijagonale

DIJAGONALA	$N_{Pl,Rd}$	N_{Ed}	$\Omega = \frac{N_{Pl,Rd}}{N_{Ed}}$
140x140/5	275	222	1,23≤1,48
140x140/8	423	344	1,23≤1,48
160x160/10	543	461	1,18->min-> Ω≤1,478
180x180/8	643	495	1,30≤1,48

13.3.1. Dijagonale prizemlja- 180x180/8



Slika 92. Uzdužna sila u dijagonalama prizemlja uslijed potresa

Otpornost elementa na izvijanje

$$N_{cr} = \frac{\pi^2 \cdot E \cdot I}{L_{cr}^2} = \frac{\pi^2 \cdot 21000 \cdot 2591}{798^2} = 843\ kN$$

$$\lambda = \sqrt{\frac{A \cdot f_y}{N_{cr}}} = \sqrt{\frac{53{,}4 \cdot 35{,}5}{843}} = 1{,}50$$

$$\phi = 0{,}5 \cdot [1 + \alpha \cdot (\lambda - 0{,}2) + \lambda^2] = 0{,}5 \cdot [1 + 21 \cdot (1{,}50 - 0{,}2) + 1{,}50^2] = 1{,}76$$

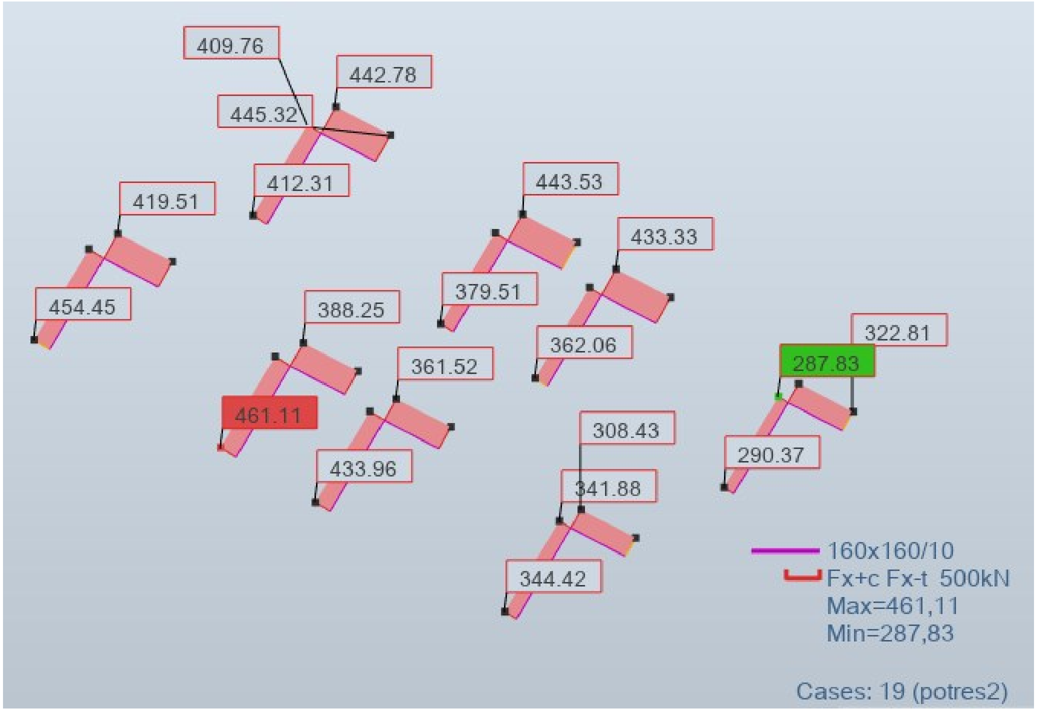
$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \lambda^2}} = \frac{1}{1{,}76 + \sqrt{1{,}76^2 - 1{,}50^2}} = 0{,}373$$

$$N_{B,Rd} = \chi \cdot \frac{A_a \cdot f_y}{y_{M1}} = 0{,}373 \cdot \frac{53{,}4 \cdot 35{,}5}{1{,}1} = 643\ kN > 495\ kN$$

Otpornost na vlak

$$N_{t,Rd} = \frac{A \cdot f_y}{\gamma_{m0}} = \frac{53{,}4 \cdot 35{,}5}{1{,}0} = 1896\ kN > 495\ kN$$

13.3.2 Dijagonale na prvom katu- 160x160/10



Slika 93. Uzdužna sila u dijagonalama prvog kata uslijed potresa

Otpornost elementa na izvijanje

$$N_{cr} = \frac{\pi^2 \cdot E \cdot I}{L_{cr}^2} = \frac{\pi^2 \cdot 21000 \cdot 2103}{798^2} = 685\ kN$$

$$\lambda = \sqrt{\frac{A \cdot f_y}{N_{cr}}} = \sqrt{\frac{57,4 \cdot 35,5}{685}} = 1,72$$

$$\phi = 0,5 \cdot [1 + \alpha \cdot (\lambda - 0,2) + \lambda^2] = 0,5 \cdot [1 + 0,21 \cdot (1,72 - 0,2) + 1,72^2] = 2,14$$

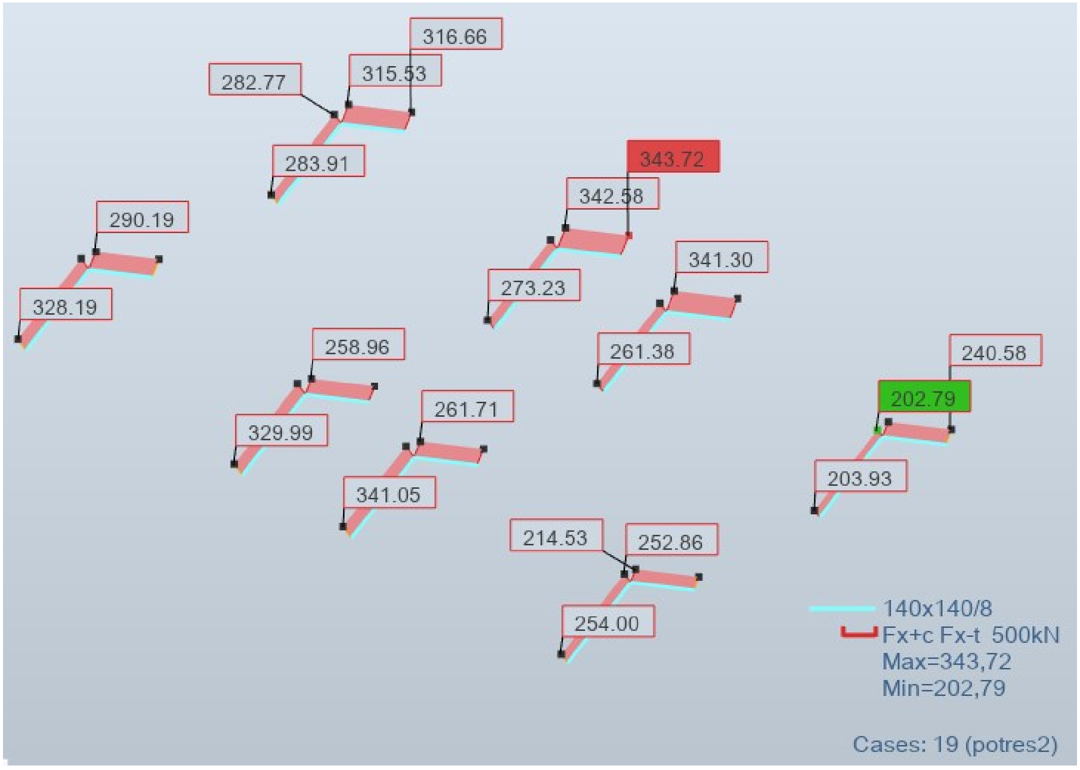
$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \lambda^2}} = \frac{1}{2,14 + \sqrt{2,14^2 - 1,72^2}} = 0,293$$

$$N_{B,Rd} = \chi \cdot \frac{A_a \cdot f_y}{\gamma_{M1}} = 0,293 \cdot \frac{57,4 \cdot 35,5}{1,1} = 543\ kN > 461\ kN$$

Otpornost na vlak

$$N_{t,Rd} = \frac{A \cdot f_y}{\gamma_{m0}} = \frac{57,4 \cdot 35,5}{1,0} = 2038\ kN > 461\ kN$$

13.3.3 Dijagonale na drugom katu- 140x140/8



Slika 94. Uzdužna sila u dijagonalama drugog kata uslijed potresa

Otpornost elementa na izvijanje

$$N_{cr} = \frac{\pi^2 \cdot E \cdot I}{L_{cr}^2} = \frac{\pi^2 \cdot 21000 \cdot 1185}{676^2} = 537\ kN$$

$$\lambda = \sqrt{\frac{A \cdot f_y}{N_{cr}}} = \sqrt{\frac{41{,}3 \cdot 35{,}5}{537}} = 1{,}65$$

$$\phi = 0{,}5 \cdot [1 + \alpha \cdot (\lambda - 0{,}2) + \lambda^2] = 0{,}5 \cdot [1 + 0{,}21 \cdot (1{,}65 - 0{,}2) + 1{,}65^2] = 2{,}01$$

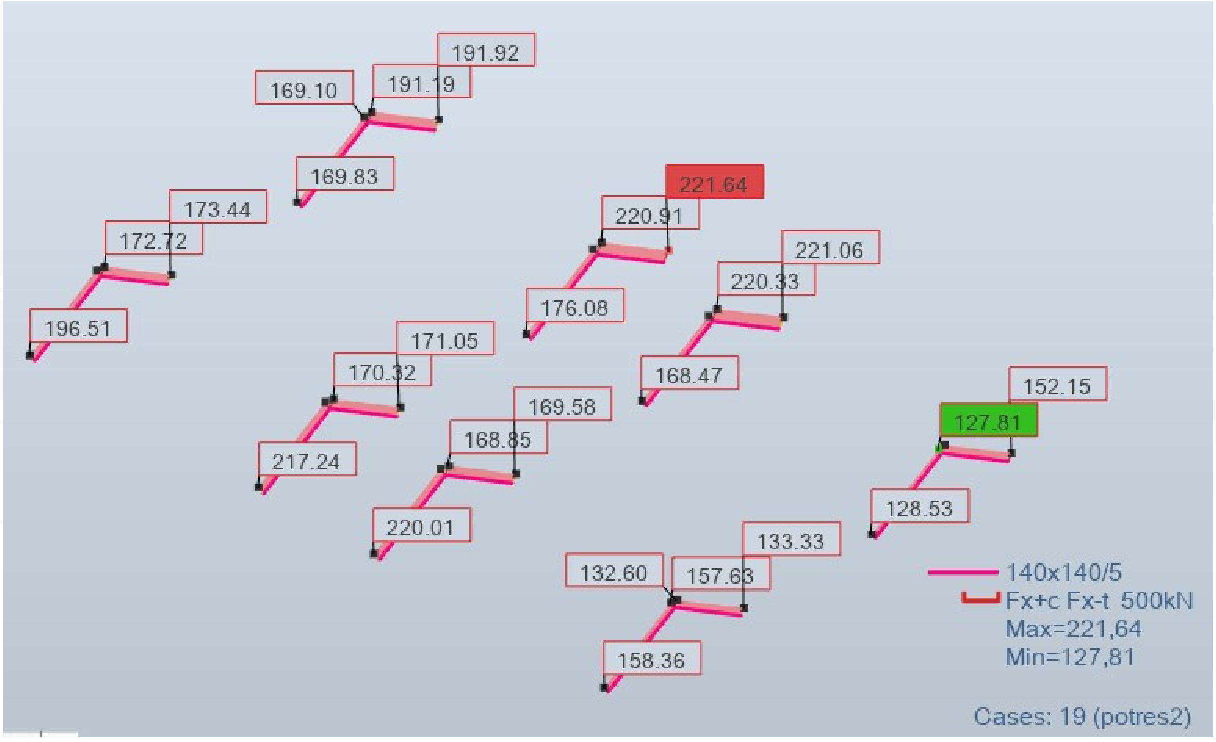
$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \lambda^2}} = \frac{1}{2{,}01 + \sqrt{2{,}01^2 - 1{,}65^2}} = 0{,}317$$

$$N_{B,Rd} = \chi \cdot \frac{A_a \cdot f_y}{y_{M1}} = 0{,}317 \cdot \frac{41{,}3 \cdot 35{,}5}{1{,}1} = 423\ kN > 344\ kN$$

Otpornost na vlak

$$N_{t,Rd} = \frac{A \cdot f_y}{\gamma_{m0}} = \frac{41{,}3 \cdot 35{,}5}{1{,}0} = 1466\ kN > 344\ kN$$

13.3.4 Dijagonale na trećem katu- 140x140/5



Slika 95. Uzdužna sila u dijagonalama trećeg kata uslijed potresa

Otpornost elementa na izvijanje

$$N_{cr} = \frac{\pi^2 \cdot E \cdot I}{L_{cr}^2} = \frac{\pi^2 \cdot 21000 \cdot 780}{676^2} = 354\ kN$$

$$\lambda = \sqrt{\frac{A \cdot f_y}{N_{cr}}} = \sqrt{\frac{26{,}1 \cdot 35{,}5}{354}} = 1{,}62$$

$$\phi = 0{,}5 \cdot [1 + \alpha \cdot (\lambda - 0{,}2) + \lambda^2] = 0{,}5 \cdot [1 + 0{,}21 \cdot (1{,}62 - 0{,}2) + 1{,}62^2] = 1{,}96$$

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \lambda^2}} = \frac{1}{1{,}96 + \sqrt{1{,}96^2 - 1{,}62^2}} = 0{,}326$$

$$N_{B,Rd} = \chi \cdot \frac{A_a \cdot f_y}{y_{M1}} = 0{,}326 \cdot \frac{26{,}1 \cdot 35{,}5}{1{,}1} = 275\ kN > 222\ kN$$

Otpornost na vlak

$$N_{t,Rd} = \frac{A \cdot f_y}{\gamma_{m0}} = \frac{26{,}1 \cdot 35{,}5}{1{,}0} = 927\ kN > 222\ kN$$

13.4. Proračun sekundarnih nosača u sklopu vertikalne stabilizacije

13.4.1. Greda prizemlja I prvog kata- HEA 800

$$M_{Ed} = \left(N_{pl,Rd.i} - 0{,}3 \cdot N_{pl,Rd.i}\right) \cdot \sin(\theta_1) \cdot {}^{L}\!/_{4} = (1896 - 0{,}3 \cdot 1896) \cdot \sin(43°32) \cdot \frac{11{,}58}{4}$$
$$= 2646\ kNm < 3089\ kNm$$

$$V_{Ed} = \left(N_{pl,Rd.i} - 0{,}3 \cdot N_{pl,Rd.i}\right) \cdot \sin(\theta_1) \cdot {}^{1}\!/_{2} = (1896 - 0{,}3 \cdot 1896) \cdot \sin(43°32) \cdot \frac{1}{2}$$
$$= 457\ kN < 2845\ kN$$

13.4.2. Greda drugog kata- HEA 550

$$M_{Ed} = \left(N_{pl,Rd.i} - 0{,}3 \cdot N_{pl,Rd.i}\right) \cdot \sin(\theta_1) \cdot {}^{L}\!/_{4} = (1466 - 0{,}3 \cdot 1466) \cdot \sin(31°9) \cdot \frac{11{,}58}{4}$$
$$= 1537\ kNm < 1641\ kNm$$

$$V_{Ed} = \left(N_{pl,Rd.i} - 0{,}3 \cdot N_{pl,Rd.i}\right) \cdot \sin(\theta_1) \cdot {}^{1}\!/_{2} = (1466 - 0{,}3 \cdot 1466) \cdot \sin(31°9) \cdot \frac{1}{2}$$
$$= \quad 265\ kN < 1716\ kN$$

13.4.3. Greda trećeg kata- HEA 450

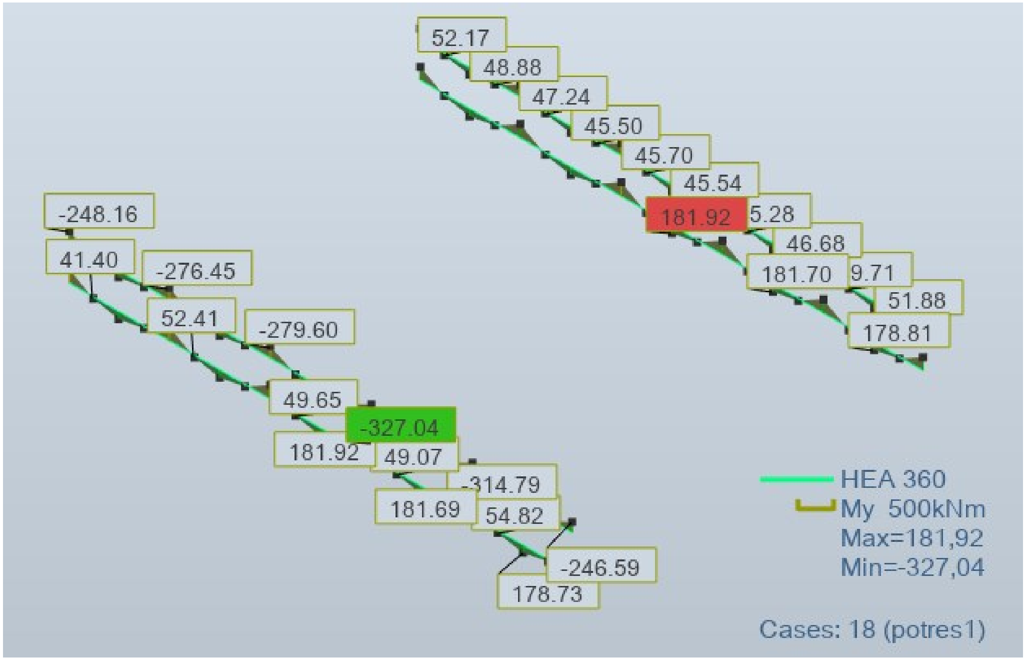
$$M_{Ed} = \left(N_{pl,Rd.i} - 0{,}3 \cdot N_{pl,Rd.i}\right) \cdot \sin(\theta_1) \cdot {}^{L}\!/_{4} = (927 - 0{,}3 \cdot 927) \cdot \sin(31°9) \cdot \frac{11{,}58}{4}$$
$$= 972\ kNm < \ 1142\ kNm$$

$$V_{Ed} = \left(N_{pl,Rd.i} - 0{,}3 \cdot N_{pl,Rd.i}\right) \cdot \sin(\theta_1) \cdot {}^{1}\!/_{2} = (275 - 0{,}3 \cdot 275) \cdot \sin(31°9) \cdot \frac{1}{2} =$$
$$= 167\ kN < 2838\ \ kN$$

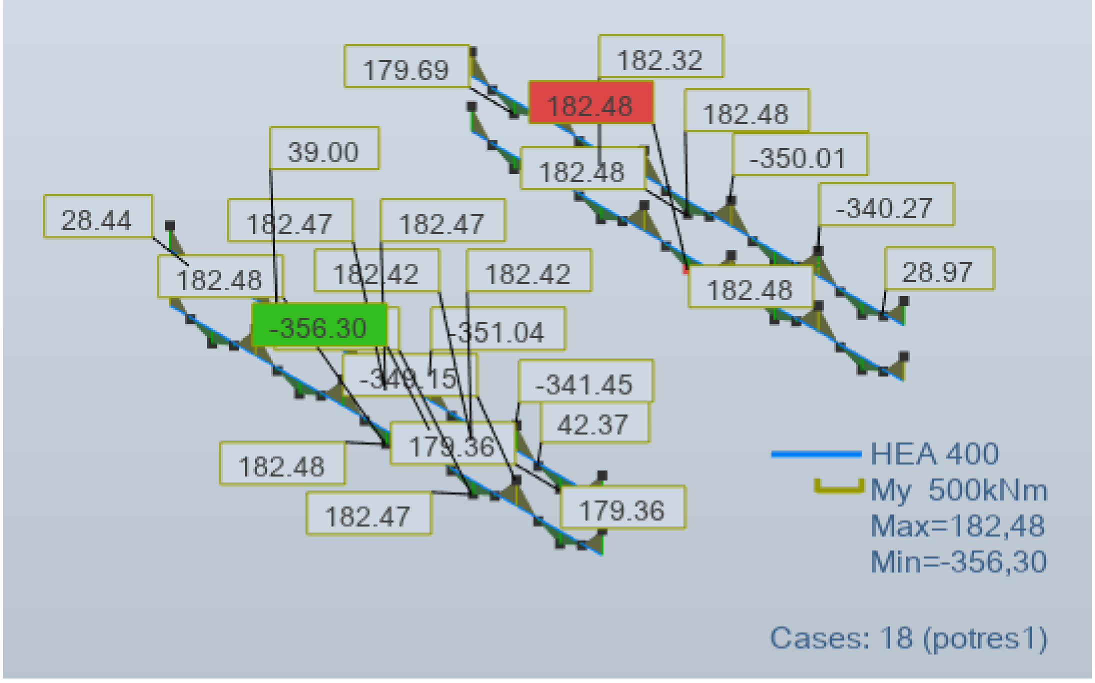
13.5. Proračun stupova

Tablica 21. Pomoćna tablica za izračun omega za proračun stupova

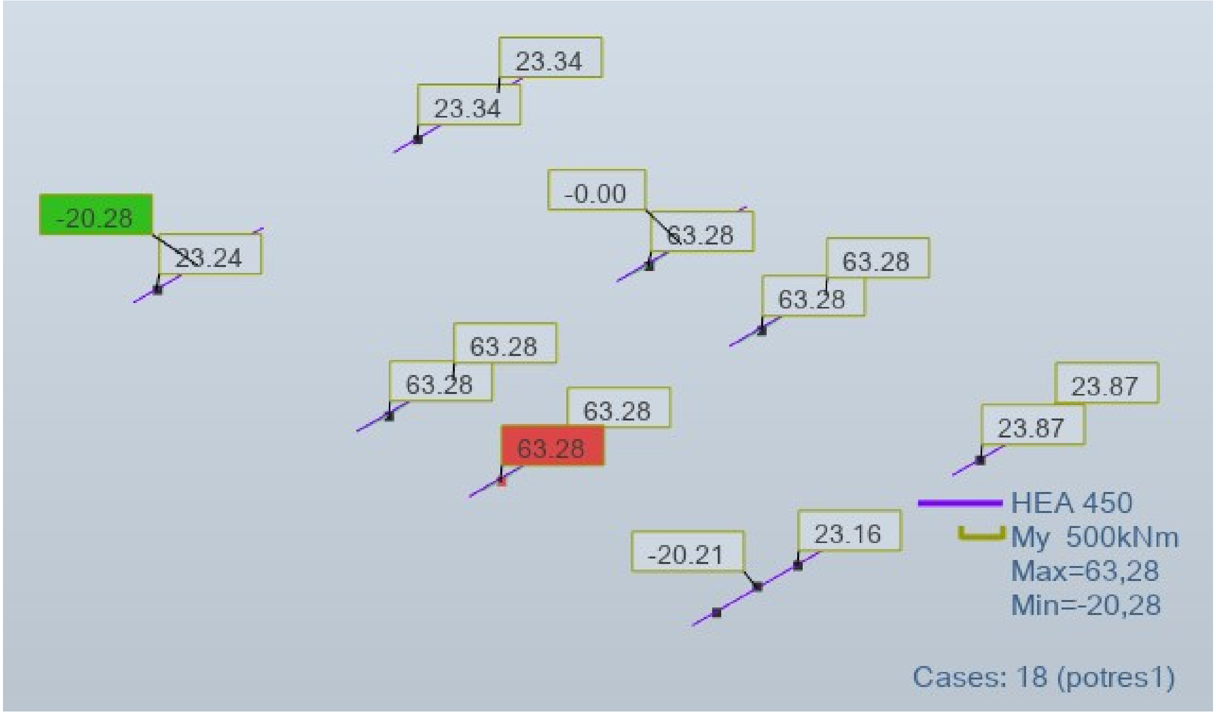
GREDA	HEA 360	HEA 400	HEA 450	HEA 500	HEA 550	HEA 600	HEA 800
$M_{pl,Rd}$	741	910	1142	1402	1641	1899	3088
M_{Ed}	327	356	63	664	72	732	74
$\Omega = \frac{M_{Pl,Rd}}{M_{Ed}}$	2,27	2,56	18,13	2,11-mjerodavno	22,79	2,59	41,73



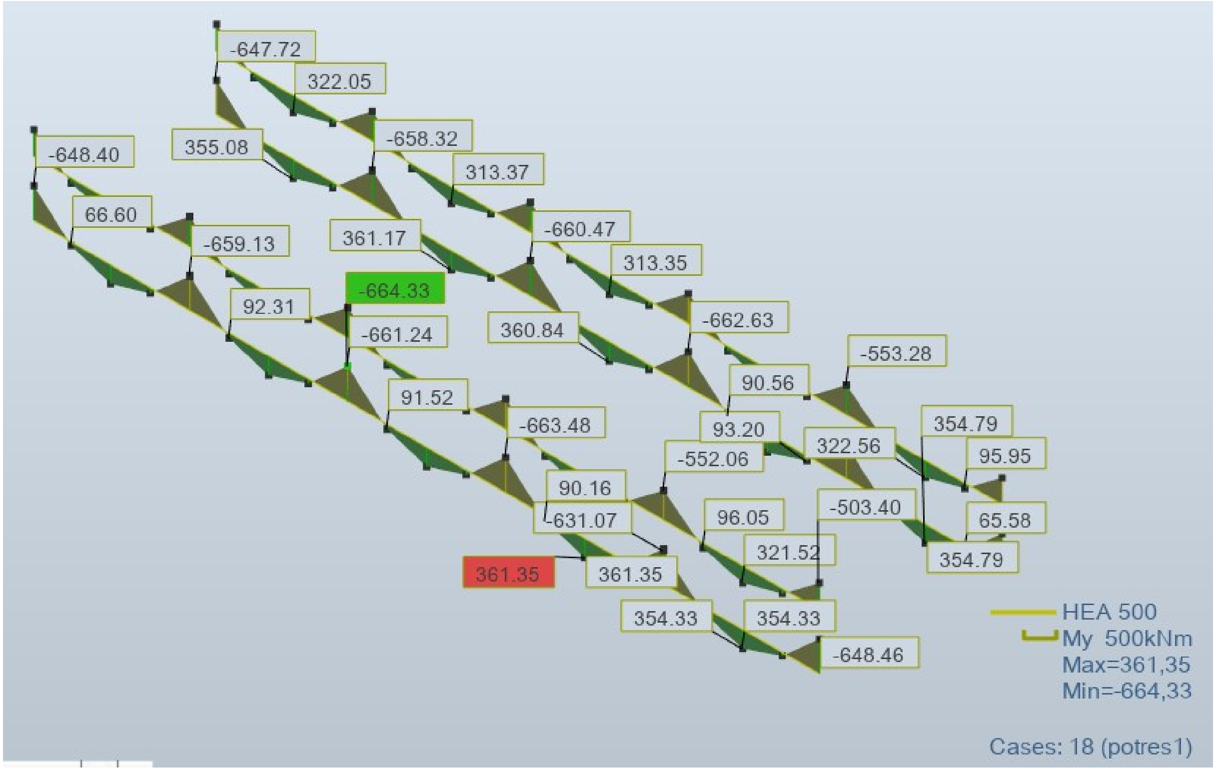
Slika 96. Momentni dijagram grede HEA 360 u potresnoj proračunskoj situaciji



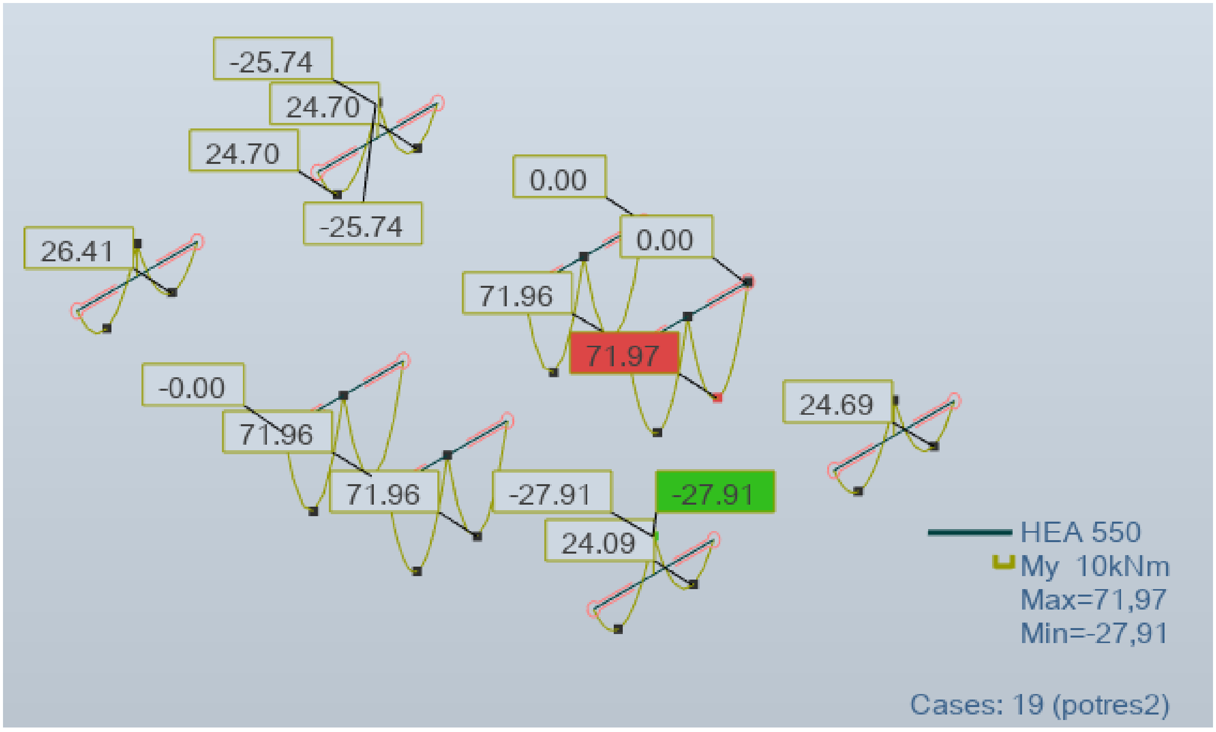
Slika 97. Momentni dijagram grede HEA 400 u potresnoj proračunskoj situaciji



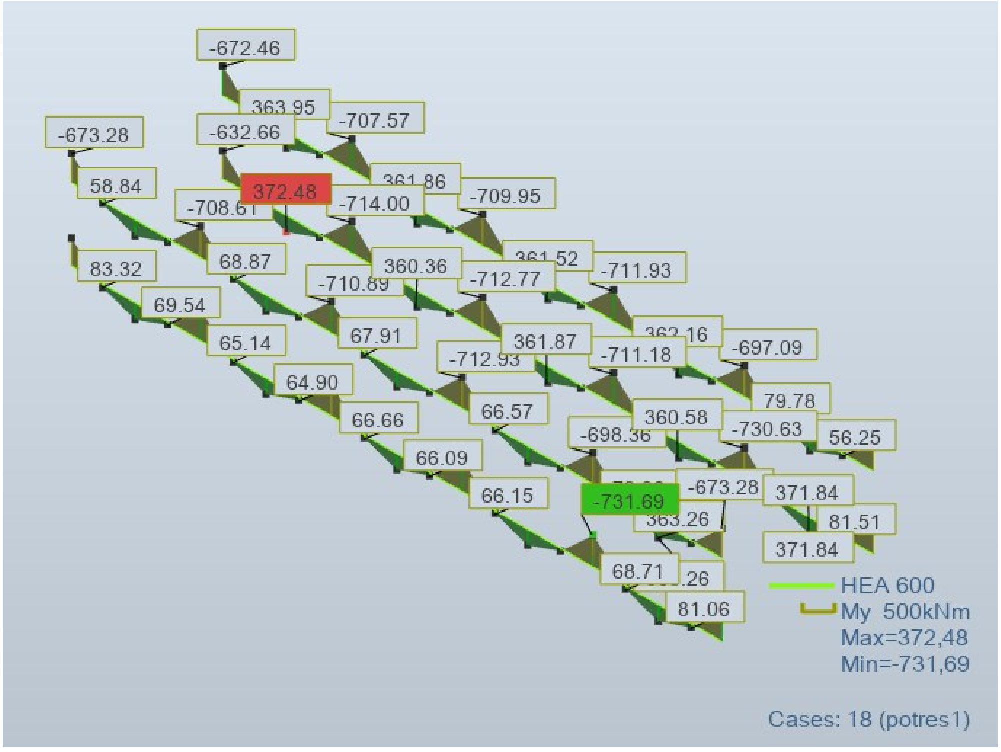
Slika 98. Momentni dijagram grede HEA 450 u potresnoj proračunskoj situaciji



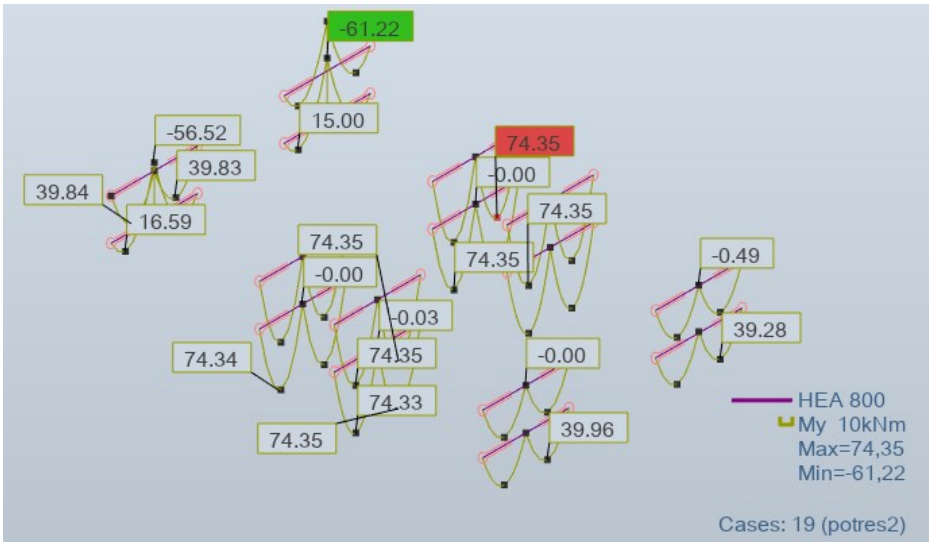
Slika 99. Momentni dijagram grede HEA 500 u potresnoj proračunskoj situaciji



Slika 100. Momentni dijagram grede HEA 550 u potresnoj proračunskoj situaciji



Slika 101. Momentni dijagram grede HEA 600 u potresnoj proračunskoj situaciji

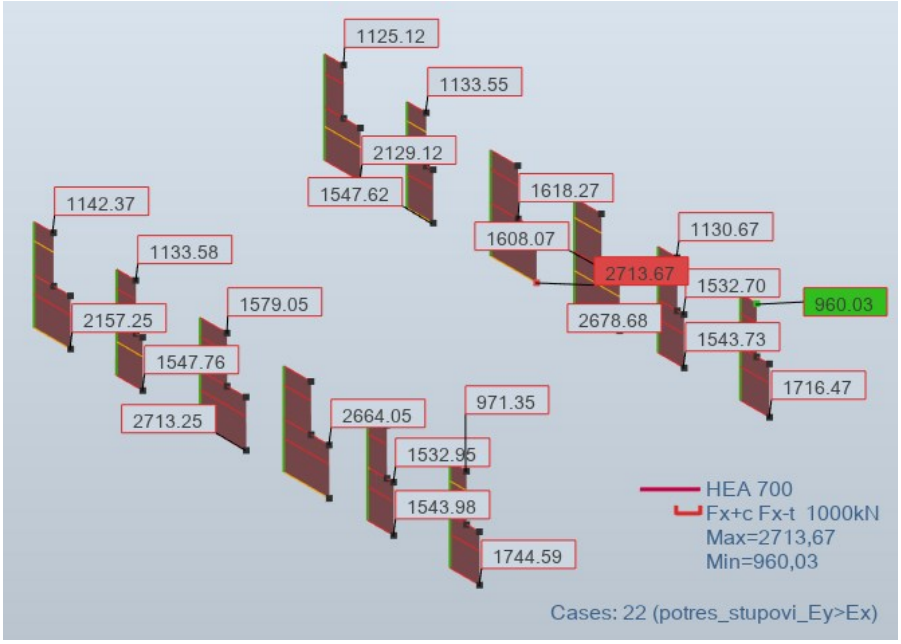


Slika 102. Momentni dijagram grede HEA 800 u potresnoj proračunskoj situaciji

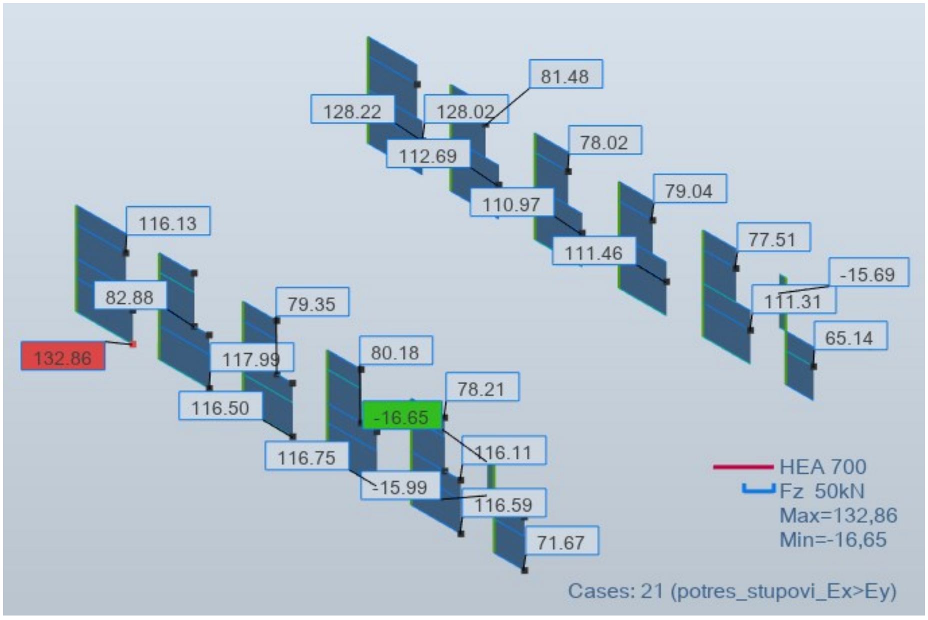
Za potrebe proračuna stupova na potres, napravljene su dvije kombinacije opterećenja u Robotu. Prva kombinacija imena potres_stupovi_Ex>Ey je (1+2+3)*1,0+27*2,90+28*0,87. Druga kombinacija imena potres_stupovi_Ey>Ex je (1+2+3)*1,0+27*0,87+28*2,9.

Koeficijent 2,9 dobiven je kao umnožak $1{,}1 * \gamma_{ov} * \Omega = 1{,}1 * 1{,}25 * 2{,}11 = 2{,}9$, dok je koeficijent 0,87 dobiven kao umnožak $0{,}3 * 1{,}1 * \gamma_{ov} * \Omega = 0{,}3 * 1{,}1 * 1{,}25 * 2{,}11 = 0{,}87$.

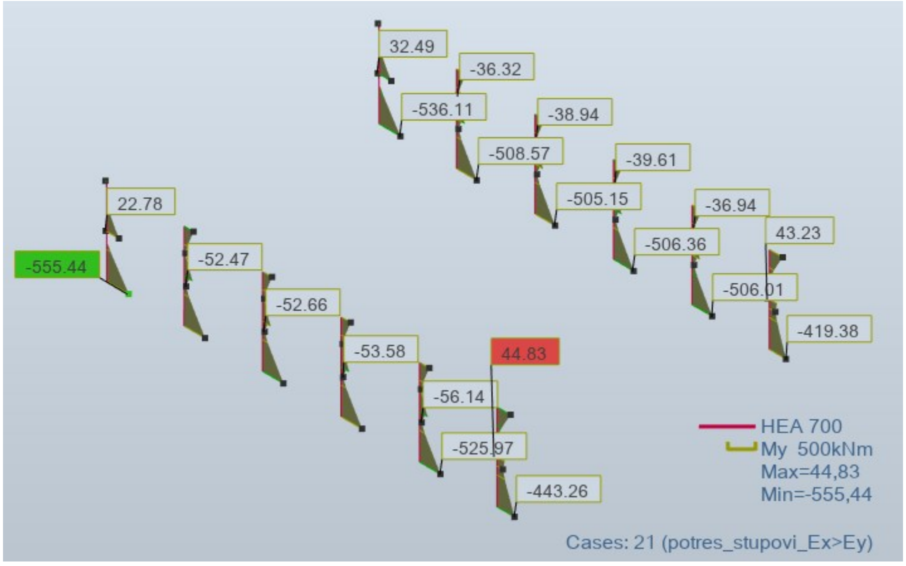
13.5.1. Vanjski stupovi prizemlja i prvog kata- HEA 700



Slika 103. Uzdužna sila stupova HEA 700 u potresnoj proračunskoj situaciji



Slika 104. Poprečna sila stupova HEA 700 u potresnoj proračunskoj situaciji



Slika 105. Moment savijanja stupova HEA 700 u potresnoj proračunskoj situaciji

$N_{Ed} = 2714 \cdot 1{,}19 = 3230\ kN < 10146\ kN$

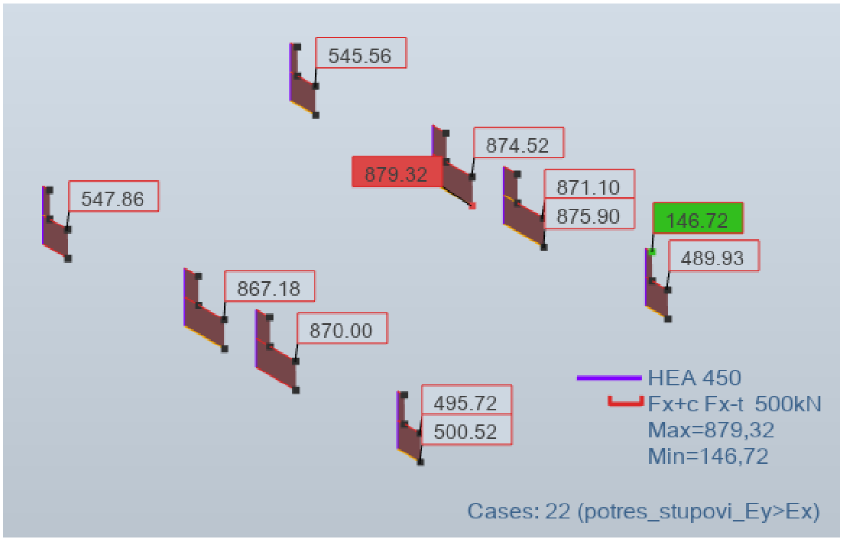
$V_{Ed} = 133 \cdot 1{,}19 = 158\ \ kN < 3786\ kN$

$M_{Ed} = 555 \cdot 1{,}19 = 660\ kNm < 2727\ kNm$

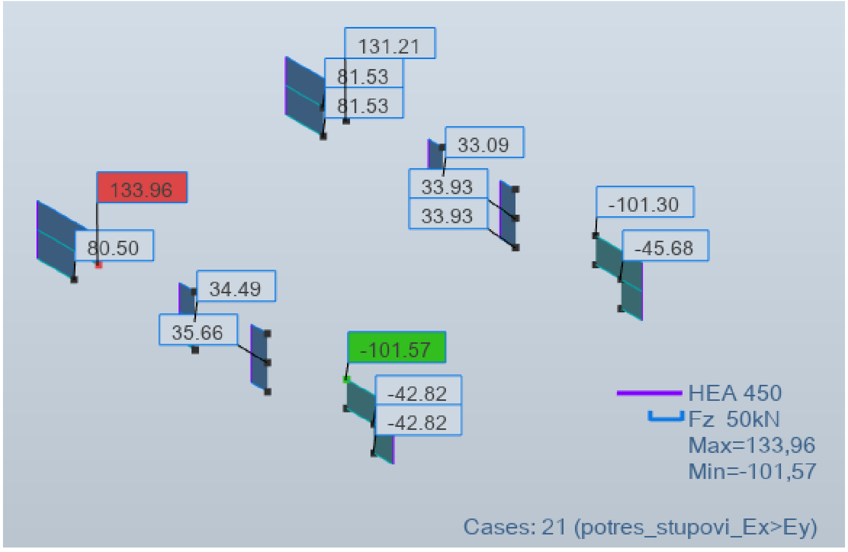
$N_{\mathrm{pl,Rd}}(M_{Ed}) \geq N_{Ed,G} + 1{,}1 \cdot \gamma_{ov} \cdot \Omega \cdot N_{Ed,E}$

$11880966\ kN \geq 2440\ kN$

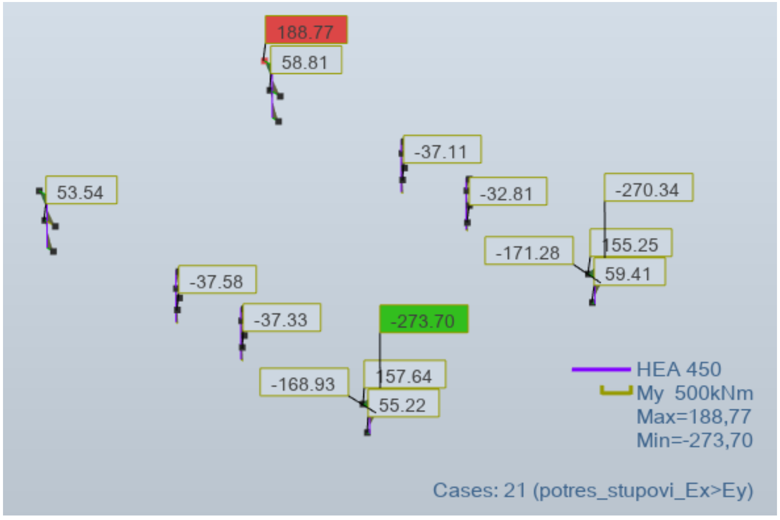
13.5.2. Vanjski stupovi drugog i trećeg kata- HEA 450



Slika 106. Uzdužna sila u stupovima HEA 450 u potresnoj proračunskoj situaciji



Slika 107. Poprečna sila u stupovima HEA 450 u potresnoj proračunskoj situaciji



Slika 108. Moment savijanja u stupovima HEA 450 u potresnoj proračunskoj situaciji

$$N_{Ed} = 879 \cdot 1{,}19 = 1046\ kN < 6320\ kN$$

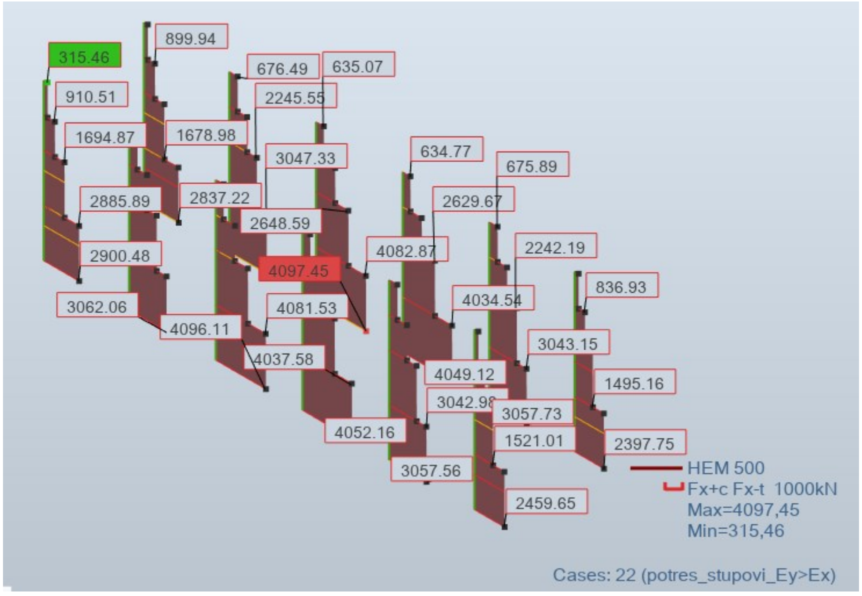
$$V_{Ed} = 134 \cdot 1{,}19 = 160\ \ kN < 2838\ kN$$

$$M_{Ed} = 274 \cdot 1{,}19 = 326\ \ kNm < 1142\ kNm$$

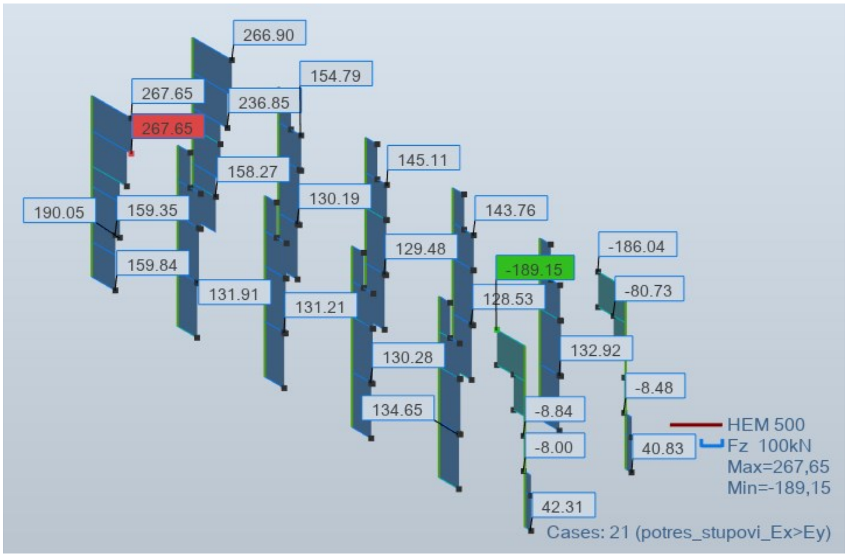
$$N_{\mathrm{pl,Rd}}(M_{Ed}) \geq N_{Ed,G} + 1{,}1 \cdot \gamma_{ov} \cdot \Omega \cdot N_{Ed,E}$$

$$1984480\ kN \geq 816\ kN$$

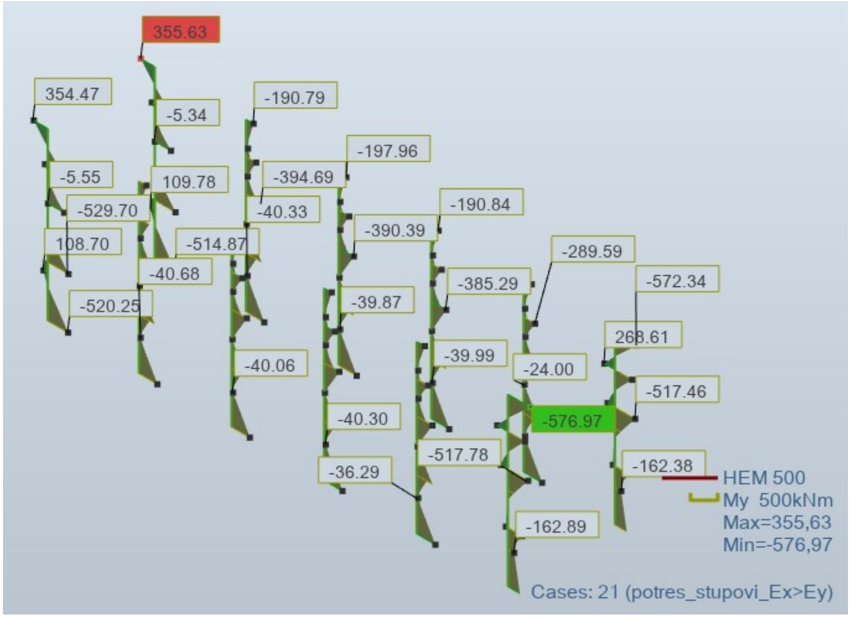
13.5.3. Unutranji stupovi sva četiri kata- HEM 500



Slika 109. Uzdužna sila u stupovima HEM 500 u potresnoj proračunskoj situaciji



Slika 110. Poprečna sila u stupovima HEM 500 u potresnoj proračunskoj situaciji



Slika 111. Moment savijanja u stupovima HEM 500 u potresnoj proračunskoj situaciji

$N_{Ed} = 4097 \cdot 1{,}19 = 4875\ kN < 12222\ kN$

$V_{Ed} = 267 \cdot 1{,}19 = 318\ kN < 5378\ kN$

$M_{Ed} = 578 \cdot 1{,}19 = 688\ kNm < 2518\ kNm$

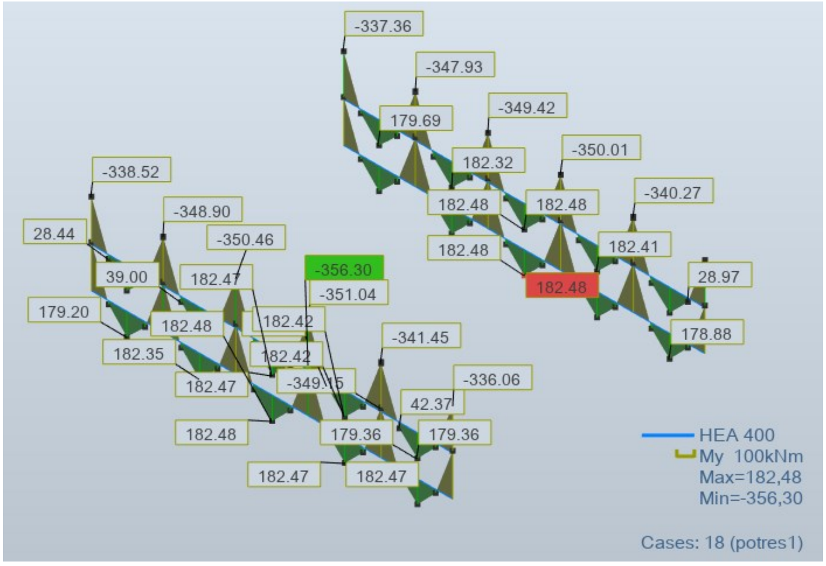
$N_{\mathrm{pl,Rd}}(M_{Ed}) \geq N_{Ed,G} + 1{,}1 \cdot \gamma_{ov} \cdot \Omega \cdot N_{Ed,E}$

$18320778\ kN \geq 3731\ kN$

13.6. Proračun uzdužnih greda

13.6.1. Vanjske uzdužne grede prizemlja i prvog kata- HEA 400

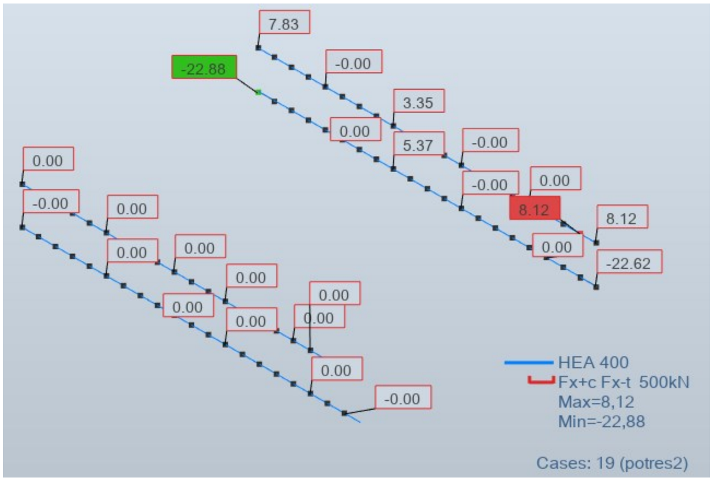
Otpornost na moment savijanja



Slika 112. Moment savijanje grede HEA 400 u potresnoj proračunskoj kombinaciji

$$\frac{M_{Ed}}{M_{el,Rd}} \leq 1{,}0 \qquad \frac{356 \cdot 1{,}19}{821} \leq 1{,}0 \qquad 0{,}52 \leq 1{,}0$$

Otpornost na uzdužnu silu



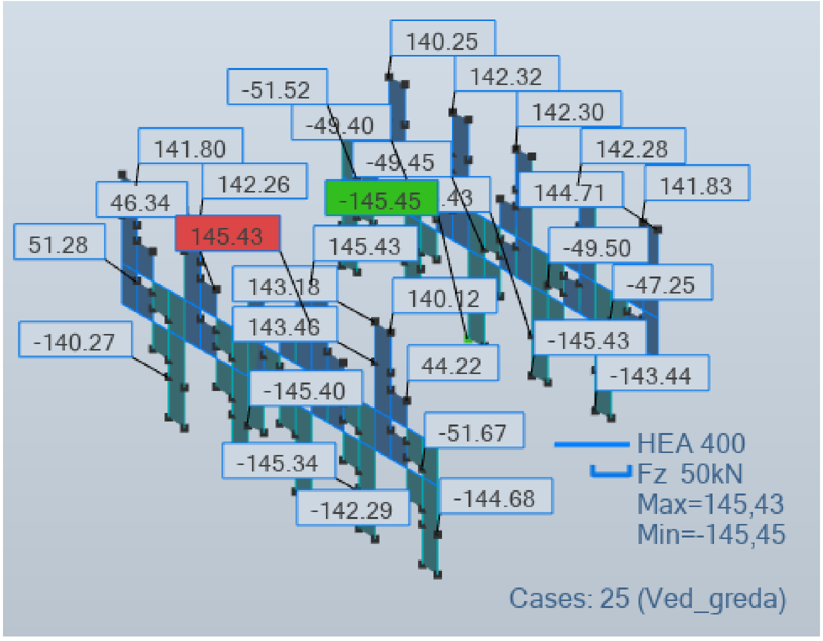
Slika 113. Uzdužna sila u gredi HEA 400 u potresnoj proračunskoj situaciji

$$\frac{N_{Ed}}{N_{el,Rd}} \leq 0{,}15 \qquad \frac{23 \cdot 1{,}19}{5645} \leq 0{,}15 \qquad 0{,}005 \leq 0{,}15$$

<u>Otpornost na poprečnu silu</u>

$$V_{ed} = V_{ed,G} + V_{ed,M} = 146 \cdot 1{,}19 + 182 = 356$$

$$V_{ed.M} = \frac{M_{Pl,Rd,A} + M_{Pl,Rd,B}}{L} = \frac{910 + 910}{10} = 182\ kN$$

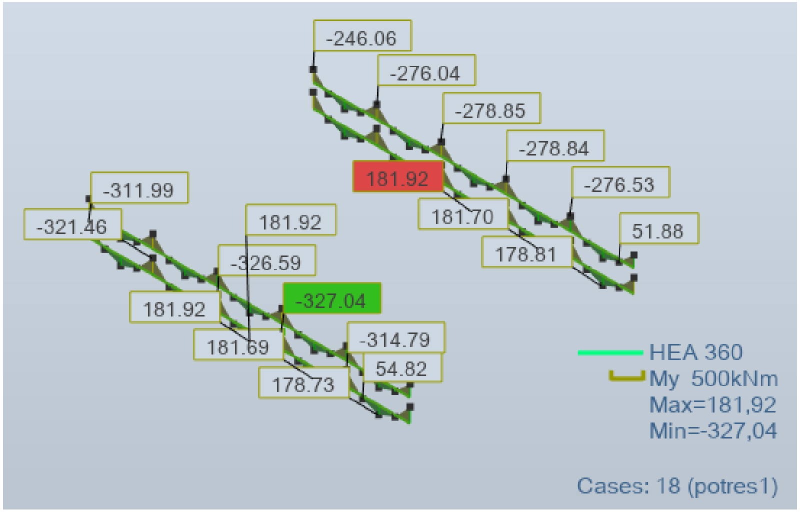


Slika 114. Poprečna sila za nepotresna djelovanja

$$\frac{V_{Ed}}{V_{el,Rd}} \leq 0{,}5 \qquad \frac{356}{1175} \leq 0{,}5 \qquad 0{,}30 \leq 0{,}5$$

13.6.2. Vanjske uzdužne grede drugog i trećeg kata- HEA 360

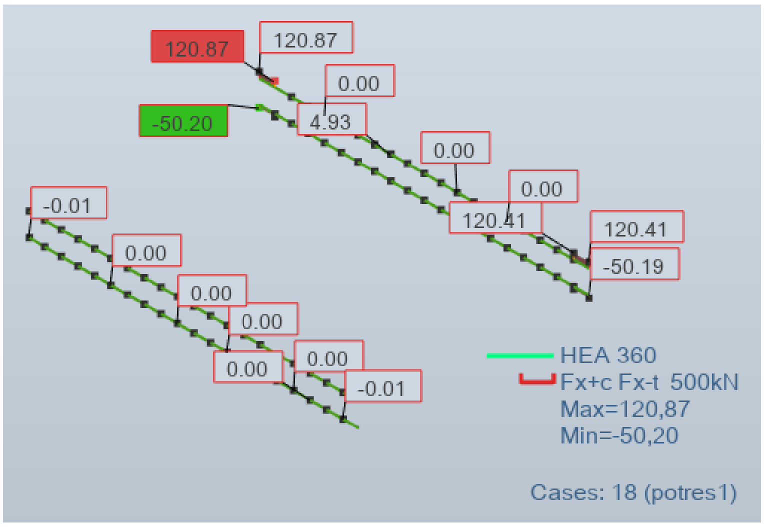
Otpornost na moment savijanja



Slika 115. Moment savijanje grede HEA 360 u potresnoj proračunskoj kombinaciji

$$\frac{M_{Ed}}{M_{el,Rd}} \leq 1{,}0 \qquad \frac{327 \cdot 1{,}19}{671} \leq 1{,}0 \qquad 0{,}58 \leq 1{,}0$$

Otpornost na uzdužnu silu



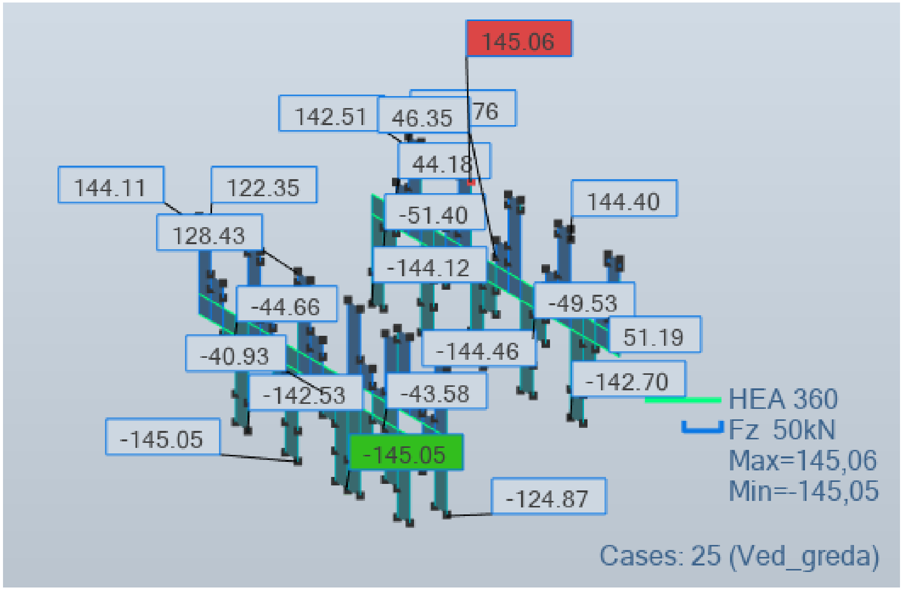
Slika 116. Uzdužna sila u gredi HEA 360 u potresnoj proračunskoj situaciji

$$\frac{N_{Ed}}{N_{el,Rd}} \leq 0{,}15 \qquad \frac{120 \cdot 1{,}19}{5068} \leq 0{,}15 \qquad 0{,}03 \leq 0{,}15$$

Otpornost na poprečnu silu

$$V_{ed} = V_{ed,G} + V_{ed,M} = 145 \cdot 1{,}19 + 148 = 329$$

$$V_{ed.M} = \frac{M_{Pl,Rd,A} + M_{Pl,Rd,B}}{L} = \frac{742 + 742}{10} = 148\ kN$$

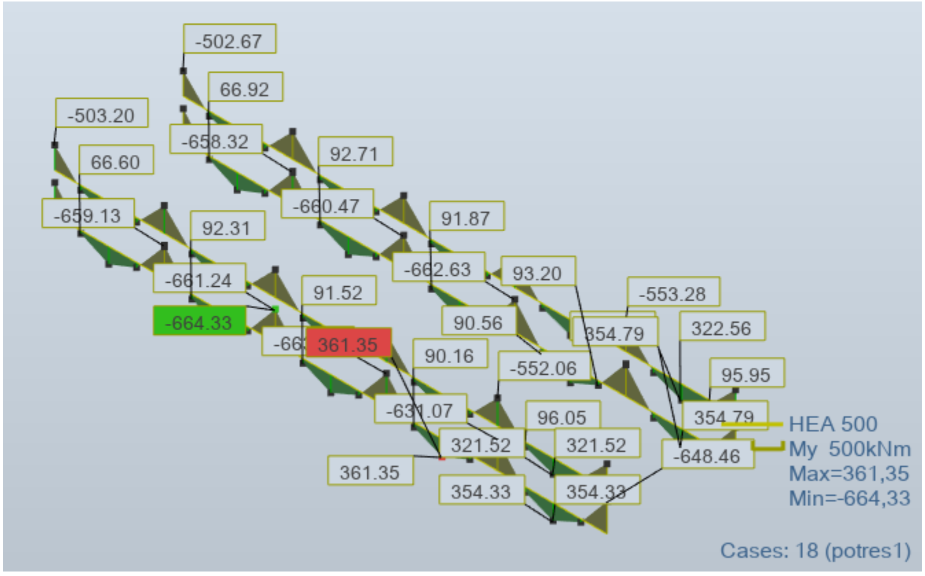


Slika 117. Poprečna sila za nepotresna djelovanja

$$\frac{V_{Ed}}{V_{el,Rd}} \leq 0{,}5 \qquad \frac{329}{1003} \leq 0{,}5 \qquad 0{,}33 \leq 0{,}5$$

13.6.3. Unutarnje uzdužne grede prizemlja i prvog kata- HEA 500

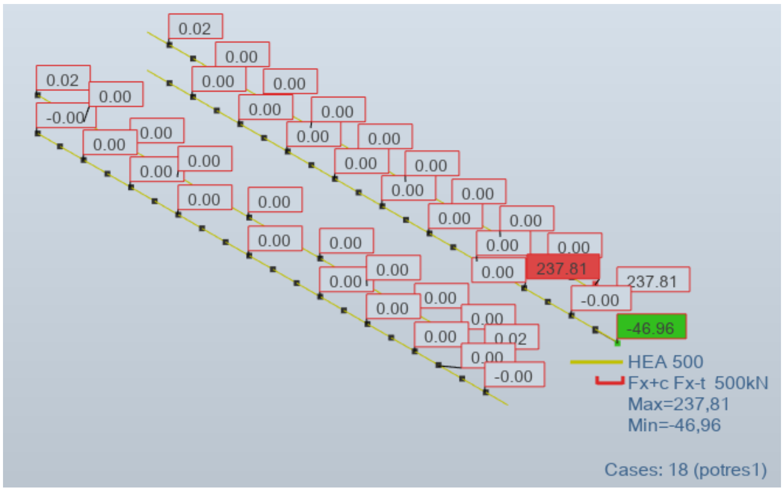
<u>Otpornost na moment savijanja</u>



Slika 118. Moment savijanja grede HEA 500 u potresnoj proračunskoj situaciji

$$\frac{M_{Ed}}{M_{el,Rd}} \leq 1{,}0 \qquad \frac{664 \cdot 1{,}19}{1260} \leq 1{,}0 \qquad 0{,}63 \leq 1{,}0$$

<u>Otpornost na uzdužnu silu</u>



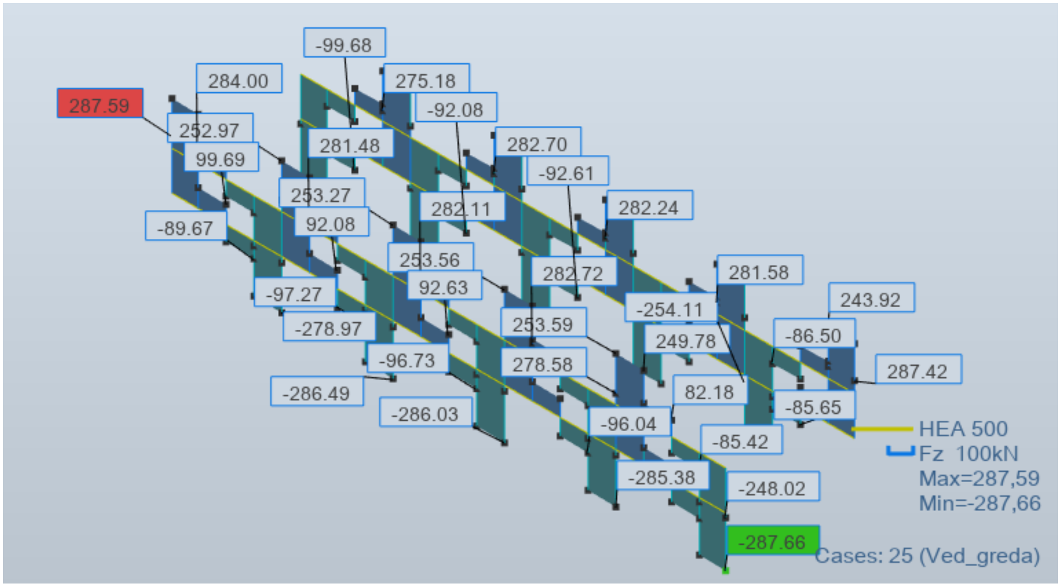
Slika 119. Uzdužna sila u gredi HEA 500 u potresnoj proračunskoj situaciji

$$\frac{N_{Ed}}{N_{el,Rd}} \leq 0{,}15 \qquad \frac{237 \cdot 1{,}19}{7013} \leq 0{,}15 \qquad 0{,}04 \leq 0{,}15$$

Otpornost na poprečnu silu

$$V_{ed} = V_{ed,G} + V_{ed,M} = 288 \cdot 1{,}19 + 380 = 723$$

$$V_{ed.M} = \frac{M_{Pl,Rd,A} + M_{Pl,Rd,B}}{L} = \frac{1900 + 1900}{10} = 380\ kN$$

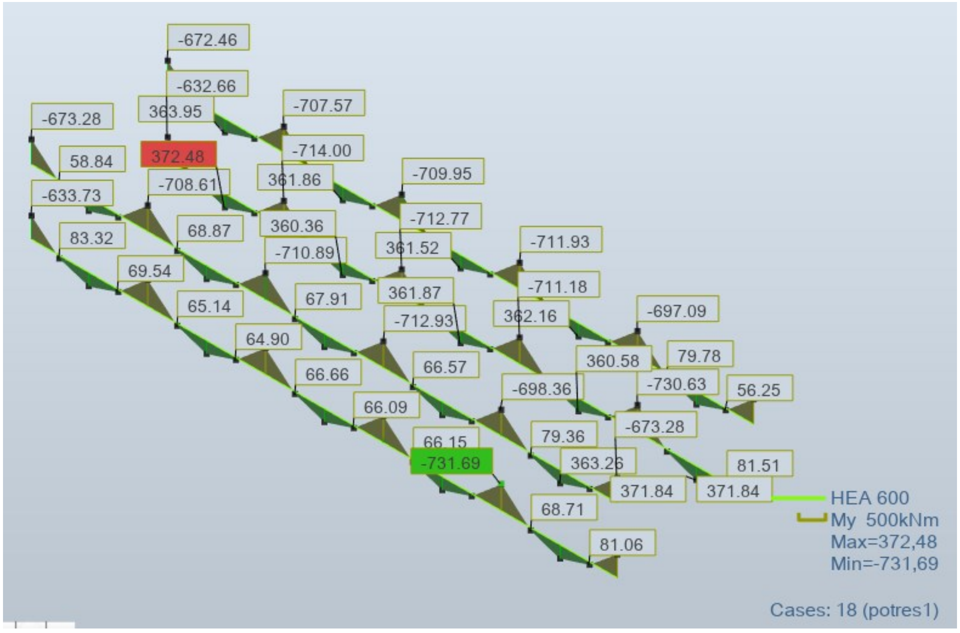


Slika 120. Poprečna sila za nepotresnu kombinaciju

$$\frac{V_{Ed}}{V_{el,Rd}} \leq 0{,}5 \qquad \frac{723}{1910} \leq 0{,}5 \qquad 0{,}38 \leq 0{,}5$$

13.6.4. Unutarnje uzdužne grede drugog i trećeg kata- HEA 600

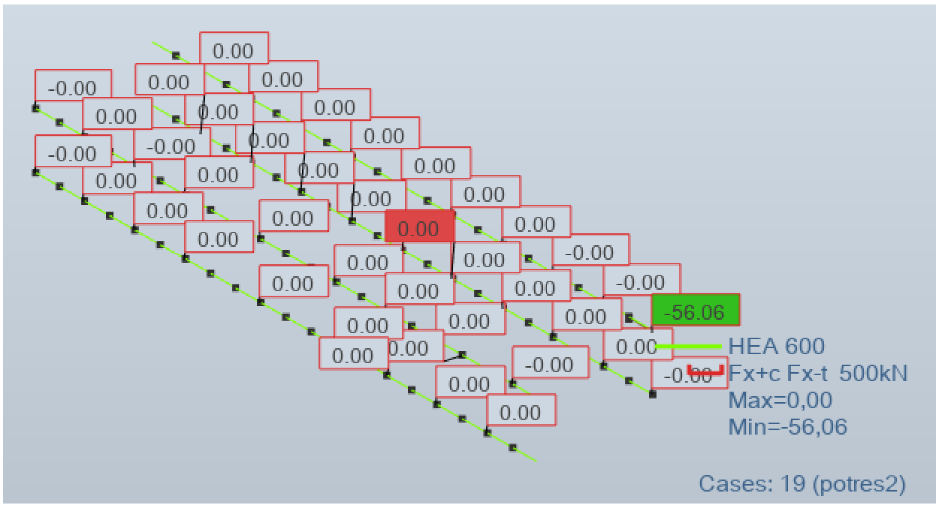
Otpornost na moment savijanja



Slika 121. Moment savijanja grede HEA 600 u potresnoj proračunskoj situaciji

$$\frac{M_{Ed}}{M_{el,Rd}} \leq 1{,}0 \qquad \frac{732 \cdot 1{,}19}{1699} \leq 1{,}0 \qquad 0{,}51 \leq 1{,}0$$

Otpornost na uzdužnu silu



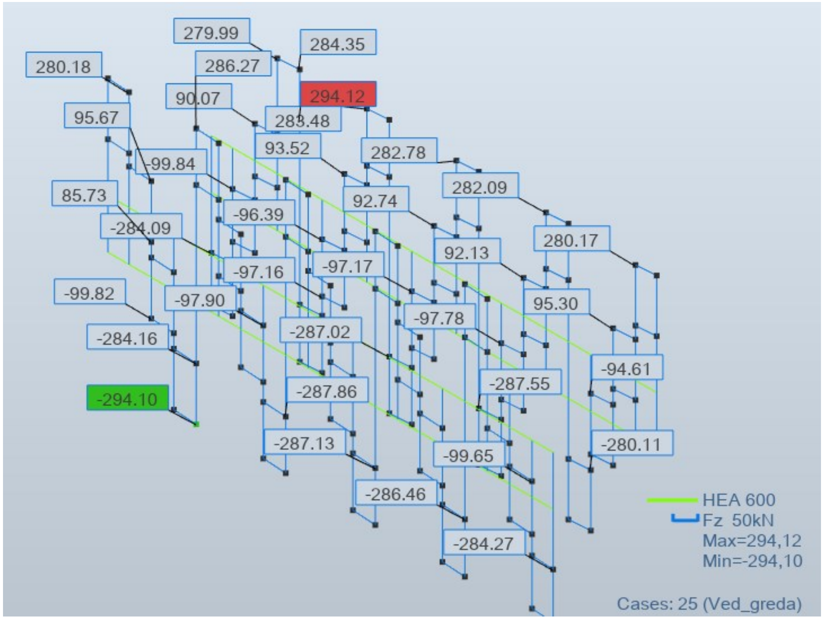
Slika 122. Uzdužna sila u hredi HEA 600 u potresnoj proračunskoj situaciji

$$\frac{N_{Ed}}{N_{el,Rd}} \leq 0{,}15 \qquad \frac{56 \cdot 1{,}19}{8039} \leq 0{,}15 \qquad 0{,}01 \leq 0{,}15$$

Otpornost na poprečnu silu

$$V_{ed} = V_{ed,G} + V_{ed,M} = 294 \cdot 1{,}19 + 280 = 630\ kN$$

$$V_{ed.M} = \frac{M_{Pl,Rd,A} + M_{Pl,Rd,B}}{L} = \frac{1402 + 1402}{10} = 280\ kN$$



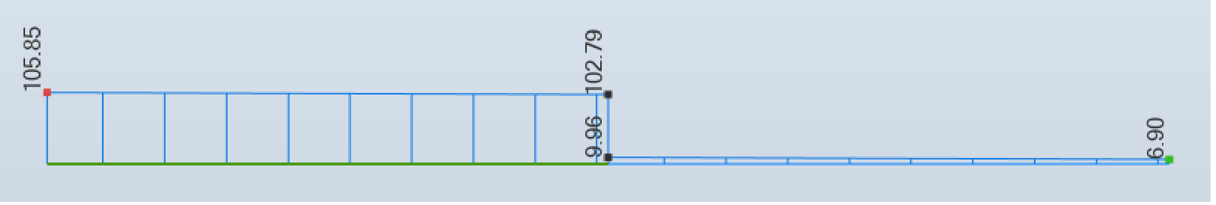
Slika 123. Poprečna sila za nepotresnu kombinaciju

$$\frac{V_{Ed}}{V_{el,Rd}} \leq 0{,}5 \qquad \frac{630}{1531} \leq 0{,}5 \qquad 0{,}41 \leq 0{,}5$$

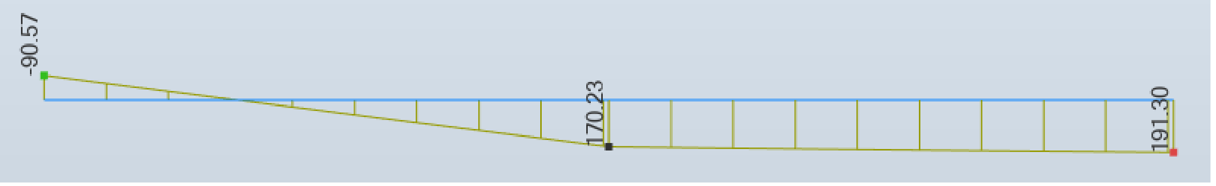
14 PRORAČUN PRIKLJUČKA

14.1. Detalj A

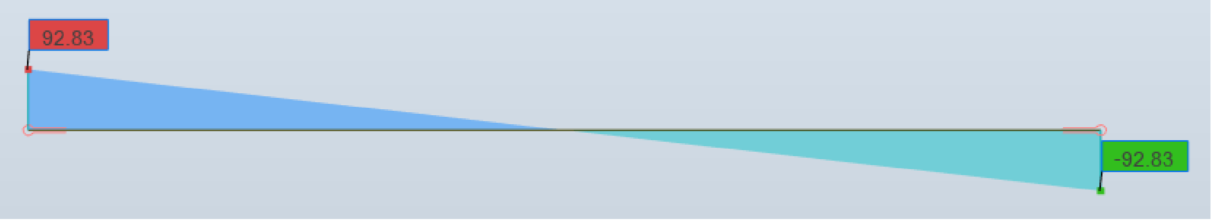
Detalj A je detalj spajanja spregnutog nosača na glavni nosač.



Slika 124. Uzdužna sila glavnog nosača



Slika 125. Moment savijanja glavnog nosača



Slika 126. Uzdužna sila u spregnutom nosaču

Project:
Project no:
Author:

Material

Steel S 355

Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

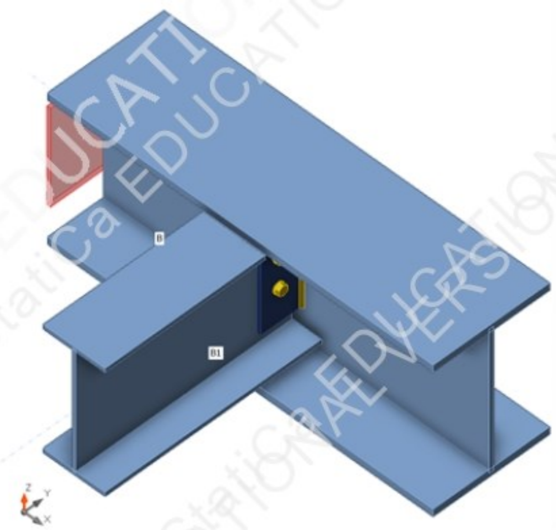
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
B	3 - HEA400	0,0	0,0	0,0	0	0	0
B1	4 - IPE330	-90,0	0,0	0,0	0	0	30

Supports and forces

Name	Support	Forces in	X [mm]
B / begin	N-Vy-Vz-Mx-My-Mz	Node	0
B / end		Node	0
B1 / end		Bolts	66



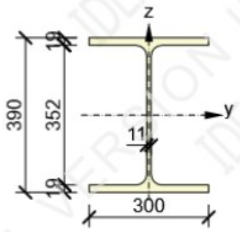
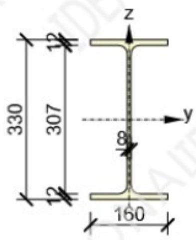
Cross-sections

Name	Material
3 - HEA400	S 355
4 - IPE330	S 355

Project:
Project no:
Author:

IDEA StatiCa® Calculate yesterday's estimates

Cross-sections

Name	Material	Drawing
3 - HEA400	S 355	
4 - IPE330	S 355	

Bolts

Name	Bolt assembly	Diameter [mm]	f_u [MPa]	Gross area [mm^2]
M16 8.8	M16 8.8	16	800,0	201

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B / Begin	0,0	0,0	103,0	0,0	170,0	0,0
	B / End	0,0	0,0	103,0	0,0	170,0	0,0
	B1 / End	0,0	0,0	-93,0	0,0	0,0	0,0

Unbalanced forces

Name	X [kN]	Y [kN]	Z [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	0,0	0,0	113,0	6,1	340,0	0,0

Check

Summary

Name	Value	Check status
Analysis	100,0%	OK
Plates	0,0 < 5,0%	OK
Bolts	84,5 < 100%	OK
Welds	98,1 < 100%	OK
Buckling	16,74	

Plates

Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
B-bfl 1	19,0	LE1	118,5	0,0	0,0	OK
B-tfl 1	19,0	LE1	119,0	0,0	0,0	OK
B-w 1	11,0	LE1	239,0	0,0	0,0	OK
B1-bfl 1	11,5	LE1	69,6	0,0	0,0	OK
B1-tfl 1	11,5	LE1	69,3	0,0	0,0	OK
B1-w 1	7,5	LE1	348,3	0,0	25,7	OK
FP1	10,0	LE1	278,1	0,0	25,7	OK

Design data

Material	f_y [MPa]	ε_{lim} [%]
S 355	355,0	5,0

Project:
Project no:
Author:

Detailed result for B-bfl 1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355,0 MPa

Where:

$f_{yk} = 355{,}0$ MPa – characteristic yield strength

$\gamma_{M0} = 1{,}00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for B-tfl 1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355,0 MPa

Where:

$f_{yk} = 355{,}0$ MPa – characteristic yield strength

$\gamma_{M0} = 1{,}00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for B-w 1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355,0 MPa

Where:

$f_{yk} = 355{,}0$ MPa – characteristic yield strength

$\gamma_{M0} = 1{,}00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for B1-bfl 1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355,0 MPa

Where:

$f_{yk} = 355{,}0$ MPa – characteristic yield strength

$\gamma_{M0} = 1{,}00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for B1-tfl 1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355,0 MPa

Where:

$f_{yk} = 355{,}0$ MPa – characteristic yield strength

$\gamma_{M0} = 1{,}00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for B1-w 1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355,0 MPa

Where:

$f_{yk} = 355{,}0$ MPa – characteristic yield strength

$\gamma_{M0} = 1{,}00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for FP1
Design values used in the analysis

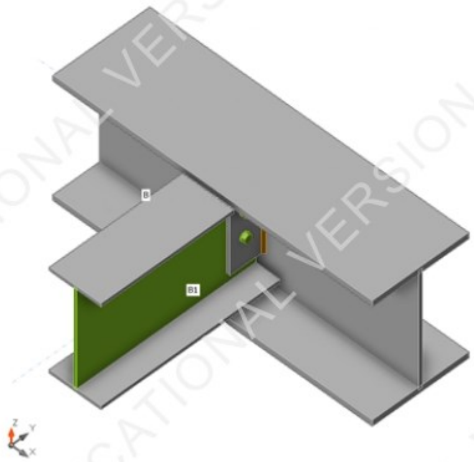
$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355,0 MPa

Where:

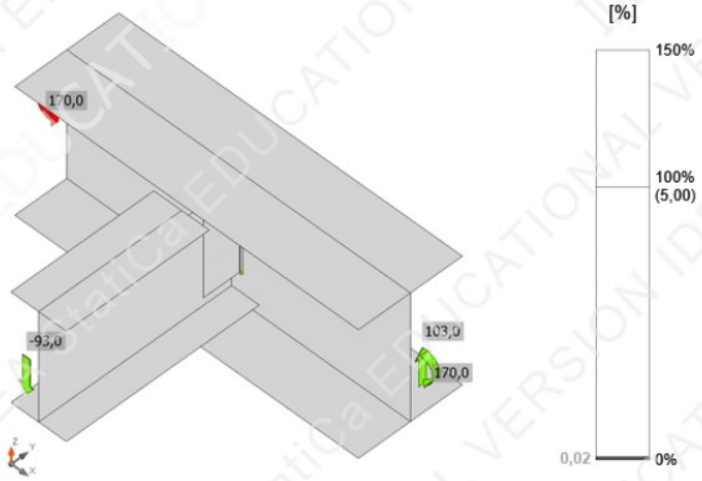
$f_{yk} = 355{,}0$ MPa – characteristic yield strength

$\gamma_{M0} = 1{,}00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

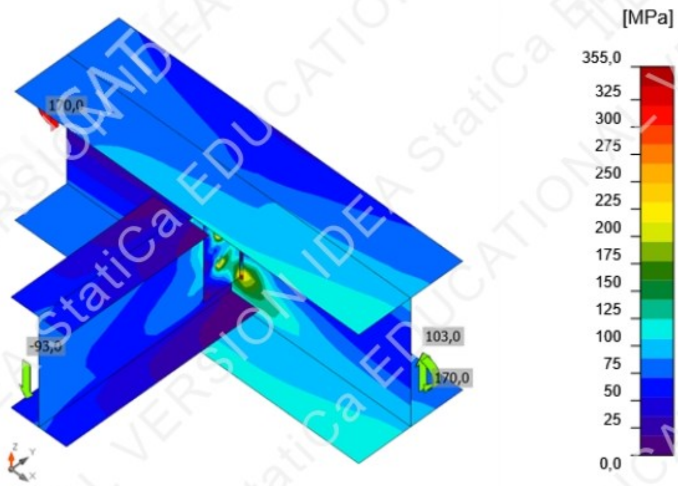
Project:
Project no:
Author:



Overall check, LE1



Strain check, LE1



Equivalent stress, LE1

Project:
Project no:
Author:

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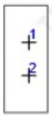
Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B1	M16 8.8 - 1	LE1	9,9	46,2	117,6	11,0	76,6	84,5	OK	OK
	B2	M16 8.8 - 1	LE1	2,9	46,8	117,6	3,3	77,6	79,9	OK	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M16 8.8 - 1	90,4	140,6	60,3

Detailed result for B1

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 90,4 kN ≥ $F_{t,Ed} =$ 9,9 kN

Where:

$k_2 = 0{,}90$ – Factor

$f_{ub} = 800{,}0$ MPa – Ultimate tensile strength of the bolt

$A_s = 157$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1{,}25$ – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 140,6 kN ≥ $F_{t,Ed} =$ 9,9 kN

Where:

$d_m = 25$ mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p = 8$ mm – Plate thickness

$f_u = 490{,}0$ MPa – Ultimate strength

$\gamma_{M2} = 1{,}25$ – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v\, f_{ub}\, A}{\gamma_{M2}} =$ 60,3 kN ≥ $F_{v,Ed} =$ 46,2 kN

Where:

$\beta_p = 1{,}00$ – Reduction factor for packing

$\alpha_v = 0{,}60$ – Reduction factor for shear stress

$f_{ub} = 800{,}0$ MPa – Ultimate tensile strength of the bolt

$A = 157$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1{,}25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\, \alpha_b\, f_u\, dt}{\gamma_{M2}} =$ 117,6 kN ≥ $F_{b,Ed} =$ 46,2 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2{,}50$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 1{,}00$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 45$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = \infty$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 18$ mm – Bolt hole diameter

$e_1 = 86$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = \infty$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 800{,}0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490{,}0$ MPa – Ultimate strength of the plate

$d = 16$ mm – Nominal diameter of the fastener

$t = 8$ mm – Thickness of the plate

$\gamma_{M2} = 1{,}25$ – Safety factor

Project:
Project no:
Author:

IDEA StatiCa® Calculate yesterday's estimates

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0,11 ≤ 1,0

Where:

$F_{t,Ed} = 9{,}9$ kN – Tensile force

$F_{t,Rd} = 90{,}4$ kN – Tension resistance

$B_{p,Rd} = 140{,}6$ kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0,77 ≤ 1,0

Where:

$F_{v,Ed} = 46{,}2$ kN – Shear force (in decisive shear plane)

$F_{v,Rd} = 60{,}3$ kN – Shear resistance

$F_{b,Ed} = 46{,}2$ kN – Bearing force (for decisive plate)

$F_{b,Rd} = 117{,}6$ kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1{,}4\, F_{t,Rd}} =$ 0,84 ≤ 1,0

Where:

$F_{v,Ed} = 46{,}2$ kN – Shear force (in decisive shear plane)

$F_{v,Rd} = 60{,}3$ kN – Shear resistance

$F_{t,Ed} = 9{,}9$ kN – Tensile force

$F_{t,Rd} = 90{,}4$ kN – Tension resistance

Detailed result for B2

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 90,4 kN ≥ $F_{t,Ed} =$ 2,9 kN

Where:

$k_2 = 0{,}90$ – Factor

$f_{ub} = 800{,}0$ MPa – Ultimate tensile strength of the bolt

$A_s = 157$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1{,}25$ – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 140,6 kN ≥ $F_{t,Ed} =$ 2,9 kN

Where:

$d_m = 25$ mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p = 8$ mm – Plate thickness

$f_u = 490{,}0$ MPa – Ultimate strength

$\gamma_{M2} = 1{,}25$ – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\, \alpha_v\, f_{ub} A}{\gamma_{M2}} =$ 60,3 kN ≥ $F_{v,Ed} =$ 46,8 kN

Where:

$\beta_p = 1{,}00$ – Reduction factor for packing

$\alpha_v = 0{,}60$ – Reduction factor for shear stress

$f_{ub} = 800{,}0$ MPa – Ultimate tensile strength of the bolt

$A = 157$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1{,}25$ – Safety factor

Project:
Project no:
Author:

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \, \alpha_b \, f_u \, d t}{\gamma_{M2}} =$ 117,6 kN ≥ $F_{b,Ed} =$ 46,8 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2,50 – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 1,00 – Factor for end distance and bolt spacing in direction of load transfer

$e_2 =$ 45 mm – Distance to the plate edge perpendicular to the shear force

$p_2 =$ ∞ mm – Distance between bolts perpendicular to the shear force

$d_0 =$ 18 mm – Bolt hole diameter

$e_1 =$ 166 mm – Distance to the plate edge in the direction of the shear force

$p_1 =$ 80 mm – Distance between bolts in the direction of the shear force

$f_{ub} =$ 800,0 MPa – Ultimate tensile strength of the bolt

$f_u =$ 490,0 MPa – Ultimate strength of the plate

$d =$ 16 mm – Nominal diameter of the fastener

$t =$ 8 mm – Thickness of the plate

$\gamma_{M2} =$ 1,25 – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0,03 ≤ 1,0

Where:

$F_{t,Ed} =$ 2,9 kN – Tensile force

$F_{t,Rd} =$ 90,4 kN – Tension resistance

$B_{p,Rd} =$ 140,6 kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0,78 ≤ 1,0

Where:

$F_{v,Ed} =$ 46,8 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 60,3 kN – Shear resistance

$F_{b,Ed} =$ 46,8 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 117,6 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1,4 \, F_{t,Rd}} =$ 0,80 ≤ 1,0

Where:

$F_{v,Ed} =$ 46,8 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 60,3 kN – Shear resistance

$F_{t,Ed} =$ 2,9 kN – Tensile force

$F_{t,Rd} =$ 90,4 kN – Tension resistance

Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_\perp$ [MPa]	$\tau_\perp$ [MPa]	$\tau_{\|\|}$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
B-w 1	FP1	◢5,0◣	259	LE1	427,3	0,3	-92,9	-95,1	221,2	98,1	77,9	OK	OK
		◢5,0◣	259	LE1	427,4	0,3	-122,6	120,4	-203,4	98,1	80,2	OK	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	490,0	0,90	435,6	352,8

Detailed result for B-w 1 / FP1 - 1

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435,6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_{\|}^2)]^{0.5} =$ 427,3 MPa

$\sigma_{\perp,Rd} = 0,9 \, f_u \, / \, \gamma_{M2} =$ 352,8 MPa ≥ $|\sigma_\perp| =$ 121,3 MPa

where:

$f_u =$ 490,0 MPa – Ultimate strength

$\beta_w =$ 0,90 – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} =$ 1,25 – Safety factor

Project:
Project no:
Author:

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}};\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0,98 ≤ 1,0

Where:

$\sigma_{w,Ed} =$ 427,3 MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} =$ 435,6 MPa – Equivalent stress resistance

$\sigma_\perp =$ 121,3 MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} =$ 352,8 MPa – Perpendicular stress resistance

Detailed result for B-w 1 / FP1 - 2

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435,6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 427,4 MPa

$\sigma_{\perp,Rd} = 0,9\, f_u\ /\ \gamma_{M2} =$ 352,8 MPa ≥ $|\sigma_\perp| =$ 167,3 MPa

where:

$f_u =$ 490,0 MPa – Ultimate strength

$\beta_w =$ 0,90 – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} =$ 1,25 – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}};\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0,98 ≤ 1,0

Where:

$\sigma_{w,Ed} =$ 427,4 MPa – Maximum normal stress transverse to the axis of the weld

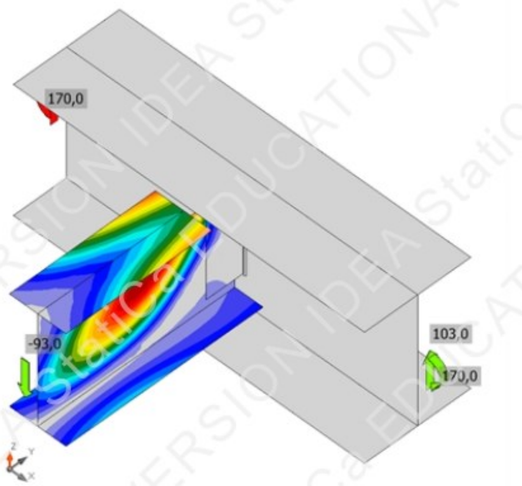
$\sigma_{w,Rd} =$ 435,6 MPa – Equivalent stress resistance

$\sigma_\perp =$ 167,3 MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} =$ 352,8 MPa – Perpendicular stress resistance

Buckling

Loads	Shape	Factor [-]
LE1	1	16,74
	2	18,67
	3	23,82
	4	24,88
	5	25,92
	6	29,07



First buckling mode shape, LE1

Project:
Project no:
Author:

Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds Throat thickness [mm]	Length [mm]	Bolts	Nr.
FP1	P10,0x105,0-260,0 (S 355)		1	Double fillet: 5,0	260,0	M16 8.8	2

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Double fillet	S 355	5,0	7,1	260,0

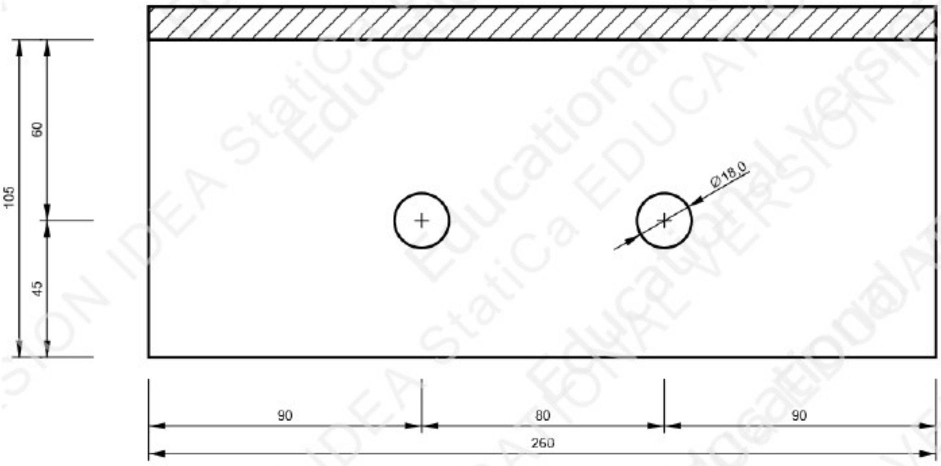
Bolts

Name	Grip length [mm]	Count
M16 8.8	18	2

Drawing

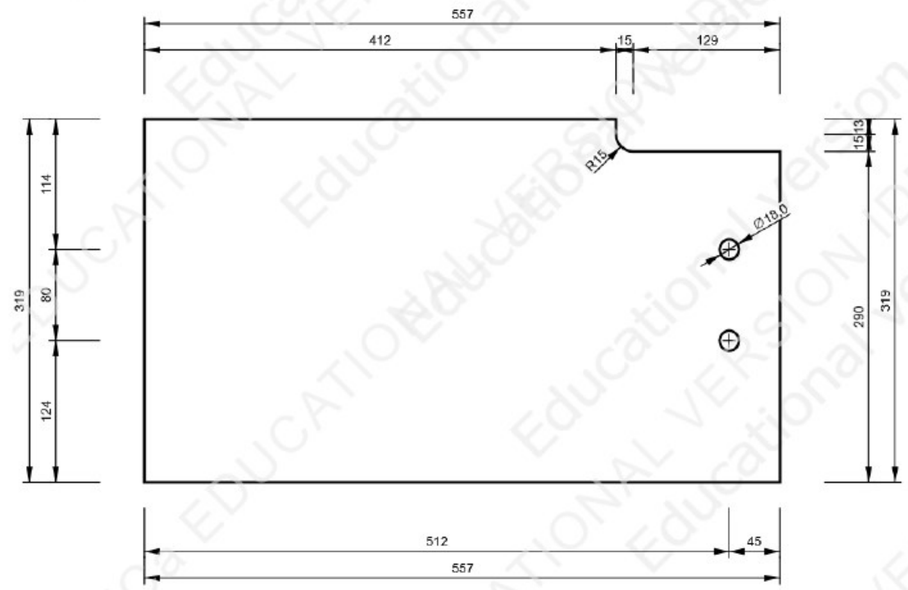
FP1

P10,0x260-105 (S 355)



Project:
Project no:
Author:

B1, IPE330 - Web 1:



Symbol explanation

Symbol	Explanation
t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain
$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4
T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\perp}$	Shear stress perpendicular to weld axis
$\tau_{\parallel}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
◢	Fillet weld
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2

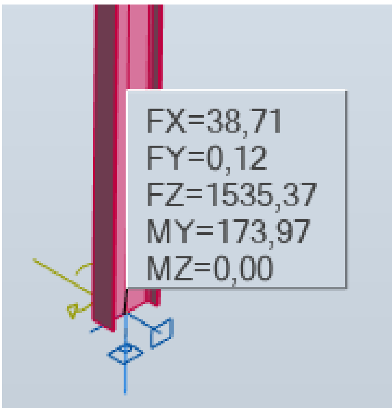
Project:
Project no:
Author:

Code settings

Item	Value	Unit	Reference
Safety factor γ_{M0}	1,00	-	EN 1993-1-1: 6.1
Safety factor γ_{M1}	1,00	-	EN 1993-1-1: 6.1
Safety factor γ_{M2}	1,25	-	EN 1993-1-1: 6.1
Safety factor γ_{M3}	1,25	-	EN 1993-1-8: 2.2
Safety factor γ_{C}	1,50	-	EN 1992-1-1: 2.4.2.4
Safety factor γ_{Inst}	1,20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0,67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0,10	-	
Friction coefficient - concrete	0,25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0,30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0,05	-	EN 1993-1-5
Detailing	Yes		
Distance between bolts [d]	2,20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1,20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	Yes		CIDECT DG 1, 3 - 1.1
Local deformation limit	0,03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

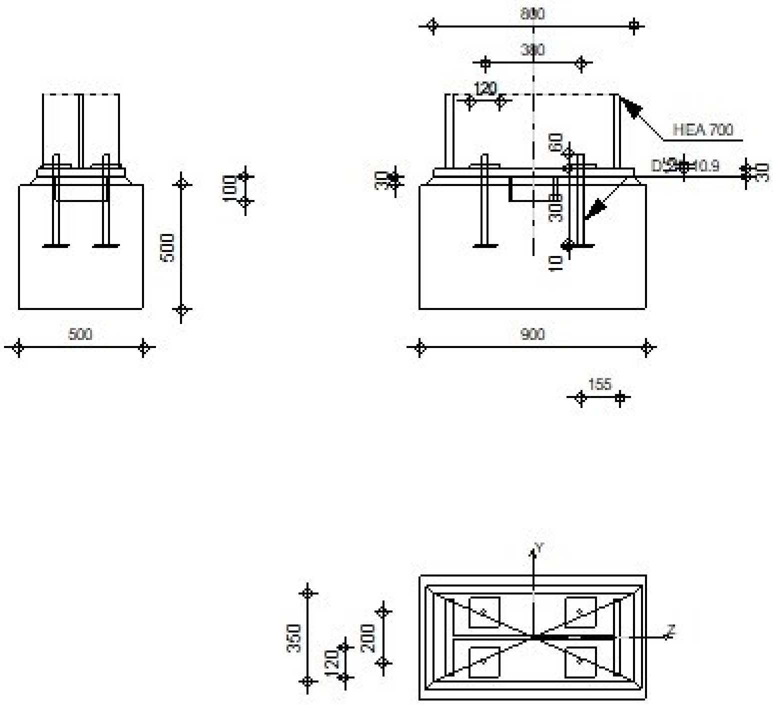
14.2. Detalj B

Detalj B prikazuje ankeriranje stupa.



Slika 127. Reakcije u stupu

	Robot Structural Analysis Professional 2024 **Fixed column base design** Eurocode 3: EN 1993-1-8:2005/AC:2009 + CEB Design Guide: Design of fastenings in concrete	OK Ratio **0,91**



General

Connection no.: 2

Connection name: Fixed column base

Geometry

Column

Section: HEA 700

L_c =	5,00	[m]	Column length
α =	0,0	[Deg]	Inclination angle
h_c =	690	[mm]	Height of column section
b_{fc} =	300	[mm]	Width of column section
t_{wc} =	14	[mm]	Thickness of the web of column section
t_{fc} =	27	[mm]	Thickness of the flange of column section
r_c =	27	[mm]	Radius of column section fillet
A_c =	260,48	[cm^2]	Cross-sectional area of a column
I_{yc} =	215301,00	[cm^4]	Moment of inertia of the column section

Material: S 355

f_{yc} =	355,00	[MPa]	Resistance
f_{uc} =	470,00	[MPa]	Yield strength of a material

Column base

l_{pd} =	800	[mm]	Length
b_{pd} =	350	[mm]	Width
t_{pd} =	30	[mm]	Thickness

Material: S 355

f_{ypd} =	355,00	[MPa]	Resistance
f_{upd} =	470,00	[MPa]	Yield strength of a material

Anchorage

The shear plane passes through the UNTHREADED portion of the bolt.

Class =	10.9		Anchor class
f_{yb} =	900,00	[MPa]	Yield strength of the anchor material
f_{ub} =	1000,00	[MPa]	Tensile strength of the anchor material
d =	24	[mm]	Bolt diameter
A_s =	3,53	[cm^2]	Effective section area of a bolt
A_v =	4,52	[cm^2]	Area of bolt section
n_H =	2		Number of bolt columns
n_V =	2		Number of bolt rows

Horizontal spacing e_{Hi} = 380 [mm]

Vertical spacing e_{Vi} = 200 [mm]

Anchor dimensions

L_1 = 60 [mm]

L_2 = 300 [mm]

L_3 = 0 [mm]

Anchor plate

l_p =	100	[mm]	Length
b_p =	100	[mm]	Width
t_p =	10	[mm]	Thickness

Material: S 355

f_y = 355,00 [MPa] Resistance

Washer

l_{wd} =	120	[mm]	Length
b_{wd} =	120	[mm]	Width
t_{wd} =	15	[mm]	Thickness

Wedge

Section: HEA 200

l_w = 100 [mm] Length

Material: S 355

f_{yw} = 355,00 [MPa] Resistance

Material factors

γ_{M0} =	1,00	Partial safety factor
γ_{M2} =	1,25	Partial safety factor
γ_C =	1,50	Partial safety factor

Spread footing

L =	900	[mm]	Spread footing length
B =	500	[mm]	Spread footing width
H =	500	[mm]	Spread footing height

Concrete

Class C30/37

f_{ck} = 30,00 [MPa] Characteristic resistance for compression

Grout layer

t_g =	30	[mm]	Thickness of leveling layer (grout)
$f_{ck,g}$ =	12,00	[MPa]	Characteristic resistance for compression
$C_{f,d}$ =	0,30		Coeff. of friction between the base plate and concrete

Welds

a_p =	6	[mm]	Footing plate of the column base
a_w =	6	[mm]	Wedge

Loads

Case: Manual calculations.

$N_{j,Ed}$ =	-1535,00	[kN]	Axial force
$V_{j,Ed,y}$ =	-1,00	[kN]	Shear force
$V_{j,Ed,z}$ =	-39,00	[kN]	Shear force
$M_{j,Ed,y}$ =	-174,00	[kN*m]	Bending moment

Results

Compression zone

COMPRESSION OF CONCRETE

f_{cd} =	20,00	[MPa]	Design compressive resistance	EN 1992-1:[3.1.6.(1)]
f_j =	16,90	[MPa]	Design bearing resistance under the base plate	[6.2.5.(7)]

$c = t_p \sqrt{(f_{yp}/(3 * f_j * \gamma_{M0}))}$

c =	79	[mm]	Additional width of the bearing pressure zone	[6.2.5.(4)]
b_{eff} =	161	[mm]	Effective width of the bearing pressure zone under the flange	[6.2.5.(3)]
l_{eff} =	350	[mm]	Effective length of the bearing pressure zone under the flange	[6.2.5.(3)]
A_{c0} =	564,82	[cm^2]	Area of the joint between the base plate and the foundation	EN 1992-1:[6.7.(3)]
A_{c1} =	1306,88	[cm^2]	Maximum design area of load distribution	EN 1992-1:[6.7.(3)]

$F_{rdu} = A_{c0} * f_{cd} * \sqrt{(A_{c1}/A_{c0})} \leq 3 * A_{c0} * f_{cd}$

F_{rdu} =	1718,31	[kN]	Bearing resistance of concrete	EN 1992-1:[6.7.(3)]
β_j =	0,67		Reduction factor for compression	[6.2.5.(7)]

$f_{jd} = \beta_j * F_{rdu}/(b_{eff} * l_{eff})$

f_{jd} =	20,28	[MPa]	Design bearing resistance	[6.2.5.(7)]
$A_{c,n}$ =	1956,48	[cm^2]	Bearing area for compression	[6.2.8.2.(1)]
$A_{c,y}$ =	564,82	[cm^2]	Bearing area for bending My	[6.2.8.3.(1)]

$F_{c,Rd,i} = A_{C,i} * f_{jd}$

$F_{c,Rd,n}$ =	3968,06	[kN]	Bearing resistance of concrete for compression	[6.2.8.2.(1)]
$F_{c,Rd,y}$ =	1145,54	[kN]	Bearing resistance of concrete for bending My	[6.2.8.3.(1)]

COLUMN FLANGE AND WEB IN COMPRESSION

CL =	4,00		Section class	EN 1993-1-1:[5.5.2]
$W_{el,y}$ =	6240,61	[cm^3]	Elastic section modulus	EN1993-1-1:[6.2.5.(2)]
$M_{c,Rd,y}$ =	2215,42	[kN*m]	Design resistance of the section for bending	EN1993-1-1:[6.2.5]
$h_{f,y}$ =	663	[mm]	Distance between the centroids of flanges	[6.2.6.7.(1)]

$CL =$ 4,00		Section class	EN 1993-1-1:[5.5.2]

$F_{c,fc,Rd,y} = M_{c,Rd,y} / h_{f,y}$

$F_{c,fc,Rd,y} =$ 3341,50	[kN]	Resistance of the compressed flange and web	[6.2.6.7.(1)]

RESISTANCES OF SPREAD FOOTING IN THE COMPRESSION ZONE

$N_{j,Rd} = F_{c,Rd,n}$

$N_{j,Rd} =$ 3968,06	[kN]	Resistance of a spread footing for axial compression	[6.2.8.2.(1)]

$F_{C,Rd,y} = \min(F_{c,Rd,y}, F_{c,fc,Rd,y})$

$F_{C,Rd,y} =$ 1145,54	[kN]	Resistance of spread footing in the compression zone	[6.2.8.3]

Connection capacity check

$N_{j,Ed} / N_{j,Rd} \leq 1,0$ (6.24)	0,39 < 1,00	verified	(0,39)

$e_y =$	113	[mm]	Axial force eccentricity	[6.2.8.3]
$z_{c,y} =$	319	[mm]	Lever arm $F_{C,Rd,y}$	[6.2.8.1.(2)]
$z_{t,y} =$	190	[mm]	Lever arm $F_{T,Rd,y}$	[6.2.8.1.(3)]
$M_{j,Rd,y} =$	191,67	[kN*m]	Connection resistance for bending	[6.2.8.3]

$M_{j,Ed,y} / M_{j,Rd,y} \leq 1,0$ (6.23)	0,91 < 1,00	verified	(0,91)

Shear

BEARING PRESSURE OF AN ANCHOR BOLT ONTO THE BASE PLATE

Shear force $V_{j,Ed,y}$

$\alpha_{d,y} =$ 0,96	Coeff. taking account of the bolt position - in the direction of shear	[Table 3.4]
$\alpha_{b,y} =$ 0,96	Coeff. for resistance calculation $F_{1,vb,Rd}$	[Table 3.4]
$k_{1,y} =$ 2,50	Coeff. taking account of the bolt position - perpendicularly to the direction of shear	[Table 3.4]

$F_{1,vb,Rd,y} = k_{1,y} * \alpha_{b,y} * f_{up} * d * t_p / \gamma_{M2}$

$F_{1,vb,Rd,y} =$ 650,77	[kN]	Resistance of an anchor bolt for bearing pressure onto the base plate	[6.2.2.(7)]

Shear force $V_{j,Ed,z}$

$\alpha_{d,z} =$ 2,69	Coeff. taking account of the bolt position - in the direction of shear	[Table 3.4]
$\alpha_{b,z} =$ 1,00	Coeff. for resistance calculation $F_{1,vb,Rd}$	[Table 3.4]
$k_{1,z} =$ 2,50	Coeff. taking account of the bolt position - perpendicularly to the direction of shear	[Table 3.4]

$F_{1,vb,Rd,z} = k_{1,z} * \alpha_{b,z} * f_{up} * d * t_p / \gamma_{M2}$

$F_{1,vb,Rd,z} =$ 676,80	[kN]	Resistance of an anchor bolt for bearing pressure onto the base plate	[6.2.2.(7)]

SHEAR OF AN ANCHOR BOLT

$\alpha_b =$	0,25		Coeff. for resistance calculation $F_{2,vb,Rd}$	[6.2.2.(7)]
$A_{vb} =$	4,52	[cm^2]	Area of bolt section	[6.2.2.(7)]
$f_{ub} =$	1000,00	[MPa]	Tensile strength of the anchor material	[6.2.2.(7)]
$\gamma_{M2} =$	1,25		Partial safety factor	[6.2.2.(7)]

$F_{2,vb,Rd} = \alpha_b * f_{ub} * A_{vb} / \gamma_{M2}$

$F_{2,vb,Rd}$ = 89,75 [kN] Shear resistance of a bolt - without lever arm [6.2.2.(7)]

α_M = 2,00 Factor related to the fastening of an anchor in the foundation CEB [9.3.2.2]

$M_{Rk,s}$ = 1,83 [kN*m] Characteristic bending resistance of an anchor CEB [9.3.2.2]

l_{sm} = 57 [mm] Lever arm length CEB [9.3.2.2]

γ_{Ms} = 1,20 Partial safety factor CEB [3.2.3.2]

$F_{v,Rd,sm} = \alpha_M * M_{Rk,s}/(l_{sm} * \gamma_{Ms})$

$F_{v,Rd,sm}$ = 53,57 [kN] Shear resistance of a bolt - with lever arm CEB [9.3.1]

CONCRETE PRY-OUT FAILURE

$N_{Rk,c}$ = 66,11 [kN] Design uplift capacity CEB [9.2.4]

k_3 = 2,00 Factor related to the anchor length CEB [9.3.3]

γ_{Mc} = 2,16 Partial safety factor CEB [3.2.3.1]

$F_{v,Rd,cp} = k_3 * N_{Rk,c}/\gamma_{Mc}$

$F_{v,Rd,cp}$ = 61,21 [kN] Concrete resistance for pry-out failure CEB [9.3.1]

CONCRETE EDGE FAILURE

Shear force $V_{j,Ed,y}$

$V_{Rk,c,y}^0$ = 49,82 [kN] Characteristic resistance of an anchor CEB [9.3.4.(a)]

$\psi_{A,V,y}$ = 1,00 Factor related to anchor spacing and edge distance CEB [9.3.4]

$\psi_{h,V,y}$ = 1,00 Factor related to the foundation thickness CEB [9.3.4.(c)]

$\psi_{s,V,y}$ = 1,00 Factor related to the influence of edges parallel to the shear load direction CEB [9.3.4.(d)]

$\psi_{ec,V,y}$ = 1,00 Factor taking account a group effect when different shear loads are acting on the individual anchors in a group CEB [9.3.4.(e)]

$\psi_{\alpha,V,y}$ = 1,00 Factor related to the angle at which the shear load is applied CEB [9.3.4.(f)]

$\psi_{ucr,V,y}$ = 1,00 Factor related to the type of edge reinforcement used CEB [9.3.4.(g)]

γ_{Mc} = 2,16 Partial safety factor CEB [3.2.3.1]

$F_{v,Rd,c,y} = V_{Rk,c,y}^0 * \psi_{A,V,y} * \psi_{h,V,y} * \psi_{s,V,y} * \psi_{ec,V,y} * \psi_{\alpha,V,y} * \psi_{ucr,V,y}/\gamma_{Mc}$

$F_{v,Rd,c,y}$ = 23,07 [kN] Concrete resistance for edge failure CEB [9.3.1]

Shear force $V_{j,Ed,z}$

$V_{Rk,c,z}^0$ = 113,70 [kN] Characteristic resistance of an anchor CEB [9.3.4.(a)]

$\psi_{A,V,z}$ = 0,38 Factor related to anchor spacing and edge distance CEB [9.3.4]

$\psi_{h,V,z}$ = 1,00 Factor related to the foundation thickness CEB [9.3.4.(c)]

$V_{Rk,c,z}{}^{0}$ =	113,70 [kN]	Characteristic resistance of an anchor	CEB [9.3.4.(a)]
$\psi_{s,V,z}$ =	0,82	Factor related to the influence of edges parallel to the shear load direction	CEB [9.3.4.(d)]
$\psi_{ec,V,z}$ =	1,00	Factor taking account a group effect when different shear loads are acting on the individual anchors in a group	CEB [9.3.4.(e)]
$\psi_{\alpha,V,z}$ =	1,00	Factor related to the angle at which the shear load is applied	CEB [9.3.4.(f)]
$\psi_{ucr,V,z}$ =	1,00	Factor related to the type of edge reinforcement used	CEB [9.3.4.(g)]
γ_{Mc} =	2,16	Partial safety factor	CEB [3.2.3.1]

$F_{v,Rd,c,z} = V_{Rk,c,z}{}^{0}*\psi_{A,V,z}*\psi_{h,V,z}*\psi_{s,V,z}*\psi_{ec,V,z}*\psi_{\alpha,V,z}*\psi_{ucr,V,z}/\gamma_{Mc}$

$F_{v,Rd,c,z}$ = 16,51 [kN] Concrete resistance for edge failure CEB [9.3.1]

SPLITTING RESISTANCE

$C_{f,d}$ = 0,30 Coeff. of friction between the base plate and concrete [6.2.2.(6)]

$N_{c,Ed}$ = 1535,00 [kN] Compressive force [6.2.2.(6)]

$F_{f,Rd} = C_{f,d}*N_{c,Ed}$

$F_{f,Rd}$ = 460,50 [kN] Slip resistance [6.2.2.(6)]

BEARING PRESSURE OF THE WEDGE ONTO CONCRETE

$F_{v,Rd,wg,y} = 1.4*l_w*b_{wy}*f_{ck}/\gamma_c$

$F_{v,Rd,wg,y}$ = 532,00 [kN] Resistance for bearing pressure of the wedge onto concrete

$F_{v,Rd,wg,z} = 1.4*l_w*b_{wz}*f_{ck}/\gamma_c$

$F_{v,Rd,wg,z}$ = 560,00 [kN] Resistance for bearing pressure of the wedge onto concrete

SHEAR CHECK

$V_{j,Rd,y} = n_b*\min(F_{1,vb,Rd,y}, F_{2,vb,Rd}, F_{v,Rd,sm}, F_{v,Rd,cp}, F_{v,Rd,c,y}) + F_{v,Rd,wg,y} + F_{f,Rd}$

$V_{j,Rd,y}$ = 1084,76 [kN] Connection resistance for shear CEB [9.3.1]

$V_{j,Ed,y} / V_{j,Rd,y} \leq 1,0$ 0,00 < 1,00 verified (0,00)

$V_{j,Rd,z} = n_b*\min(F_{1,vb,Rd,z}, F_{2,vb,Rd}, F_{v,Rd,sm}, F_{v,Rd,cp}, F_{v,Rd,c,z}) + F_{v,Rd,wg,z} + F_{f,Rd}$

$V_{j,Rd,z}$ = 1086,53 [kN] Connection resistance for shear CEB [9.3.1]

$V_{j,Ed,z} / V_{j,Rd,z} \leq 1,0$ 0,04 < 1,00 verified (0,04)

$V_{j,Ed,y} / V_{j,Rd,y} + V_{j,Ed,z} / V_{j,Rd,z} \leq 1,0$ 0,04 < 1,00 verified (0,04)

Welds between the column and the base plate

$\sigma_{\perp}$ =	97,33	[MPa]	Normal stress in a weld	[4.5.3.(7)]
$\tau_{\perp}$ =	97,33	[MPa]	Perpendicular tangent stress	[4.5.3.(7)]
τ_{yII} =	-0,14	[MPa]	Tangent stress parallel to $V_{j,Ed,y}$	[4.5.3.(7)]
τ_{zII} =	-5,11	[MPa]	Tangent stress parallel to $V_{j,Ed,z}$	[4.5.3.(7)]
β_W =	0,90		Resistance-dependent coefficient	[4.5.3.(7)]

$\sigma_{\perp} / (0.9 \cdot f_u/\gamma_{M2}) \leq 1.0$ (4.1)	0,29 < 1,00	verified	(0,29)
$\sqrt{(\sigma_{\perp}^2 + 3.0 (\tau_{yII}^2 + \tau_{\perp}^2))} / (f_u/(\beta_W \cdot \gamma_{M2})) \leq 1.0$ (4.1)	0,47 < 1,00	verified	(0,47)
$\sqrt{(\sigma_{\perp}^2 + 3.0 (\tau_{zII}^2 + \tau_{\perp}^2))} / (f_u/(\beta_W \cdot \gamma_{M2})) \leq 1.0$ (4.1)	0,45 < 1,00	verified	(0,45)

Connection stiffness

Bending moment $M_{j,Ed,y}$

b_{eff} = 161 [mm] Effective width of the bearing pressure zone under the flange [6.2.5.(3)]

l_{eff} = 350 [mm] Effective length of the bearing pressure zone under the flange [6.2.5.(3)]

$k_{13,y} = E_c \cdot \sqrt{(b_{eff} \cdot l_{eff})}/(1.275 \cdot E)$

$k_{13,y}$ = 29 [mm] Stiffness coeff. of compressed concrete [Table 6.11]

l_{eff} = 406 [mm] Effective length for a single bolt row for mode 2 [6.2.6.5]

m = 86 [mm] Distance of a bolt from the stiffening edge [6.2.6.5]

$k_{15,y} = 0.425 \cdot l_{eff} \cdot t_p^3/(m^3)$

$k_{15,y}$ = 7 [mm] Stiffness coeff. of the base plate subjected to tension [Table 6.11]

L_b = 279 [mm] Effective anchorage depth [Table 6.11]

$k_{16,y} = 1.6 \cdot A_b/L_b$

$k_{16,y}$ = 2 [mm] Stiffness coeff. of an anchor subjected to tension [Table 6.11]

$\lambda_{0,y}$ = 0,23 Column slenderness [5.2.2.5.(2)]

$S_{j,ini,y}$ = 544948,32 [kN*m] Initial rotational stiffness [Table 6.12]

$\lambda_{0,y} \leq 0.5$ RIGID [5.2.2.5.(2)]

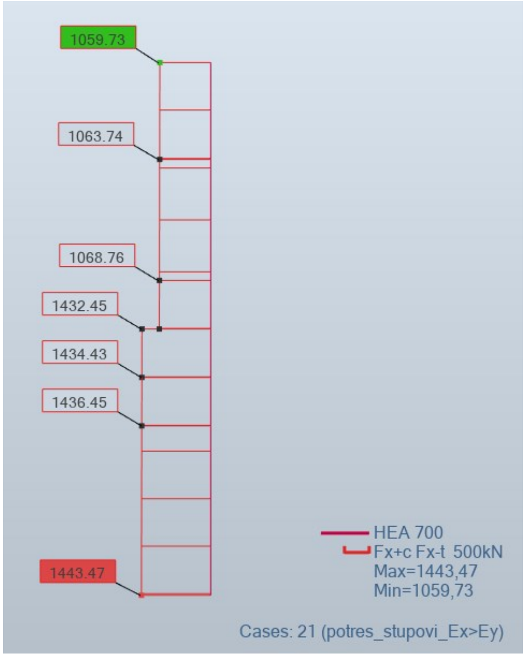
Weakest component:

FOUNDATION - BEARING PRESSURE ONTO CONCRETE

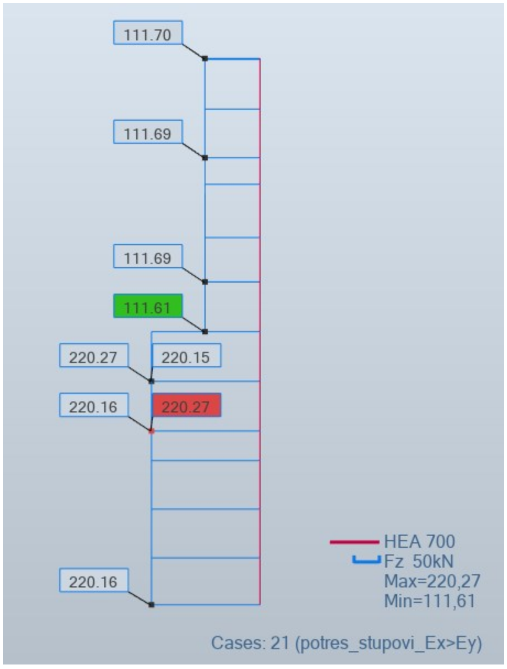
Connection conforms to the code Ratio 0,91

14.3. Detalj C

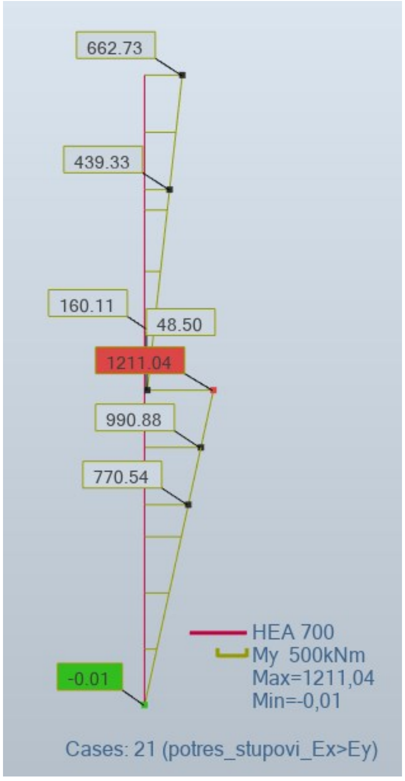
Detaljem C se prikazuje spajanje glavnog stupa s uzdužnim gredama.



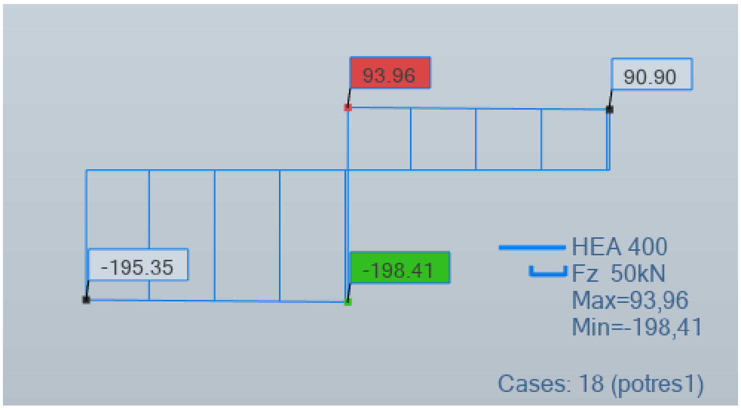
Slika 128. Uzdužna sila stupa detalja C



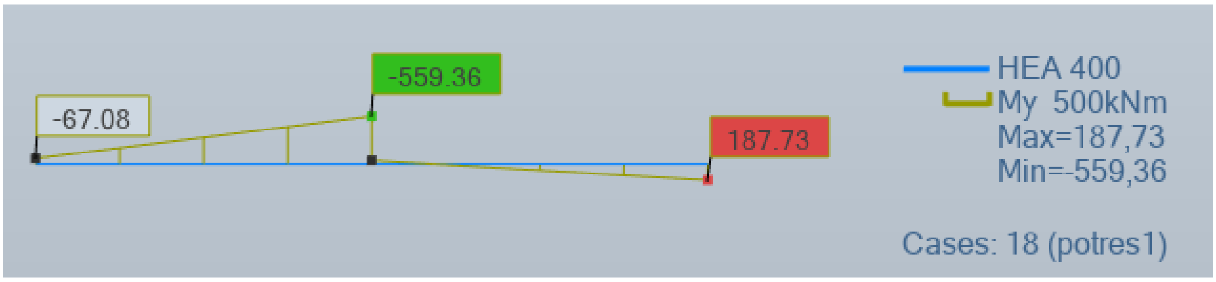
Slika 129. Poprečna sila stupa detalja C



Slika 130. Moment savijanja stupa detalja C



Slika 131. Poprečna sila grede detalja C



Slika 132. Moment savijanja grede detalja C

Project:
Project no:
Author:

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Project item CON1

Design

Name	CON1
Description	
Analysis	Stiffness

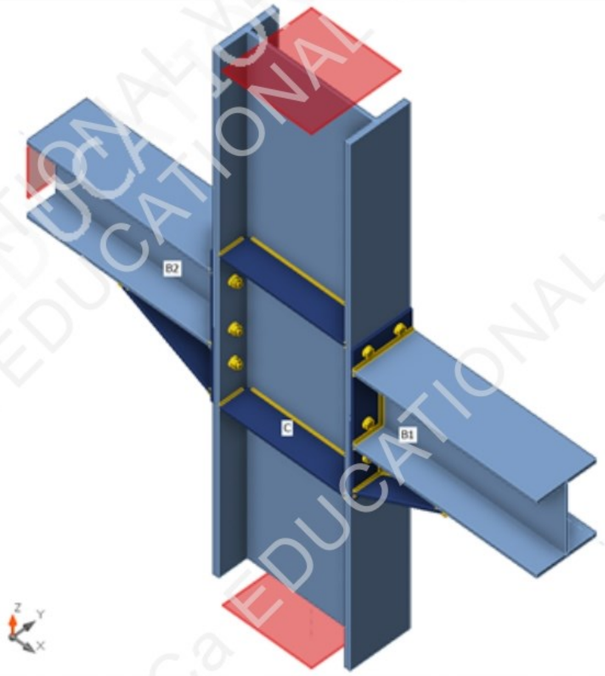
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
C	6 - HEA700	0.0	90.0	0.0	0	0	0
B1	5 - HEA400	0.0	0.0	0.0	0	0	0
B2	5 - HEA400	180.0	0.0	0.0	0	0	0

Supports and forces

Name	Support	Forces in	X [mm]
C / begin	N-Vy-Vz-Mx-My-Mz	Node	0
C / end	N-Vy-Vz-Mx-My-Mz	Node	0
B1 / end		Node	0
B2 / end	N-Vy-Vz-Mx-My-Mz	Node	0



Project:
Project no:
Author:

Cross-sections

Name	Material
6 - HEA700	S 355
5 - HEA400	S 355

Bolts

Name	Diameter [mm]	f_y [MPa]	f_u [MPa]	Gross area [mm^2]
M24 10.9	24	900.0	1000.0	452

Load effects

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	C / Begin	1432.0	0.0	220.0	0.0	1211.0	0.0
	C / End	1069.0	0.0	112.0	0.0	48.5	0.0
	B1 / End	0.0	0.0	94.0	0.0	-43.0	0.0
	B2 / End	0.0	0.0	-198.0	0.0	560.0	0.0

Check

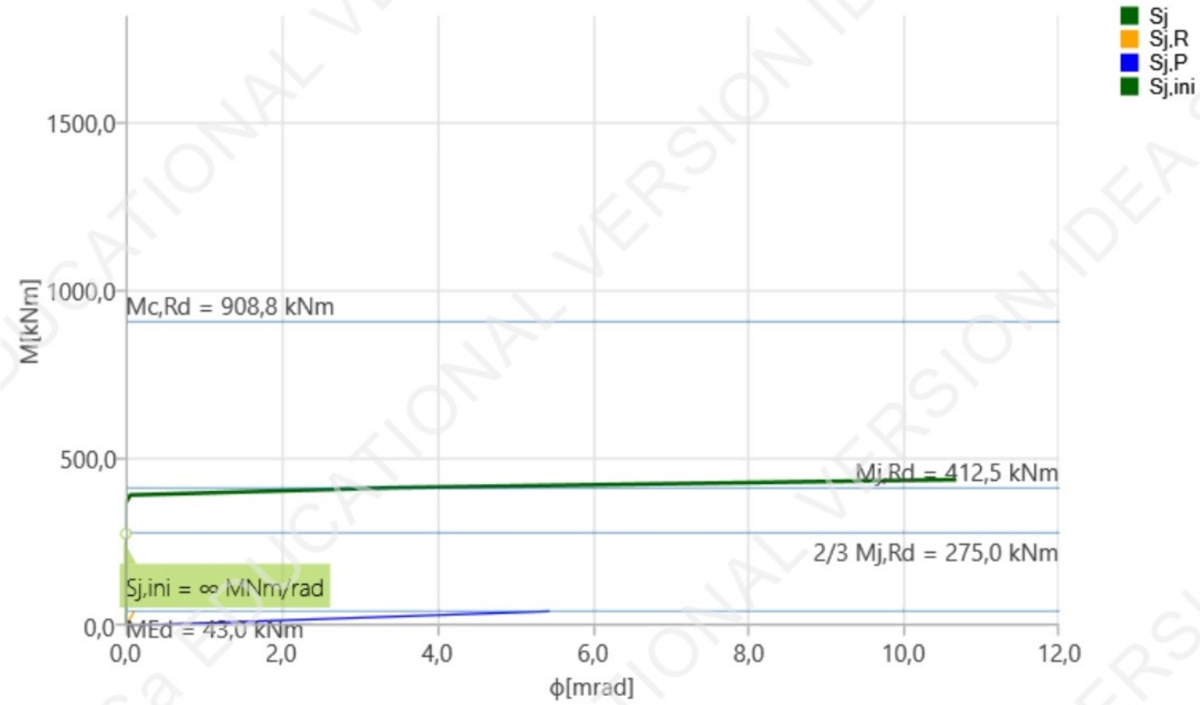
Rotational stiffness

Name	Comp.	Loads	$M_{j,Rd}$ [kNm]	$S_{j,ini}$ [MNm/rad]	Φc [mrad]	L [m]	$S_{j,R}$ [MNm/rad]	$S_{j,P}$ [MNm/rad]	Class.
B1	My	LE1	-412.5	∞	3.6	6.00	394.6	7.9	Rigid

Secant rotational stiffness

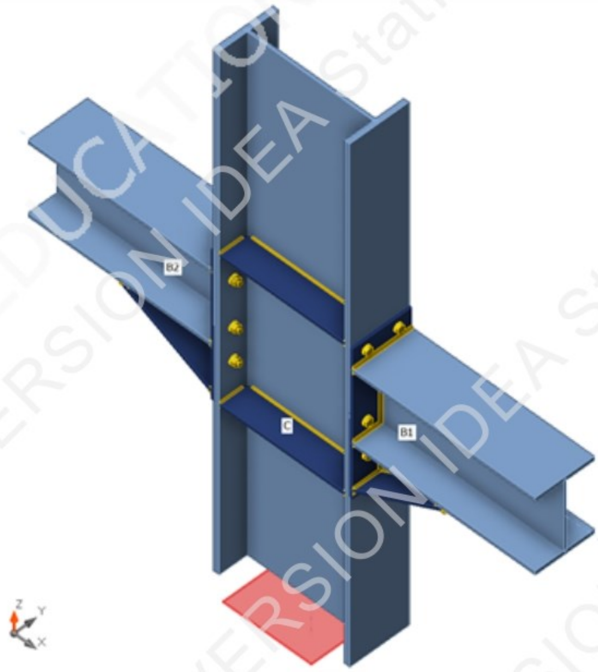
Name	Comp.	Loads	M [kNm]	$S_{j,s}$ [MNm/rad]	Φ [mrad]
B1	My	LE1	-43.0	∞	0.0

Project:
Project no:
Author:



Stiffness diagram My - ϕy, LE1

Project:
Project no:
Author:



Cross-sections

Name	Material
6 - HEA700	S 355
5 - HEA400	S 355

Bolts

Name	Diameter [mm]	f_y [MPa]	f_u [MPa]	Gross area [mm^2]
M24 10.9	24	900.0	1000.0	452

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	C / Begin	1432.0	0.0	220.0	0.0	1211.0	0.0
	C / End	1069.0	0.0	112.0	0.0	48.5	0.0
	B1 / End	0.0	0.0	94.0	0.0	-43.0	0.0
	B2 / End	0.0	0.0	-198.0	0.0	560.0	0.0

Unbalanced forces

Name	X [kN]	Y [kN]	Z [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	-332.0	0.0	2397.0	0.0	656.5	0.0

Project:
Project no:
Author:

IDEA StatiCa® Calculate yesterday's estimates

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	4.2 < 5.0%	OK
Bolts	96.5 < 100%	OK
Welds	99.0 < 100%	OK
Buckling	Not calculated	

Plates

Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
C-bfl 1	27.0	LE1	184.1	0.0	9.8	OK
C-tfl 1	27.0	LE1	338.1	0.0	316.4	OK
C-w 1	14.5	LE1	288.6	0.0	0.0	OK
B1-bfl 1	19.0	LE1	35.2	0.0	0.0	OK
B1-tfl 1	19.0	LE1	35.2	0.0	0.0	OK
B1-w 1	11.0	LE1	47.1	0.0	0.0	OK
B2-bfl 1	19.0	LE1	355.1	0.1	0.0	OK
B2-tfl 1	19.0	LE1	293.5	0.0	0.0	OK
B2-w 1	11.0	LE1	339.3	0.0	0.0	OK
EP1a	13.0	LE1	83.6	0.0	9.8	OK
EP1b	13.0	LE1	363.9	4.2	316.4	OK
STIFF1a	15.0	LE1	164.6	0.0	0.0	OK
STIFF1b	15.0	LE1	168.5	0.0	0.0	OK
STIFF1c	15.0	LE1	216.5	0.0	0.0	OK
STIFF1d	15.0	LE1	219.6	0.0	0.0	OK
WID1a	10.0	LE1	21.2	0.0	0.0	OK
WID1b	15.0	LE1	10.3	0.0	0.0	OK
WID2a	10.0	LE1	308.2	0.1	0.0	OK
WID2b	15.0	LE1	355.1	0.0	0.0	OK

Design data

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

Detailed result for EP1b

Design values used in the analysis

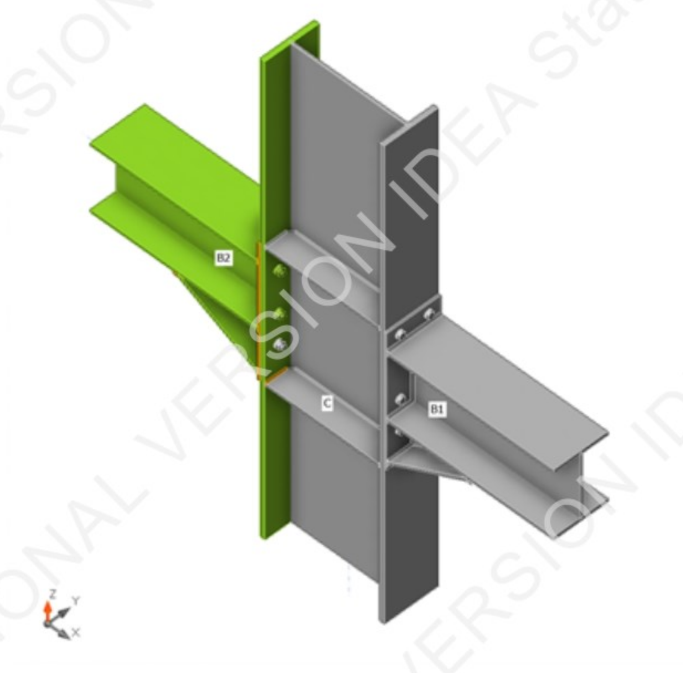
$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

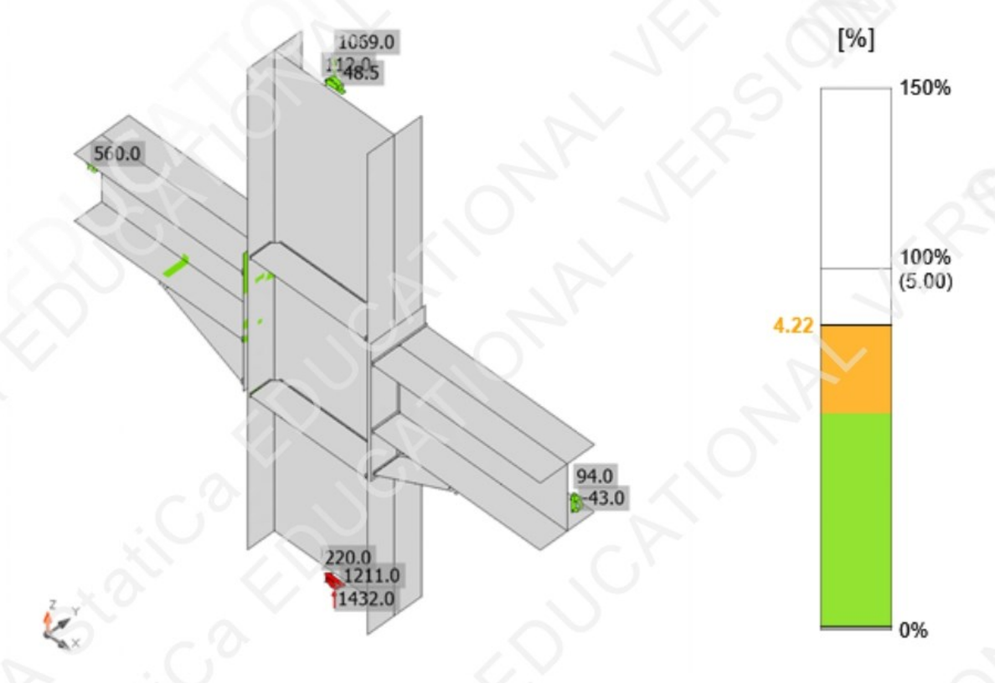
$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Project:
Project no:
Author:

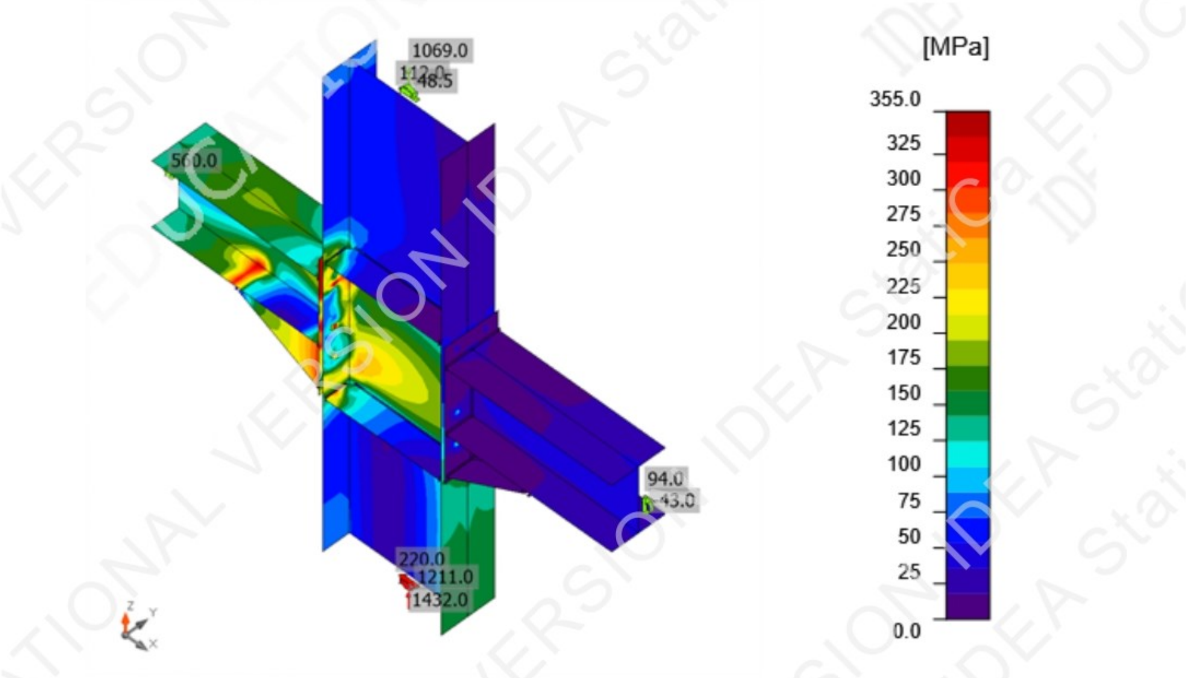


Overall check, LE1



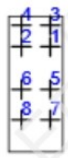
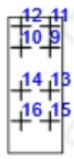
Strain check, LE1

Project:
Project no:
Author:



Equivalent stress, LE1

Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B1	M24 10.9 - 1	LE1	2.8	7.4	305.8	1.1	5.3	6.0	OK	OK
	B2	M24 10.9 - 1	LE1	2.8	7.4	305.8	1.1	5.2	6.0	OK	OK
	B3	M24 10.9 - 1	LE1	0.0	6.0	305.8	0.0	4.3	4.3	OK	OK
	B4	M24 10.9 - 1	LE1	0.0	6.0	305.8	0.0	4.2	4.2	OK	OK
	B5	M24 10.9 - 1	LE1	7.0	13.3	305.8	2.7	9.4	11.4	OK	OK
	B6	M24 10.9 - 1	LE1	6.9	13.3	305.8	2.7	9.4	11.3	OK	OK
	B7	M24 10.9 - 1	LE1	12.0	20.5	305.8	4.7	14.5	17.9	OK	OK
	B8	M24 10.9 - 1	LE1	11.8	20.4	305.8	4.6	14.5	17.8	OK	OK
	B9	M24 10.9 - 1	LE1	239.5	2.2	292.0	94.2	1.5	68.9	OK	OK
	B10	M24 10.9 - 1	LE1	238.6	1.5	291.4	93.9	1.1	68.1	OK	OK
	B11	M24 10.9 - 1	LE1	237.5	42.0	196.0	93.5	29.7	96.5	OK	OK
	B12	M24 10.9 - 1	LE1	237.5	41.9	196.0	93.4	29.7	96.4	OK	OK
	B13	M24 10.9 - 1	LE1	172.1	27.1	305.8	67.7	19.2	67.6	OK	OK
	B14	M24 10.9 - 1	LE1	175.5	27.2	305.8	69.1	19.3	68.6	OK	OK
	B15	M24 10.9 - 1	LE1	58.8	32.1	305.8	23.1	22.7	39.2	OK	OK
	B16	M24 10.9 - 1	LE1	58.5	32.0	305.8	23.0	22.7	39.1	OK	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M24 10.9 - 1	254.2	364.9	141.2

Project:
Project no:
Author:

Detailed result for B11

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\ f_{ub}\ A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 237.5 kN

Where:

$k_2 = 0.90$ – Factor

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A_s = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\ \pi\ d_m\ t_p\ f_u}{\gamma_{M2}} =$ 364.9 kN ≥ $F_{t,Ed} =$ 237.5 kN

Where:

$d_m = 38$ mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p = 13$ mm – Plate thickness

$f_u = 490.0$ MPa – Ultimate strength

$\gamma_{M2} = 1.25$ – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \ \alpha_v\, f_{ub}\, A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 42.0 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Project:
Project no:
Author:

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \, \alpha_b \, f_u \, dt}{\gamma_{M2}} =$ 196.0 kN ≥ $F_{b,Ed} =$ 42.0 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.64	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 70 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ 160 mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 50 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ ∞ mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 13 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.93 ≤ 1,0

Where:

$F_{t,Ed} =$ 237.5 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

$B_{p,Rd} =$ 364.9 kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.30 ≤ 1,0

Where:

$F_{v,Ed} =$ 42.0 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 42.0 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 196.0 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4 \, F_{t,Rd}} =$ 0.96 ≤ 1,0

Where:

$F_{v,Ed} =$ 42.0 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 237.5 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Project:
Project no:
Author:

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Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\perp}$ [MPa]	$\tau_{\|\|}$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
EP1a	B1-bfl 1	◢8.0◣	299	LE1	15.8	0.0	-10.3	-6.9	-0.1	3.6	3.6	OK	OK
		◢8.0◣	299	LE1	12.5	0.0	-3.5	6.9	0.0	2.9	0.0	OK	OK
EP1a	B1-tfl 1	◢8.0◣	299	LE1	35.7	0.0	-24.6	-14.9	0.1	8.2	6.5	OK	OK
		◢8.0◣	299	LE1	21.1	0.0	-2.4	12.1	-0.1	4.8	4.8	OK	OK
EP1a	B1-w 1	◢8.0◣	370	LE1	24.3	0.0	3.5	3.3	13.5	5.6	5.6	OK	OK
		◢8.0◣	370	LE1	24.0	0.0	3.2	-3.4	-13.3	5.5	5.5	OK	OK
EP1b	B2-bfl 1	◢8.0◣	299	LE1	279.4	0.0	157.8	106.6	79.7	64.1	29.3	OK	OK
		◢8.0◣	299	LE1	174.2	0.0	-59.3	92.6	-19.2	40.0	21.0	OK	OK
EP1b	B2-tfl 1	◢8.0◣	299	LE1	427.0	0.1	124.1	213.7	100.0	98.0	74.7	OK	OK
		◢8.0◣	299	LE1	427.0	0.1	237.4	-144.6	-145.3	98.0	78.7	OK	OK
EP1b	B2-w 1	◢8.0◣	370	LE1	428.4	0.9	208.3	205.5	67.0	98.4	91.2	OK	OK
		◢8.0◣	370	LE1	428.3	0.8	203.7	-206.5	-68.4	98.3	90.9	OK	OK
C-bfl 1	STIFF1a	◢5.0◣	116	LE1	19.1	0.0	-7.6	-6.4	7.9	4.4	4.4	OK	OK
		◢5.0◣	116	LE1	15.2	0.0	7.2	-6.0	-4.8	3.5	3.5	OK	OK
C-w 1	STIFF1a	◢5.0◣	581	LE1	79.5	0.0	37.8	13.2	-38.2	18.3	14.8	OK	OK
		◢5.0◣	581	LE1	92.4	0.0	-37.3	12.7	47.1	21.2	16.8	OK	OK
C-tfl 1	STIFF1a	◢5.0◣	116	LE1	144.4	0.0	12.7	83.0	0.9	33.1	26.8	OK	OK
		◢5.0◣	116	LE1	254.1	0.0	155.4	-85.4	-78.6	58.3	57.3	OK	OK
C-bfl 1	STIFF1b	◢5.0◣	116	LE1	16.2	0.0	7.5	6.6	5.1	3.7	3.7	OK	OK
		◢5.0◣	116	LE1	20.1	0.0	-7.5	6.6	-8.5	4.6	4.6	OK	OK
C-w 1	STIFF1b	◢5.0◣	581	LE1	91.1	0.0	-37.3	-12.2	-46.4	20.9	16.6	OK	OK
		◢5.0◣	581	LE1	79.6	0.0	39.5	-14.4	37.2	18.3	15.0	OK	OK
C-tfl 1	STIFF1b	◢5.0◣	116	LE1	260.8	0.0	160.5	88.6	78.9	59.9	58.4	OK	OK
		◢5.0◣	116	LE1	150.6	0.0	14.4	-86.5	0.8	34.6	27.9	OK	OK
C-bfl 1	STIFF1c	◢5.0◣	116	LE1	102.2	0.0	-46.5	-38.5	-35.8	23.5	19.8	OK	OK
		◢5.0◣	116	LE1	70.3	0.0	-9.8	17.8	36.0	16.1	15.1	OK	OK
C-w 1	STIFF1c	◢5.0◣	581	LE1	117.4	0.0	-10.5	-9.8	66.8	26.9	19.4	OK	OK
		◢5.0◣	581	LE1	131.8	0.0	-26.7	27.4	-69.3	30.3	20.7	OK	OK
C-tfl 1	STIFF1c	◢5.0◣	116	LE1	426.9	0.0	-220.5	-179.2	-111.4	98.0	90.5	OK	OK
		◢5.0◣	116	LE1	367.4	0.0	-137.5	183.6	70.7	84.4	71.6	OK	OK
C-bfl 1	STIFF1d	◢5.0◣	116	LE1	71.3	0.0	-9.8	-17.7	-36.7	16.4	15.2	OK	OK
		◢5.0◣	116	LE1	103.2	0.0	-46.8	39.0	36.0	23.7	20.0	OK	OK
C-w 1	STIFF1d	◢5.0◣	581	LE1	133.1	0.0	-28.0	-28.3	69.6	30.6	21.0	OK	OK
		◢5.0◣	581	LE1	118.8	0.0	-11.2	10.7	-67.4	27.3	19.4	OK	OK
C-tfl 1	STIFF1d	◢5.0◣	116	LE1	375.4	0.0	-139.3	-188.7	-70.1	86.2	72.8	OK	OK
		◢5.0◣	116	LE1	426.9	0.0	-221.9	178.8	111.1	98.0	91.6	OK	OK
EP1a	WID1a	◢10.0◣	219	LE1	13.4	0.0	6.2	6.2	-2.9	3.1	0.0	OK	OK
		◢10.0◣	219	LE1	14.0	0.0	6.4	-6.4	3.3	3.2	0.0	OK	OK
B1-bfl 1	WID1a	◢10.0◣	439	LE1	10.2	0.0	3.0	3.1	4.6	2.3	2.3	OK	OK
		◢10.0◣	439	LE1	10.2	0.0	3.1	-3.0	-4.7	2.3	2.3	OK	OK

Project:
Project no:
Author:

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
WID1b	WID1a	◢ 10.0 ◣	490	LE1	4.4	0.0	-0.1	-0.1	2.5	1.0	0.0	OK	OK
		◢ 10.0 ◣	490	LE1	4.4	0.0	-0.1	0.1	-2.5	1.0	0.0	OK	OK
EP1a	WID1b	◢ 10.0 ◣	299	LE1	4.7	0.0	0.4	0.3	2.7	1.1	0.0	OK	OK
		◢ 10.0 ◣	299	LE1	3.3	0.0	-0.3	0.7	1.8	0.8	0.0	OK	OK
B1-bfl 1	WID1b	◢ 10.0 ◣	299	LE1	9.1	0.0	0.9	-4.8	-2.1	2.1	0.0	OK	OK
		◢ 10.0 ◣	299	LE1	7.0	0.0	-0.8	0.0	4.0	1.6	0.0	OK	OK
EP1b	WID2a	◢ 7.0 ◣	220	LE1	372.3	0.0	-169.4	-171.6	84.8	85.5	44.8	OK	OK
		◢ 7.0 ◣	220	LE1	376.5	0.0	-173.9	171.6	-88.0	86.5	44.7	OK	OK
B2-bfl 1	WID2a	◢ 7.0 ◣	438	LE1	296.1	0.0	-95.1	-95.0	-131.1	68.0	43.0	OK	OK
		◢ 7.0 ◣	438	LE1	296.1	0.0	-94.9	95.0	131.1	68.0	44.5	OK	OK
WID2b	WID2a	◢ 7.0 ◣	490	LE1	184.4	0.0	-47.3	-47.4	-91.3	42.3	27.0	OK	OK
		◢ 7.0 ◣	490	LE1	184.4	0.0	-47.5	47.4	91.3	42.3	27.5	OK	OK
EP1b	WID2b	◢ 7.0 ◣	299	LE1	429.0	1.3	-154.2	-222.3	63.4	98.5	85.0	OK	OK
		◢ 7.0 ◣	299	LE1	427.4	0.3	-289.7	175.5	-45.8	98.1	78.9	OK	OK
B2-bfl 1	WID2b	◢ 7.0 ◣	299	LE1	431.3	2.6	-77.5	-183.1	-162.8	99.0	80.1	OK	OK
		◢ 7.0 ◣	299	LE1	427.0	0.1	-291.0	40.2	175.8	98.0	46.4	OK	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	490.0	0.90	435.6	352.8

Detailed result for B2-bfl 1 / WID2b

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 431.3 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2} =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 77.7 MPa

where:

$f_u =$ 490.0 MPa – Ultimate strength

$\beta_w =$ 0.90 – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} =$ 1.25 – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.99 ≤ 1,0

Where:

$\sigma_{w,Ed} =$ 431.3 MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} =$ 435.6 MPa – Equivalent stress resistance

$\sigma_\perp =$ -77.7 MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} =$ 352.8 MPa – Perpendicular stress resistance

Buckling

Buckling analysis was not calculated.

Project:
Project no:
Author:

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Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds Throat thickness [mm]	Length [mm]	Bolts	Nr.
EP1	P13.0x300.0-760.0 (S 355)		1	Double fillet: 8.0	1942.0	M24 10.9	16
	P13.0x300.0-760.0 (S 355)		1				
STIFF1	P15.0x142.7-636.0 (S 355)		4	Double fillet: 5.0	3254.0		
WID1	P10.0x220.0-440.0 (S 355)		1	Double fillet: 10.0	1751.9		
	P15.0x300.0-491.9 (S 355)		1				
WID2	P10.0x220.0-440.0 (S 355)		1	Double fillet: 7.0	1751.9		
	P15.0x300.0-491.9 (S 355)		1				

Project:
Project no:
Author:

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Double fillet	S 355	8.0	11.3	1942.0
Double fillet	S 355	5.0	7.1	3254.0
Double fillet	S 355	10.0	14.1	1751.9
Double fillet	S 355	7.0	9.9	1751.9

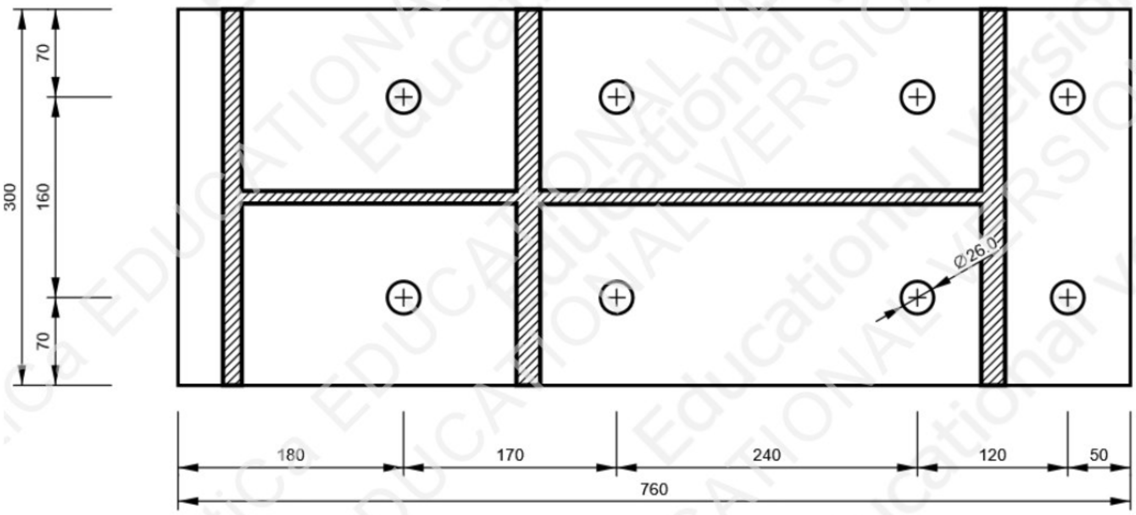
Bolts

Name	Grip length [mm]	Count
M24 10.9	40	16

Drawing

EP1 - EP1a

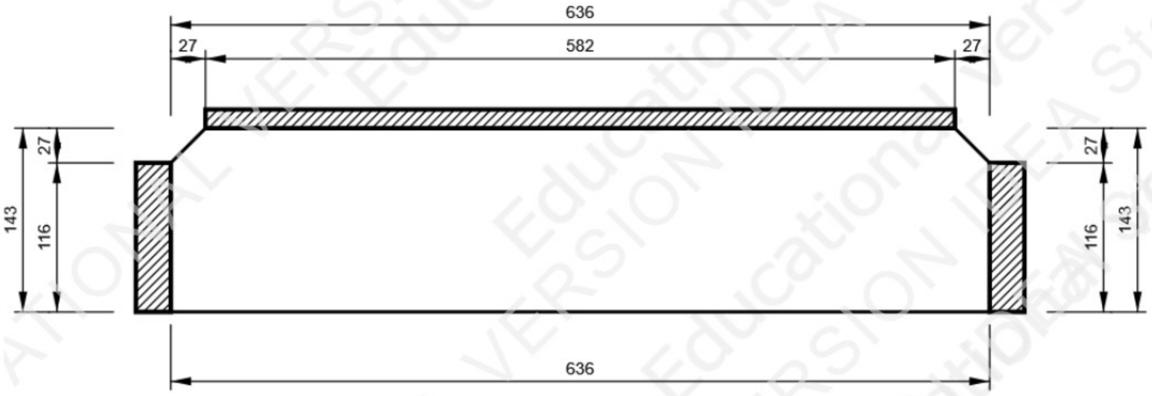
P13.0x760-300 (S 355)



Project:
Project no:
Author:

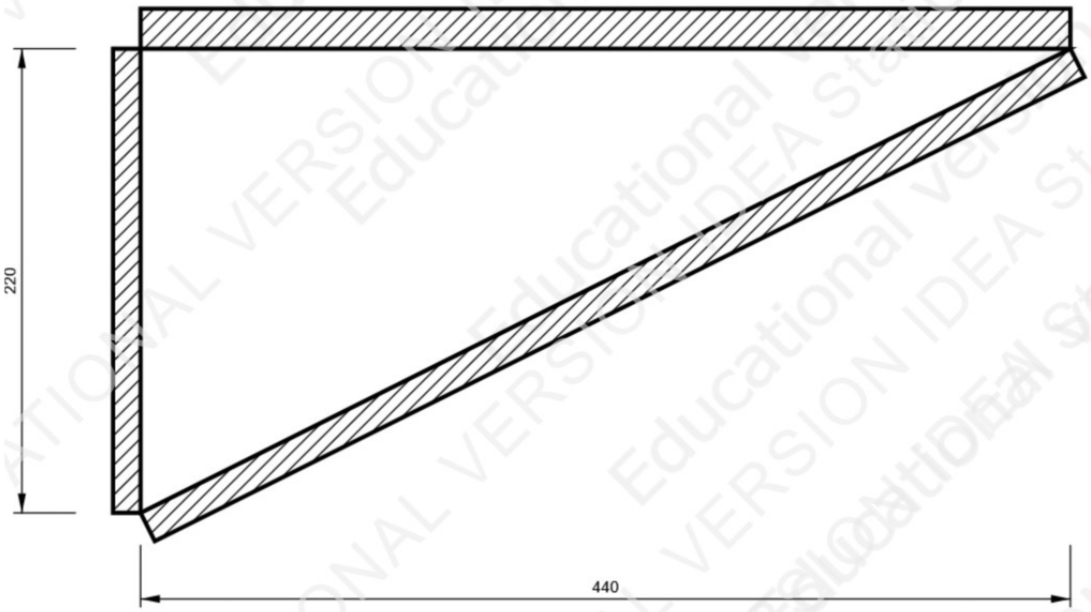
STIFF1

P15.0x636-143 (S 355)



WID1 - WID1a

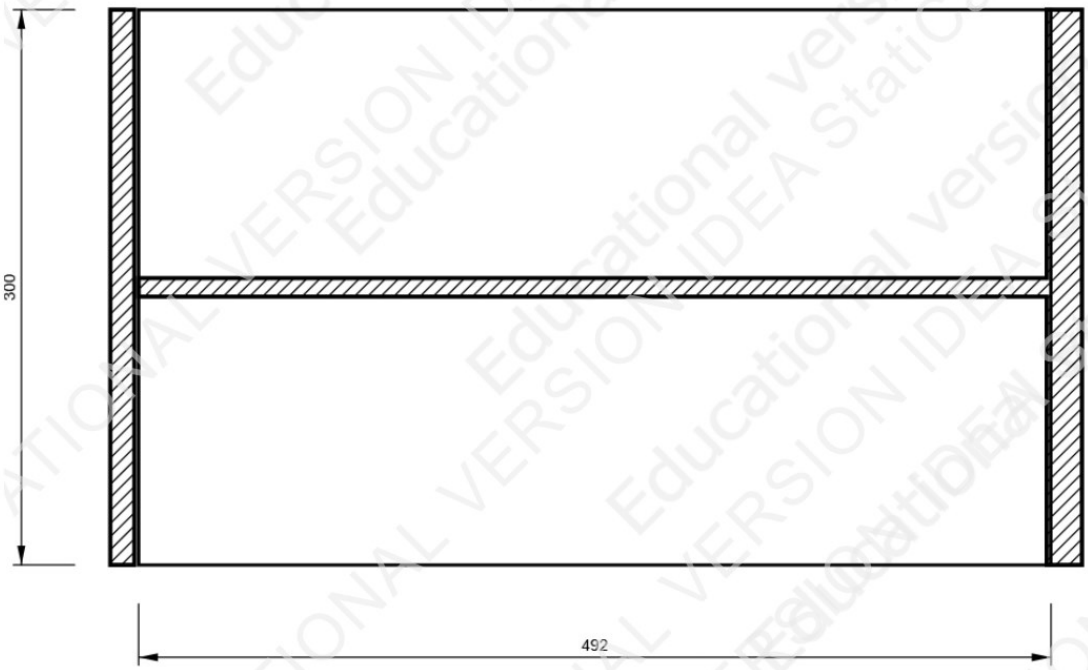
P10.0x440-220 (S 355)



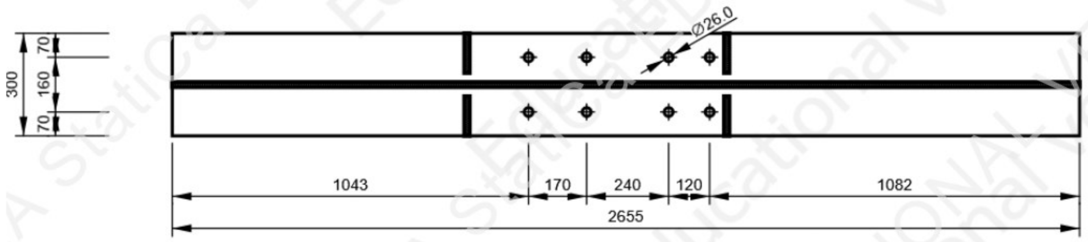
Project:
Project no:
Author:

WID1 - WID1b

P15.0x492-300 (S 355)



C, HEA700 - Bottom flange 1:



Project:
Project no:
Author:

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Symbol explanation

Symbol	Explanation
t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain
$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4
T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\perp}$	Shear stress perpendicular to weld axis
$\tau_{\parallel}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
◢	Fillet weld
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2

Project:
Project no:
Author:

Code settings

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

14.4. Detalj D

Detalj D prikazuje spoj vertikalne stabilizacije i glavnog poprečnog nosača.

Sila u dijagonalama je izračunata u poglavlju 13.1.4.

Project:
Project no:
Author:

Project data

Project name	
Project number	
Author	
Description	
Date	6/19/2024
Code	EN

Material

Steel	S 355

Project:
Project no:
Author:

Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

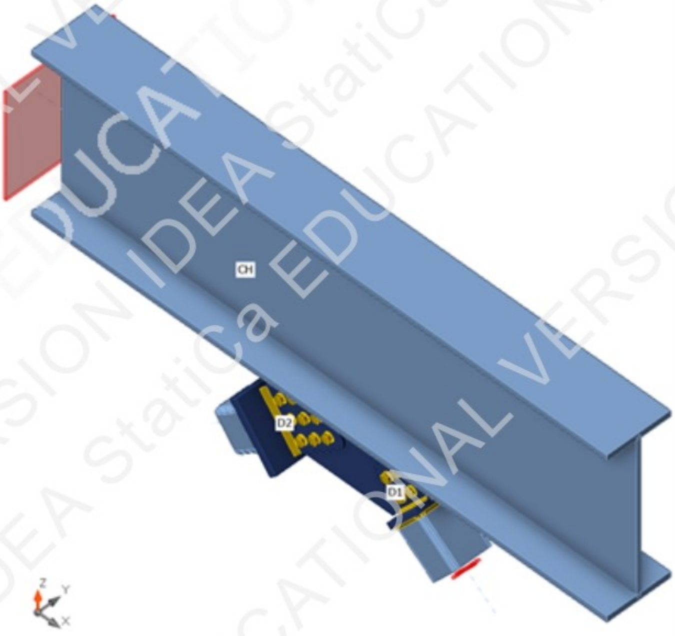
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
CH	4 - HEA800	0.0	0.0	0.0	0	0	0
D1	5 - SHS180/180/8.0	0.0	-39.0	0.0	250	0	-300
D2	5 - SHS180/180/8.0	180.0	-39.0	0.0	250	0	-350

Supports and forces

Name	Support	Forces in	X [mm]
CH / begin	N-Vy-Vz-Mx-My-Mz	Node	0
CH / end		Node	0
D1 / end	Mx-My-Mz	Node	0
D2 / end	Mx-My-Mz	Node	0



Project:
Project no:
Author:

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Cross-sections

Name	Material
4 - HEA800	S 355
5 - SHS180/180/8.0	S 355

Bolts

Name	Diameter [mm]	f_y [MPa]	f_u [MPa]	Gross area [mm^2]
M24 10.9	24	900.0	1000.0	452

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	CH / Begin	0.0	0.0	40.0	0.0	-68.0	0.0
	CH / End	0.0	0.0	-40.0	0.0	-68.0	0.0
	D1 / End	-569.0	0.0	0.0	0.0	0.0	0.0
	D2 / End	1896.0	0.0	0.0	0.0	0.0	0.0

Unbalanced forces

Name	X [kN]	Y [kN]	Z [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	-1915.7	0.0	-835.1	0.0	698.3	0.0

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	4.7 < 5.0%	OK
Loc. deformation	1.1 < 3%	OK
Bolts	99.8 < 100%	OK
Welds	98.4 < 100%	OK
Buckling	4.88	

Project:
Project no:
Author:

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Plates

Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
CH-bfl 1	28.0	LE1	319.8	0.0	0.0	OK
CH-tfl 1	28.0	LE1	184.3	0.0	0.0	OK
CH-w 1	15.0	LE1	314.7	0.0	0.0	OK
D1	8.0	LE1	356.0	0.5	0.0	OK
D2	8.0	LE1	364.8	4.7	0.0	OK
SP1	30.0	LE1	355.2	0.1	27.2	OK
CPL1a	25.0	LE1	236.5	0.0	0.0	OK
CPL1b	15.0	LE1	355.8	0.4	26.6	OK
CPL1c	15.0	LE1	355.8	0.4	26.6	OK
CPL2a	35.0	LE1	357.8	1.3	0.0	OK
CPL2b	18.0	LE1	355.3	0.1	17.6	OK
CPL2c	18.0	LE1	355.3	0.1	17.7	OK

Design data

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

Detailed result for CH-bfl 1

Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} =$ 355.0 MPa – characteristic yield strength

$\gamma_{M0} =$ 1.00 – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CH-tfl 1

Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} =$ 355.0 MPa – characteristic yield strength

$\gamma_{M0} =$ 1.00 – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CH-w 1

Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} =$ 355.0 MPa – characteristic yield strength

$\gamma_{M0} =$ 1.00 – partial safety factor for steel material EN 1993-1-1 – 6.1

Project:
Project no:
Author:

Detailed result for D1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for D2
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for SP1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL1a
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL1b
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Project:
Project no:
Author:

Detailed result for CPL1c
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL2a
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL2b
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL2c
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

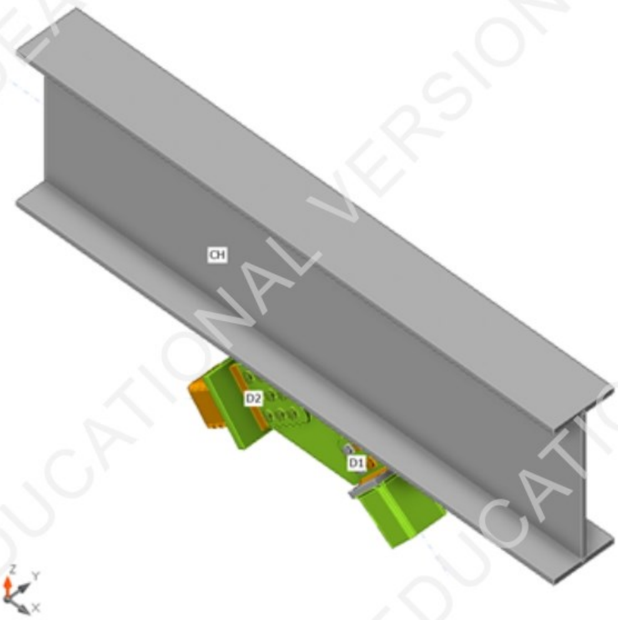
$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

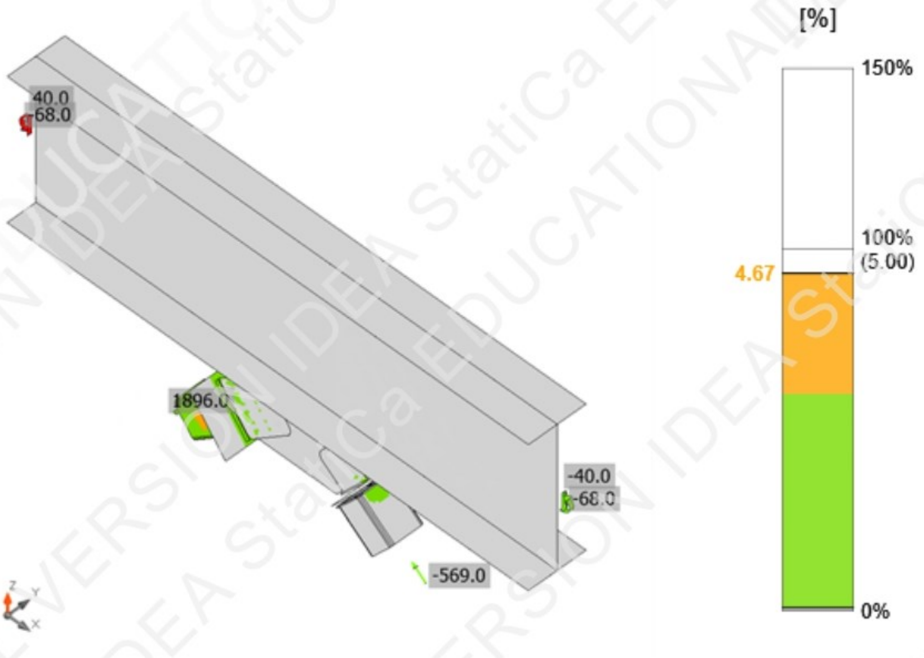
Loc. deformation

Name	d_0 [mm]	Loads	δ [mm]	δ_{lim} [mm]	δ/d_0 [%]	Check status
D1	180	LE1	0	5	0.1	OK
D2	180	LE1	2	5	1.1	OK

Project:
Project no:
Author:

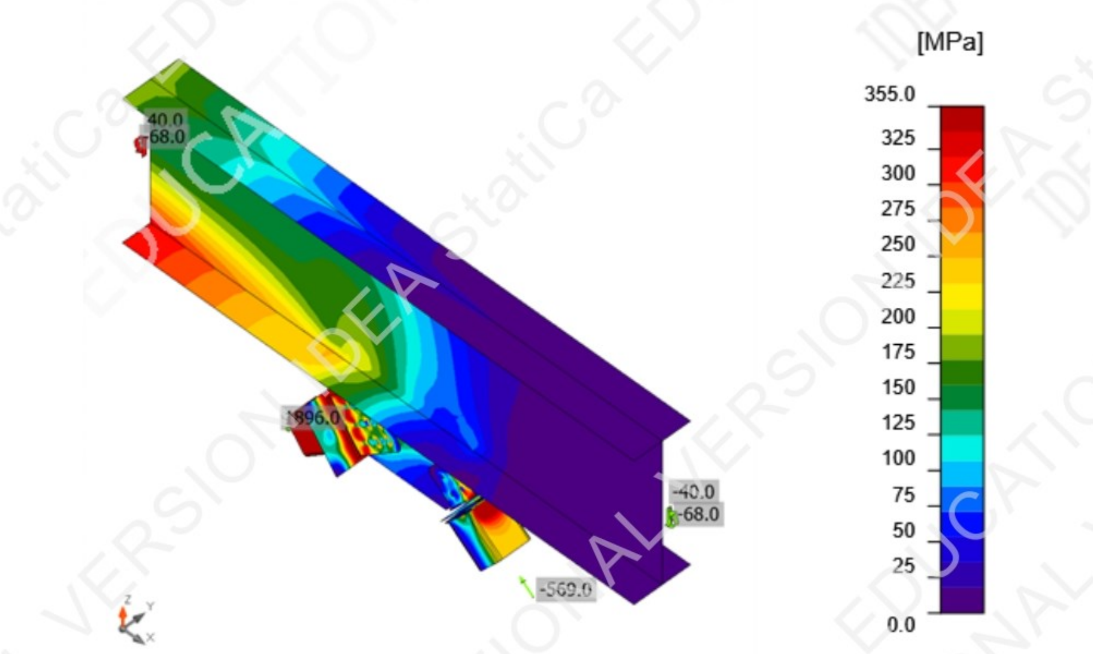


Overall check, LE1



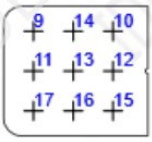
Strain check, LE1

Project:
Project no:
Author:



Equivalent stress, LE1

Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B3	M24 10.9 - 1	LE1	4.7	55.3	273.6	1.8	39.2	40.5	OK	OK
	B4	M24 10.9 - 1	LE1	4.3	55.9	271.4	1.7	39.6	40.8	OK	OK
	B5	M24 10.9 - 1	LE1	14.6	134.6	337.7	5.7	95.4	99.5	OK	OK
	B6	M24 10.9 - 1	LE1	2.7	139.9	226.2	1.0	99.1	99.8	OK	OK
	B9	M24 10.9 - 2	LE1	30.3	104.2	547.3	11.9	73.8	82.3	OK	OK
	B10	M24 10.9 - 2	LE1	8.5	110.4	517.4	3.3	78.2	80.6	OK	OK
	B11	M24 10.9 - 2	LE1	31.4	99.5	547.3	12.4	70.4	79.3	OK	OK
	B12	M24 10.9 - 2	LE1	8.1	104.7	534.7	3.2	74.1	76.4	OK	OK
	B13	M24 10.9 - 2	LE1	2.0	99.6	547.3	0.8	70.5	71.1	OK	OK
	B14	M24 10.9 - 2	LE1	2.4	104.9	547.3	1.0	74.3	75.0	OK	OK
	B15	M24 10.9 - 2	LE1	8.6	112.4	551.9	3.4	79.6	82.0	OK	OK
	B16	M24 10.9 - 2	LE1	2.5	106.6	547.3	1.0	75.5	76.2	OK	OK
	B17	M24 10.9 - 2	LE1	30.9	106.1	547.3	12.1	75.1	83.8	OK	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M24 10.9 - 1	254.2	421.1	141.2
M24 10.9 - 2	254.2	505.3	141.2

Detailed result for B3

Project:
Project no:
Author:

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\ f_{ub}\ A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 4.7 kN

Where:

$k_2 = 0.90$	– Factor
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$A_s = 353$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0,6\ \pi\ d_m\ t_p\ f_u}{\gamma_{M2}} =$ 421.1 kN ≥ $F_{t,Ed} =$ 4.7 kN

Where:

$d_m = 38$ mm	– The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller
$t_p = 15$ mm	– Plate thickness
$f_u = 490.0$ MPa	– Ultimate strength
$\gamma_{M2} = 1.25$	– Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 55.3 kN

Where:

$\beta_p = 1.00$	– Reduction factor for packing
$\alpha_v = 0.50$	– Reduction factor for shear stress
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$A = 353$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\ \alpha_b\ f_u\ dt}{\gamma_{M2}} =$ 273.6 kN ≥ $F_{b,Ed} =$ 55.3 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.78$	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 51 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ 80 mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 140 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ 80 mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 15 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.02 ≤ 1,0

Where:

$F_{t,Ed} =$ 4.7 kN	– Tensile force
$F_{t,Rd} =$ 254.2 kN	– Tension resistance
$B_{p,Rd} =$ 421.1 kN	– Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.39 ≤ 1,0

Where:

$F_{v,Ed} =$ 55.3 kN	– Shear force (in decisive shear plane)
$F_{v,Rd} =$ 141.2 kN	– Shear resistance
$F_{b,Ed} =$ 55.3 kN	– Bearing force (for decisive plate)
$F_{b,Rd} =$ 273.6 kN	– Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\ F_{t,Rd}} =$ 0.40 ≤ 1,0

Where:

$F_{v,Ed} =$ 55.3 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 4.7 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B4

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\ f_{ub}\ A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 4.3 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0,6\ \pi\ d_m\ t_p\ f_u}{\gamma_{M2}} =$ 421.1 kN ≥ $F_{t,Ed} =$ 4.3 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 15 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v\ f_{ub}\ A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 55.9 kN

Where:

$\beta_p =$ 1.00 – Reduction factor for packing

$\alpha_v =$ 0.50 – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \, \alpha_b \, f_u \, dt}{\gamma_{M2}} =$ 271.4 kN ≥ $F_{b,Ed} =$ 55.9 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.77$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 50$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 80$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 26$ mm – Bolt hole diameter

$e_1 = 60$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = \infty$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 24$ mm – Nominal diameter of the fastener

$t = 15$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.02 ≤ 1,0

Where:

$F_{t,Ed} = 4.3$ kN – Tensile force

$F_{t,Rd} = 254.2$ kN – Tension resistance

$B_{p,Rd} = 421.1$ kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.40 ≤ 1,0

Where:

$F_{v,Ed} = 55.9$ kN – Shear force (in decisive shear plane)

$F_{v,Rd} = 141.2$ kN – Shear resistance

$F_{b,Ed} = 55.9$ kN – Bearing force (for decisive plate)

$F_{b,Rd} = 271.4$ kN – Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.41 ≤ 1,0

Where:

$F_{v,Ed} =$ 55.9 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 4.3 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B5

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 14.6 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 421.1 kN ≥ $F_{t,Ed} =$ 14.6 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 15 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v\, f_{ub}\, A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 134.6 kN

Where:

$\beta_p =$ 1.00 – Reduction factor for packing

$\alpha_v =$ 0.50 – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\, \alpha_b\, f_u\, dt}{\gamma_{M2}} =$ 337.7 kN ≥ $F_{b,Ed} =$ 134.6 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.96	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 60 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ ∞ mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 75 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ ∞ mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 15 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd};\, B_{p,Rd})} =$ 0.06 ≤ 1,0

Where:

$F_{t,Ed} =$ 14.6 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

$B_{p,Rd} =$ 421.1 kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.95 ≤ 1,0

Where:

$F_{v,Ed} =$ 134.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 134.6 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 337.7 kN – Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.99 ≤ 1,0

Where:

$F_{v,Ed} =$ 134.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 14.6 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B6

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 2.7 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 421.1 kN ≥ $F_{t,Ed} =$ 2.7 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 15 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 139.9 kN

Where:

$\beta_p =$ 1.00 – Reduction factor for packing

$\alpha_v =$ 0.50 – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \alpha_b f_u dt}{\gamma_{M2}} =$ 226.2 kN ≥ $F_{b,Ed} =$ 139.9 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.64$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 50$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = \infty$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 26$ mm – Bolt hole diameter

$e_1 = 50$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = \infty$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 24$ mm – Nominal diameter of the fastener

$t = 15$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.01 ≤ 1,0

Where:

$F_{t,Ed} = 2.7$ kN – Tensile force

$F_{t,Rd} = 254.2$ kN – Tension resistance

$B_{p,Rd} = 421.1$ kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.99 ≤ 1,0

Where:

$F_{v,Ed} = 139.9$ kN – Shear force (in decisive shear plane)

$F_{v,Rd} = 141.2$ kN – Shear resistance

$F_{b,Ed} = 139.9$ kN – Bearing force (for decisive plate)

$F_{b,Rd} = 226.2$ kN – Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 1.00 ≤ 1,0

Where:

$F_{v,Ed} =$ 139.9 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 2.7 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B9

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 30.3 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 505.3 kN ≥ $F_{t,Ed} =$ 30.3 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 18 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\;\alpha_v f_{ub} A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 104.2 kN

Where:

$\beta_p =$ 1.00 – Reduction factor for packing

$\alpha_v =$ 0.50 – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\ \alpha_b\ f_u\ dt}{\gamma_{M2}} =$ 547.3 kN ≥ $F_{b,Ed} =$ 208.3 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50 – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.78 – Factor for end distance and bolt spacing in direction of load transfer

$e_2 =$ 184 mm – Distance to the plate edge perpendicular to the shear force

$p_2 =$ 80 mm – Distance between bolts perpendicular to the shear force

$d_0 =$ 26 mm – Bolt hole diameter

$e_1 =$ 194 mm – Distance to the plate edge in the direction of the shear force

$p_1 =$ 80 mm – Distance between bolts in the direction of the shear force

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$f_u =$ 490.0 MPa – Ultimate strength of the plate

$d =$ 24 mm – Nominal diameter of the fastener

$t =$ 30 mm – Thickness of the plate

$\gamma_{M2} =$ 1.25 – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd};\ B_{p,Rd})} =$ 0.12 ≤ 1,0

Where:

$F_{t,Ed} =$ 30.3 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

$B_{p,Rd} =$ 505.3 kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.74 ≤ 1,0

Where:

$F_{v,Ed} =$ 104.2 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 208.3 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 547.3 kN – Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.82 ≤ 1,0

Where:

$F_{v,Ed} =$ 104.2 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 30.3 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B10

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 8.5 kN

Where:

$k_2 = 0.90$ – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 505.3 kN ≥ $F_{t,Ed} =$ 8.5 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 18 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v\, f_{ub}\, A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 110.4 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \alpha_b f_u dt}{\gamma_{M2}} =$ 517.4 kN ≥ $F_{b,Ed} =$ 220.8 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.73	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 83 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ 80 mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 57 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ ∞ mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 30 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.03 ≤ 1,0

Where:

$F_{t,Ed} =$ 8.5 kN	– Tensile force
$F_{t,Rd} =$ 254.2 kN	– Tension resistance
$B_{p,Rd} =$ 505.3 kN	– Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.78 ≤ 1,0

Where:

$F_{v,Ed} =$ 110.4 kN	– Shear force (in decisive shear plane)
$F_{v,Rd} =$ 141.2 kN	– Shear resistance
$F_{b,Ed} =$ 220.8 kN	– Bearing force (for decisive plate)
$F_{b,Rd} =$ 517.4 kN	– Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\ F_{t,Rd}} =$ 0.81 ≤ 1,0

Where:

$F_{v,Ed} =$ 110.4 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 8.5 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B11

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\ f_{ub}\ A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 31.4 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0,6\ \pi\ d_m\ t_p\ f_u}{\gamma_{M2}} =$ 505.3 kN ≥ $F_{t,Ed} =$ 31.4 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 18 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 99.5 kN

Where:

$\beta_p =$ 1.00 – Reduction factor for packing

$\alpha_v =$ 0.50 – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\ \alpha_b\ f_u\ dt}{\gamma_{M2}} =$ 547.3 kN ≥ $F_{b,Ed} =$ 198.9 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.78	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 186 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ 80 mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 219 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ 80 mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 30 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.12 ≤ 1,0

Where:

$F_{t,Ed} =$ 31.4 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

$B_{p,Rd} =$ 505.3 kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.70 ≤ 1,0

Where:

$F_{v,Ed} =$ 99.5 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 198.9 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 547.3 kN – Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} = \quad 0.79 \quad \leq \quad 1{,}0$$

Where:

$F_{v,Ed} = 99.5$ kN – Shear force (in decisive shear plane)

$F_{v,Rd} = 141.2$ kN – Shear resistance

$F_{t,Ed} = 31.4$ kN – Tensile force

$F_{t,Rd} = 254.2$ kN – Tension resistance

Detailed result for B12

Tension resistance check (EN 1993-1-8 – Table 3.4)

$$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} = \quad 254.2 \text{ kN} \quad \geq \quad F_{t,Ed} = \quad 8.1 \text{ kN}$$

Where:

$k_2 = 0.90$ – Factor

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A_s = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$$B_{p,Rd} = \frac{0{,}6\,\pi\, d_m\, t_p\, f_u}{\gamma_{M2}} = \quad 505.3 \text{ kN} \quad \geq \quad F_{t,Ed} = \quad 8.1 \text{ kN}$$

Where:

$d_m = 38$ mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p = 18$ mm – Plate thickness

$f_u = 490.0$ MPa – Ultimate strength

$\gamma_{M2} = 1.25$ – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$$F_{v,Rd} = \frac{\beta_p\ \alpha_v\, f_{ub}\, A}{\gamma_{M2}} = \quad 141.2 \text{ kN} \quad \geq \quad F_{v,Ed} = \quad 104.7 \text{ kN}$$

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \, \alpha_b \, f_u \, dt}{\gamma_{M2}} =$ 534.7 kN ≥ $F_{b,Ed} =$ 209.4 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.76$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 135$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 80$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 26$ mm – Bolt hole diameter

$e_1 = 59$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = \infty$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 24$ mm – Nominal diameter of the fastener

$t = 30$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.03 ≤ 1,0

Where:

$F_{t,Ed} = 8.1$ kN – Tensile force

$F_{t,Rd} = 254.2$ kN – Tension resistance

$B_{p,Rd} = 505.3$ kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.74 ≤ 1,0

Where:

$F_{v,Ed} = 104.7$ kN – Shear force (in decisive shear plane)

$F_{v,Rd} = 141.2$ kN – Shear resistance

$F_{b,Ed} = 209.4$ kN – Bearing force (for decisive plate)

$F_{b,Rd} = 534.7$ kN – Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.76 ≤ 1,0

Where:

$F_{v,Ed} =$ 104.7 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 8.1 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B13

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 2.0 kN

Where:

$k_2 = 0.90$ – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 505.3 kN ≥ $F_{t,Ed} =$ 2.0 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 18 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} = 1.25$ – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v\, f_{ub}\, A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 99.6 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\,\alpha_b\,f_u\,dt}{\gamma_{M2}} =$ 547.3 kN ≥ $F_{b,Ed} =$ 199.1 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.78	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 186 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ 80 mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 139 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ 80 mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 30 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd};\,B_{p,Rd})} =$ 0.01 ≤ 1,0

Where:

$F_{t,Ed} =$ 2.0 kN	– Tensile force
$F_{t,Rd} =$ 254.2 kN	– Tension resistance
$B_{p,Rd} =$ 505.3 kN	– Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.71 ≤ 1,0

Where:

$F_{v,Ed} =$ 99.6 kN	– Shear force (in decisive shear plane)
$F_{v,Rd} =$ 141.2 kN	– Shear resistance
$F_{b,Ed} =$ 199.1 kN	– Bearing force (for decisive plate)
$F_{b,Rd} =$ 547.3 kN	– Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.71 ≤ 1,0

Where:

$F_{v,Ed} =$ 99.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 2.0 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B14

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\,f_{ub}\,A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 2.4 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\,d_m\,t_p\,f_u}{\gamma_{M2}} =$ 505.3 kN ≥ $F_{t,Ed} =$ 2.4 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 18 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\;\alpha_v\,f_{ub}\,A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 104.9 kN

Where:

$\beta_p =$ 1.00 – Reduction factor for packing

$\alpha_v =$ 0.50 – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\ \alpha_b\ f_u\ dt}{\gamma_{M2}} =$ 547.3 kN ≥ $F_{b,Ed} =$ 209.8 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.78$	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 134 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ 80 mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 137 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ 80 mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 30 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.01 ≤ 1,0

Where:

$F_{t,Ed} =$ 2.4 kN	– Tensile force
$F_{t,Rd} =$ 254.2 kN	– Tension resistance
$B_{p,Rd} =$ 505.3 kN	– Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.74 ≤ 1,0

Where:

$F_{v,Ed} =$ 104.9 kN	– Shear force (in decisive shear plane)
$F_{v,Rd} =$ 141.2 kN	– Shear resistance
$F_{b,Ed} =$ 209.8 kN	– Bearing force (for decisive plate)
$F_{b,Rd} =$ 547.3 kN	– Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.75 ≤ 1,0

Where:

$F_{v,Ed} =$ 104.9 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 2.4 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B15

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\,f_{ub}\,A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 8.6 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\,d_m\,t_p\,f_u}{\gamma_{M2}} =$ 505.3 kN ≥ $F_{t,Ed} =$ 8.6 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 18 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v\,f_{ub}\,A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 112.4 kN

Where:

$\beta_p =$ 1.00 – Reduction factor for packing

$\alpha_v =$ 0.50 – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \, \alpha_b \, f_u \, dt}{\gamma_{M2}} =$ 551.9 kN ≥ $F_{b,Ed} =$ 224.7 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50 – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.78 – Factor for end distance and bolt spacing in direction of load transfer

$e_2 =$ 74 mm – Distance to the plate edge perpendicular to the shear force

$p_2 =$ 80 mm – Distance between bolts perpendicular to the shear force

$d_0 =$ 26 mm – Bolt hole diameter

$e_1 =$ 61 mm – Distance to the plate edge in the direction of the shear force

$p_1 =$ ∞ mm – Distance between bolts in the direction of the shear force

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$f_u =$ 490.0 MPa – Ultimate strength of the plate

$d =$ 24 mm – Nominal diameter of the fastener

$t =$ 30 mm – Thickness of the plate

$\gamma_{M2} =$ 1.25 – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.03 ≤ 1,0

Where:

$F_{t,Ed} =$ 8.6 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

$B_{p,Rd} =$ 505.3 kN – Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.80 ≤ 1,0

Where:

$F_{v,Ed} =$ 112.4 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 224.7 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 551.9 kN – Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.82 ≤ 1,0

Where:

$F_{v,Ed} =$ 112.4 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 8.6 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B16

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\ f_{ub}\ A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 2.5 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\ \pi\ d_m\ t_p\ f_u}{\gamma_{M2}} =$ 505.3 kN ≥ $F_{t,Ed} =$ 2.5 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 18 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v\, f_{ub}\, A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 106.6 kN

Where:

$\beta_p =$ 1.00 – Reduction factor for packing

$\alpha_v =$ 0.50 – Reduction factor for shear stress

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

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Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \, \alpha_b \, f_u \, dt}{\gamma_{M2}} =$ 547.3 kN ≥ $F_{b,Ed} =$ 213.2 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.78	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 136 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ 80 mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 137 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ 80 mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 30 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.01 ≤ 1,0

Where:

$F_{t,Ed} =$ 2.5 kN	– Tensile force
$F_{t,Rd} =$ 254.2 kN	– Tension resistance
$B_{p,Rd} =$ 505.3 kN	– Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.76 ≤ 1,0

Where:

$F_{v,Ed} =$ 106.6 kN	– Shear force (in decisive shear plane)
$F_{v,Rd} =$ 141.2 kN	– Shear resistance
$F_{b,Ed} =$ 213.2 kN	– Bearing force (for decisive plate)
$F_{b,Rd} =$ 547.3 kN	– Bearing resistance

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Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} = \quad 0.76 \quad \leq \quad 1{,}0$$

Where:

$F_{v,Ed} = 106.6$ kN – Shear force (in decisive shear plane)

$F_{v,Rd} = 141.2$ kN – Shear resistance

$F_{t,Ed} = 2.5$ kN – Tensile force

$F_{t,Rd} = 254.2$ kN – Tension resistance

Detailed result for B17

Tension resistance check (EN 1993-1-8 – Table 3.4)

$$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} = \quad 254.2 \quad \text{kN} \quad \geq \quad F_{t,Ed} = \quad 30.9 \quad \text{kN}$$

Where:

$k_2 = 0.90$ – Factor

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A_s = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$$B_{p,Rd} = \frac{0{,}6\,\pi\, d_m\, t_p\, f_u}{\gamma_{M2}} = \quad 505.3 \quad \text{kN} \quad \geq \quad F_{t,Ed} = \quad 30.9 \quad \text{kN}$$

Where:

$d_m = 38$ mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p = 18$ mm – Plate thickness

$f_u = 490.0$ MPa – Ultimate strength

$\gamma_{M2} = 1.25$ – Safety factor

Shear resistance check (EN 1993-1-8 – Table 3.4)

$$F_{v,Rd} = \frac{\beta_p\;\alpha_v\, f_{ub}\, A}{\gamma_{M2}} = \quad 141.2 \quad \text{kN} \quad \geq \quad F_{v,Ed} = \quad 106.1 \quad \text{kN}$$

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Project:
Project no:
Author:

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \alpha_b f_u dt}{\gamma_{M2}} =$ 547.3 kN ≥ $F_{b,Ed} =$ 212.1 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.78$	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 107 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ 80 mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 26 mm	– Bolt hole diameter
$e_1 =$ 199 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ 80 mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 1000.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength of the plate
$d =$ 24 mm	– Nominal diameter of the fastener
$t =$ 30 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.12 ≤ 1,0

Where:

$F_{t,Ed} =$ 30.9 kN	– Tensile force
$F_{t,Rd} =$ 254.2 kN	– Tension resistance
$B_{p,Rd} =$ 505.3 kN	– Punching resistance

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.75 ≤ 1,0

Where:

$F_{v,Ed} =$ 106.1 kN	– Shear force (in decisive shear plane)
$F_{v,Rd} =$ 141.2 kN	– Shear resistance
$F_{b,Ed} =$ 212.1 kN	– Bearing force (for decisive plate)
$F_{b,Rd} =$ 547.3 kN	– Bearing resistance

Project:
Project no:
Author:

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\ F_{t,Rd}} =$ 0.84 ≤ 1,0

Where:

$F_{v,Ed} =$ 106.1 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 30.9 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
CH-bfl 1	SP1	◢ 9.0 ◣	739	LE1	427.2	0.2	-77.7	77.7	-229.7	98.1	76.9	OK	OK
		◢ 9.0 ◣	739	LE1	427.2	0.2	-77.6	-77.7	229.7	98.1	76.9	OK	OK
CPL1a	CPL1b	◢ 9.0 ◣	198	LE1	427.0	0.1	-227.9	-198.2	64.8	98.0	65.9	OK	OK
		◢ 9.0 ◣	198	LE1	426.9	0.1	-184.7	217.1	-47.7	98.0	67.5	OK	OK
CPL1a	CPL1c	◢ 9.0 ◣	198	LE1	426.9	0.1	-184.7	-217.1	47.6	98.0	67.6	OK	OK
		◢ 9.0 ◣	198	LE1	427.0	0.1	-227.7	198.2	-64.9	98.0	65.9	OK	OK
CPL2a	CPL2b	◢ 12.5	125	LE1	428.8	1.1	229.7	206.1	34.7	98.4	97.4	OK	OK
CPL2a	CPL2b	◢ 12.5	125	LE1	428.6	1.0	234.4	206.7	-13.4	98.4	97.0	OK	OK
CPL2a	CPL2c	◢ 12.5	125	LE1	428.8	1.1	229.7	-206.1	-34.8	98.4	97.4	OK	OK
CPL2a	CPL2c	◢ 12.5	125	LE1	428.6	1.0	234.4	-206.7	13.7	98.4	97.0	OK	OK
CPL1a	D1	◢ 9.0 ◣	654	LE1	258.2	0.0	-125.3	-130.4	-1.4	59.3	26.4	OK	OK
CPL2a	D2	◢ 12.0	655	LE1	427.1	0.1	215.0	-206.1	-53.9	98.0	82.7	OK	OK
		◢ 9.0 ◣	654	LE1	271.6	0.0	-124.6	130.2	-49.7	62.4	29.1	OK	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	490.0	0.90	435.6	352.8

Detailed result for CH-bfl 1 / SP1 - 1

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5} =$ 427.2 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2} =$ 352.8 MPa ≥ $|\sigma_{\perp}| =$ 129.3 MPa

where:

$f_u =$ 490.0 MPa – Ultimate strength

$\beta_w =$ 0.90 – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} =$ 1.25 – Safety factor

Project:
Project no:
Author:

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:

$\sigma_{w,Ed} = 427.2$ MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance

$\sigma_\perp = 129.3$ MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Detailing check

- *Weld is too small. Throat thickness should be greater or equal to 13.8 mm where rupture of the weld is to be avoided for ductility purposes. (FprEN 1993-1-8:2023 – 6.9(4))*

Detailed result for CH-bfl 1 / SP1 - 2

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 427.2 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}\ =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 129.3 MPa

where:

$f_u = 490.0$ MPa – Ultimate strength

$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:

$\sigma_{w,Ed} = 427.2$ MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance

$\sigma_\perp = 129.3$ MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Detailing check

- *Weld is too small. Throat thickness should be greater or equal to 13.8 mm where rupture of the weld is to be avoided for ductility purposes. (FprEN 1993-1-8:2023 – 6.9(4))*

Project:
Project no:
Author:

Detailed result for CPL1a / CPL1b - 1
Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 427.0 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2} =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 233.6 MPa

where:
$f_u = 490.0$ MPa – Ultimate strength
$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1
$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:
$\sigma_{w,Ed} = 427.0$ MPa – Maximum normal stress transverse to the axis of the weld
$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance
$\sigma_\perp = -233.6$ MPa – Normal stress perpendicular to the throat
$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Detailed result for CPL1a / CPL1b - 2
Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 426.9 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2} =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 184.7 MPa

where:
$f_u = 490.0$ MPa – Ultimate strength
$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1
$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:
$\sigma_{w,Ed} = 426.9$ MPa – Maximum normal stress transverse to the axis of the weld
$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance
$\sigma_\perp = -184.7$ MPa – Normal stress perpendicular to the throat
$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Project:
Project no:
Author:

Detailed result for CPL1a / CPL1c - 1

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 426.9 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}\ =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 184.7 MPa

where:

$f_u = 490.0$ MPa – Ultimate strength

$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:

$\sigma_{w,Ed} = 426.9$ MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance

$\sigma_\perp = -184.7$ MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Detailed result for CPL1a / CPL1c - 2

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 427.0 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}\ =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 233.4 MPa

where:

$f_u = 490.0$ MPa – Ultimate strength

$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:

$\sigma_{w,Ed} = 427.0$ MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance

$\sigma_\perp = -233.4$ MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Project:
Project no:
Author:

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Detailed result for CPL2a / CPL2b - 1
Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 428.8 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}$ = 352.8 MPa ≥ $|\sigma_\perp| =$ 237.0 MPa

where:
$f_u = 490.0$ MPa – Ultimate strength
$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1
$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:
$\sigma_{w,Ed} = 428.8$ MPa – Maximum normal stress transverse to the axis of the weld
$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance
$\sigma_\perp = 237.0$ MPa – Normal stress perpendicular to the throat
$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Detailing check

- *Weld is too small. Throat thickness should be greater or equal to 16.5 mm where rupture of the weld is to be avoided for ductility purposes. (FprEN 1993-1-8:2023 – 6.9(4))*

Detailed result for CPL2a / CPL2b - 1
Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 428.6 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}$ = 352.8 MPa ≥ $|\sigma_\perp| =$ 237.4 MPa

where:
$f_u = 490.0$ MPa – Ultimate strength
$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1
$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:
$\sigma_{w,Ed} = 428.6$ MPa – Maximum normal stress transverse to the axis of the weld
$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance
$\sigma_\perp = 237.4$ MPa – Normal stress perpendicular to the throat
$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Project:
Project no:
Author:

Detailing check

- *Weld is too small. Throat thickness should be greater or equal to 16.5 mm where rupture of the weld is to be avoided for ductility purposes. (FprEN 1993-1-8:2023 – 6.9(4))*

Detailed result for CPL2a / CPL2c - 1
Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 428.8 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}\ =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 237.1 MPa

where:
$f_u =$ 490.0 MPa – Ultimate strength
$\beta_w =$ 0.90 – Correlation factor EN 1993-1-8 – Tab. 4.1
$\gamma_{M2} =$ 1.25 – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:
$\sigma_{w,Ed} =$ 428.8 MPa – Maximum normal stress transverse to the axis of the weld
$\sigma_{w,Rd} =$ 435.6 MPa – Equivalent stress resistance
$\sigma_\perp =$ 237.1 MPa – Normal stress perpendicular to the throat
$\sigma_{\perp,Rd} =$ 352.8 MPa – Perpendicular stress resistance

Detailing check

- *Weld is too small. Throat thickness should be greater or equal to 16.5 mm where rupture of the weld is to be avoided for ductility purposes. (FprEN 1993-1-8:2023 – 6.9(4))*

Detailed result for CPL2a / CPL2c - 1
Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 428.6 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}\ =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 237.4 MPa

where:
$f_u =$ 490.0 MPa – Ultimate strength
$\beta_w =$ 0.90 – Correlation factor EN 1993-1-8 – Tab. 4.1
$\gamma_{M2} =$ 1.25 – Safety factor

Project:
Project no:
Author:

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}} ; \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:

$\sigma_{w,Ed} = 428.6$ MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance

$\sigma_\perp = 237.4$ MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Detailing check

- *Weld is too small. Throat thickness should be greater or equal to 16.5 mm where rupture of the weld is to be avoided for ductility purposes. (FprEN 1993-1-8:2023 – 6.9(4))*

Detailed result for CPL1a / D1 - 1

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 258.2 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2} =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 125.3 MPa

where:

$f_u = 490.0$ MPa – Ultimate strength

$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}} ; \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.59 ≤ 1,0

Where:

$\sigma_{w,Ed} = 258.2$ MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance

$\sigma_\perp = -125.3$ MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Detailed result for CPL2a / D2 - 1

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 427.1 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2} =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 215.0 MPa

where:

$f_u = 490.0$ MPa – Ultimate strength

$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} = 1.25$ – Safety factor

Project:
Project no:
Author:

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:

$\sigma_{w,Ed} =$ 427.1 MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} =$ 435.6 MPa – Equivalent stress resistance

$\sigma_\perp =$ 215.0 MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} =$ 352.8 MPa – Perpendicular stress resistance

Detailed result for CPL2a / D2 - 2

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 271.6 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2} =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 127.8 MPa

where:

$f_u =$ 490.0 MPa – Ultimate strength

$\beta_w =$ 0.90 – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} =$ 1.25 – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.62 ≤ 1,0

Where:

$\sigma_{w,Ed} =$ 271.6 MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} =$ 435.6 MPa – Equivalent stress resistance

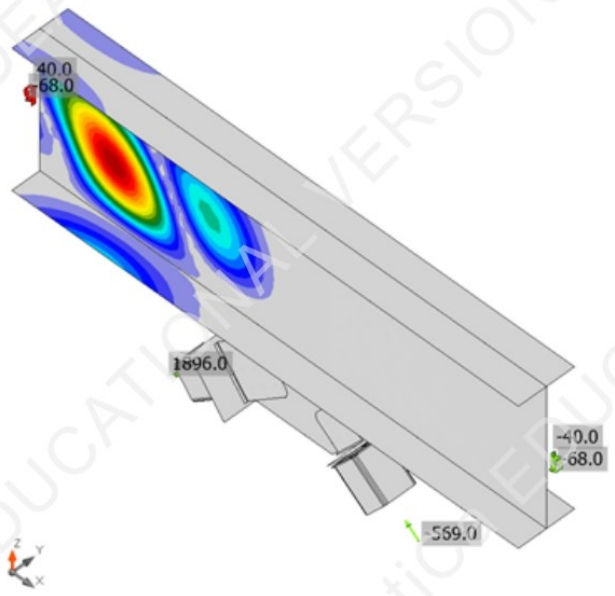
$\sigma_\perp =$ -127.8 MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} =$ 352.8 MPa – Perpendicular stress resistance

Buckling

Loads	Shape	Factor [-]
LE1	1	4.88
	2	4.97
	3	6.44
	4	7.02
	5	9.31
	6	10.05

Project:
Project no:
Author:

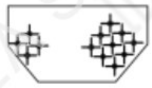
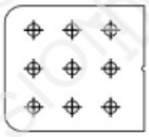
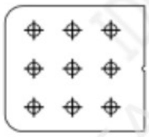


First buckling mode shape, LE1

Project:
Project no:
Author:

Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds Throat thickness [mm]	Length [mm]	Bolts	Nr.
SP1	P30.0x740.0-400.0 (S 355)		1	Double fillet: 9.0	740.0	M24 10.9	13
CPL1	P25.0x200.0-200.0 (S 355)		1	Double fillet: 9.0	1059.4	M24 10.9	4
	P15.0x180.0-200.0 (S 355)		1				
	P15.0x180.0-200.0 (S 355)		1				
CPL2	P35.0x300.0-300.0 (S 355)		1	Fillet: 12.0 Fillet: 12.5 Fillet: 12.5	659.4 250.0 250.0	M24 10.9	9
	P18.0x290.0-260.0 (S 355)		1				
	P18.0x290.0-260.0 (S 355)		1				

Project:
Project no:
Author:

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Double fillet	S 355	9.0	12.7	1799.4
Fillet	S 355	12.5	17.7	250.0
Fillet	S 355	12.0	17.0	659.4
Fillet	S 355	12.5	17.7	250.0

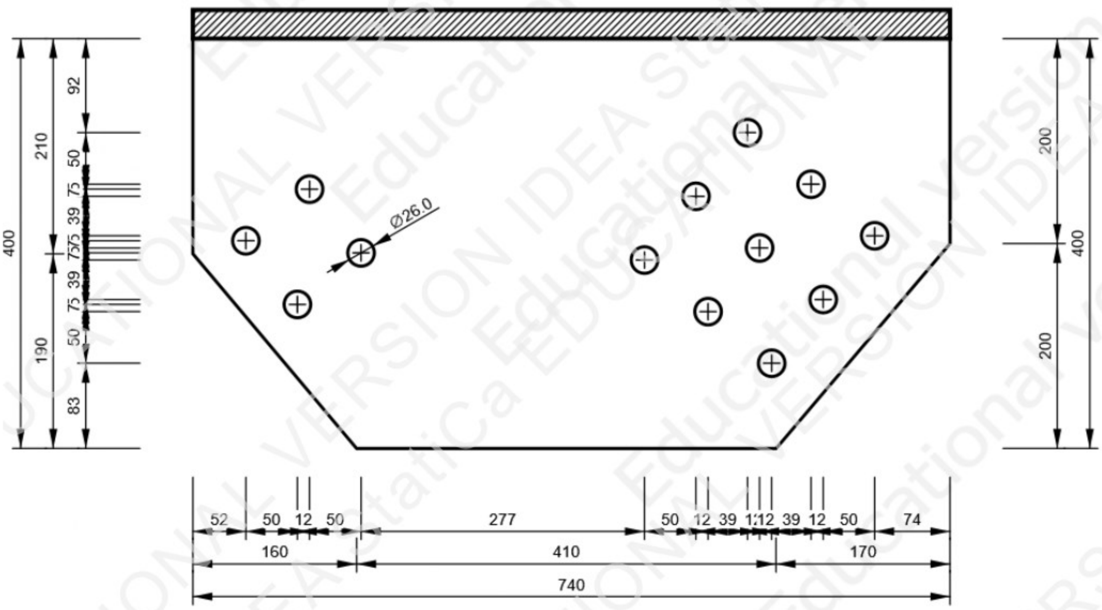
Bolts

Name	Grip length [mm]	Count
M24 10.9	60	4
M24 10.9	66	9

Drawing

SP1

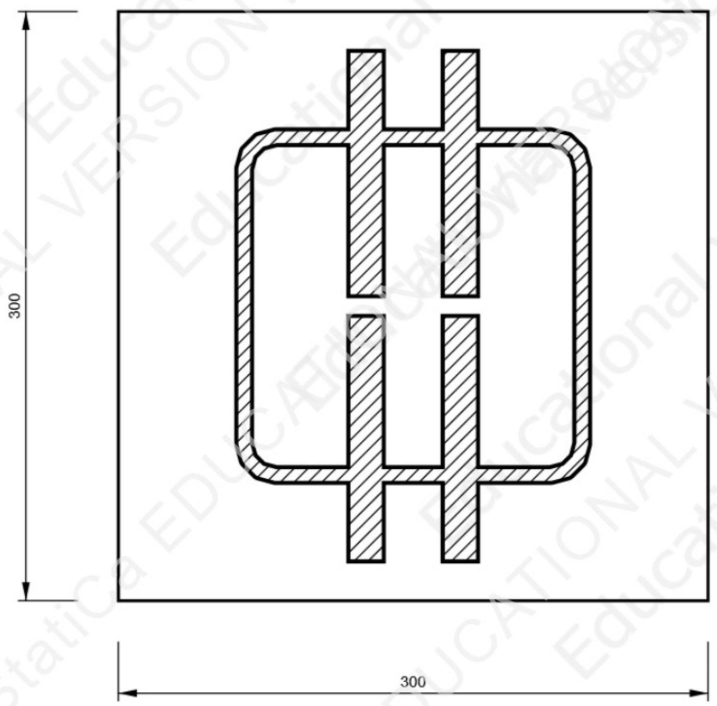
P30.0x400-740 (S 355)



Project:
Project no:
Author:

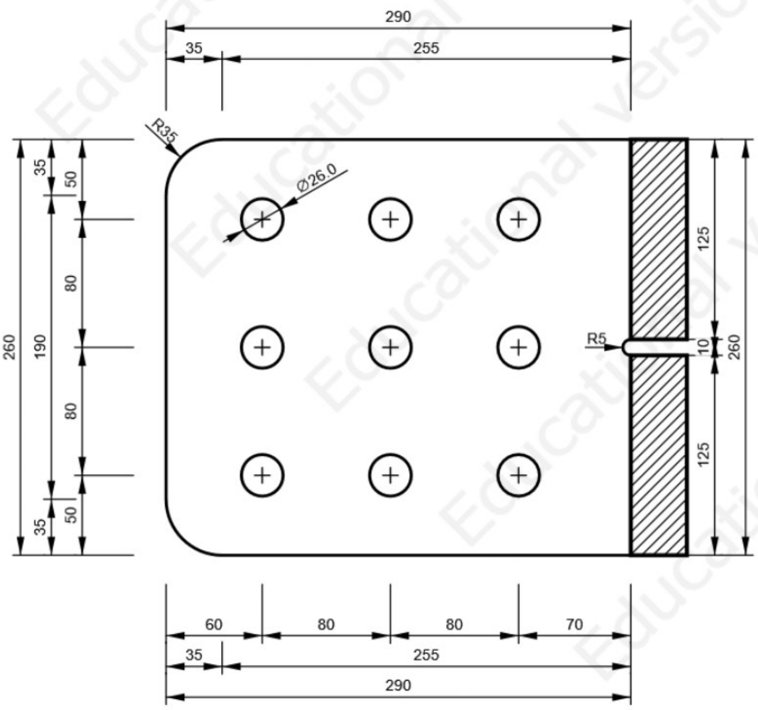
CPL2 - CPL2a

P35.0x300-300 (S 355)



CPL2 - CPL2c

P18.0x260-290 (S 355)



Project:
Project no:
Author:

Symbol explanation

Symbol	Explanation
t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain
$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4
T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\perp}$	Shear stress perpendicular to weld axis
$\tau_{\|\|}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
◢	Fillet weld
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2
d_0	Cross-section size
δ	Local cross-section deformation
δ_{lim}	Allowed deformation

Project:
Project no:
Author:

Code settings

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

14.4. Detalj E

Detalj E prikazuje detalj spajanja vertikalne stabilizacije prvog kata.

Sila u dijagonalama je izračunata u poglavlju 13.1.3.

Project:
Project no:
Author:

Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

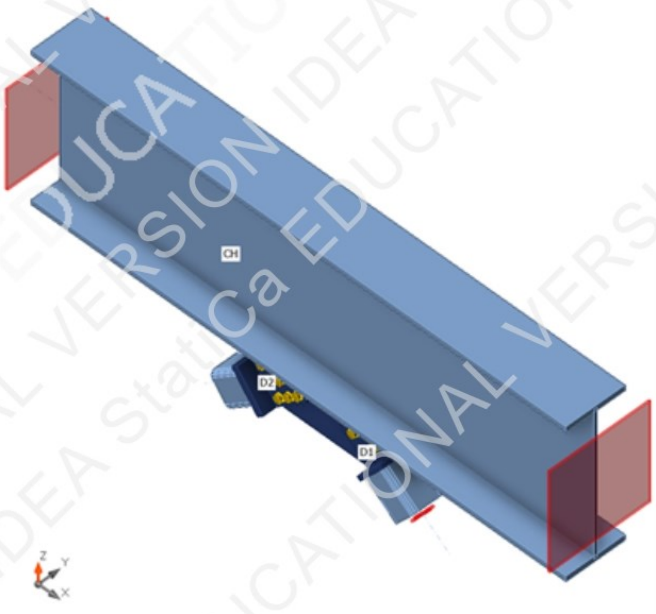
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
CH	4 - HEA800	0.0	0.0	0.0	0	0	0
D1	6 - SHS160/160/10.0	0.0	-39.0	0.0	250	0	-300
D2	6 - SHS160/160/10.0	180.0	-39.0	0.0	250	0	-300

Supports and forces

Name	Support	Forces in	X [mm]
CH / begin	N-Vy-Vz-Mx-My-Mz	Node	0
CH / end	N-Vy-Vz-Mx-My-Mz	Node	0
D1 / end	Mx-My-Mz	Node	0
D2 / end	Mx-My-Mz	Node	0



Project:
Project no:
Author:

Cross-sections

Name	Material
4 - HEA800	S 355
6 - SHS160/160/10.0	S 355

Bolts

Name	Diameter [mm]	f_y [MPa]	f_u [MPa]	Gross area [mm^2]
M24 10.9	24	900.0	1000.0	452
M22 10.9	22	900.0	1000.0	380

Load effects (Equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	D1 / End	-611.0	0.0	0.0	0.0	0.0	0.0
	D2 / End	2037.0	0.0	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	4.0 < 5.0%	OK
Loc. deformation	0.9 < 3%	OK
Bolts	99.9 < 100%	OK
Welds	98.0 < 100%	OK
Buckling	Not calculated	

Plates

Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
CH-bfl 1	28.0	LE1	270.2	0.0	0.0	OK
CH-tfl 1	28.0	LE1	123.4	0.0	0.0	OK
CH-w 1	15.0	LE1	260.9	0.0	0.0	OK
D1	10.0	LE1	342.8	0.0	0.0	OK
D2	10.0	LE1	363.3	4.0	0.0	OK
SP1	22.0	LE1	360.2	2.5	15.2	OK
CPL1a	20.0	LE1	142.4	0.0	0.0	OK
CPL1b	15.0	LE1	288.5	0.0	32.3	OK
CPL1c	15.0	LE1	288.3	0.0	32.3	OK
CPL2a	35.0	LE1	356.2	0.6	0.0	OK
CPL2b	23.0	LE1	355.9	0.4	0.0	OK
CPL2c	23.0	LE1	355.9	0.4	0.0	OK

Project:
Project no:
Author:

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Design data

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

Detailed result for CH-bfl 1

Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CH-tfl 1

Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CH-w 1

Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for D1

Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for D2

Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Project:
Project no:
Author:

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Detailed result for SP1
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:
$f_{yk} = 355.0$ MPa – characteristic yield strength
$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL1a
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:
$f_{yk} = 355.0$ MPa – characteristic yield strength
$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL1b
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:
$f_{yk} = 355.0$ MPa – characteristic yield strength
$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL1c
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:
$f_{yk} = 355.0$ MPa – characteristic yield strength
$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL2a
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:
$f_{yk} = 355.0$ MPa – characteristic yield strength
$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Project:
Project no:
Author:

Detailed result for CPL2b
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

Detailed result for CPL2c
Design values used in the analysis

$f_{yd} = \frac{f_{yk}}{\gamma_{M0}} =$ 355.0 MPa

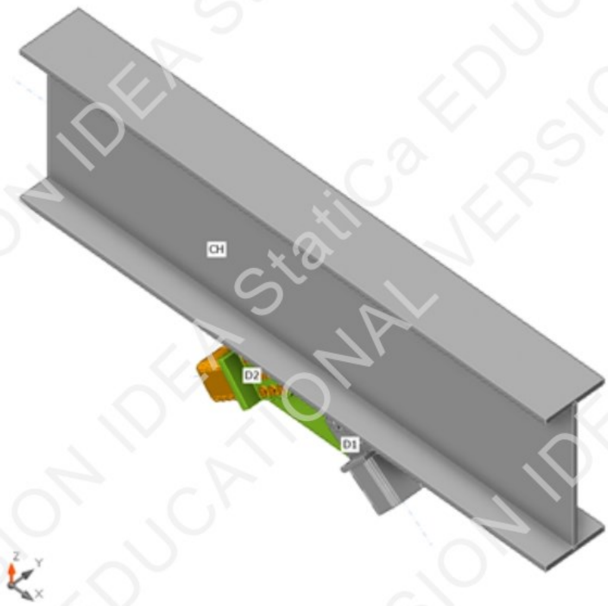
Where:

$f_{yk} = 355.0$ MPa – characteristic yield strength

$\gamma_{M0} = 1.00$ – partial safety factor for steel material EN 1993-1-1 – 6.1

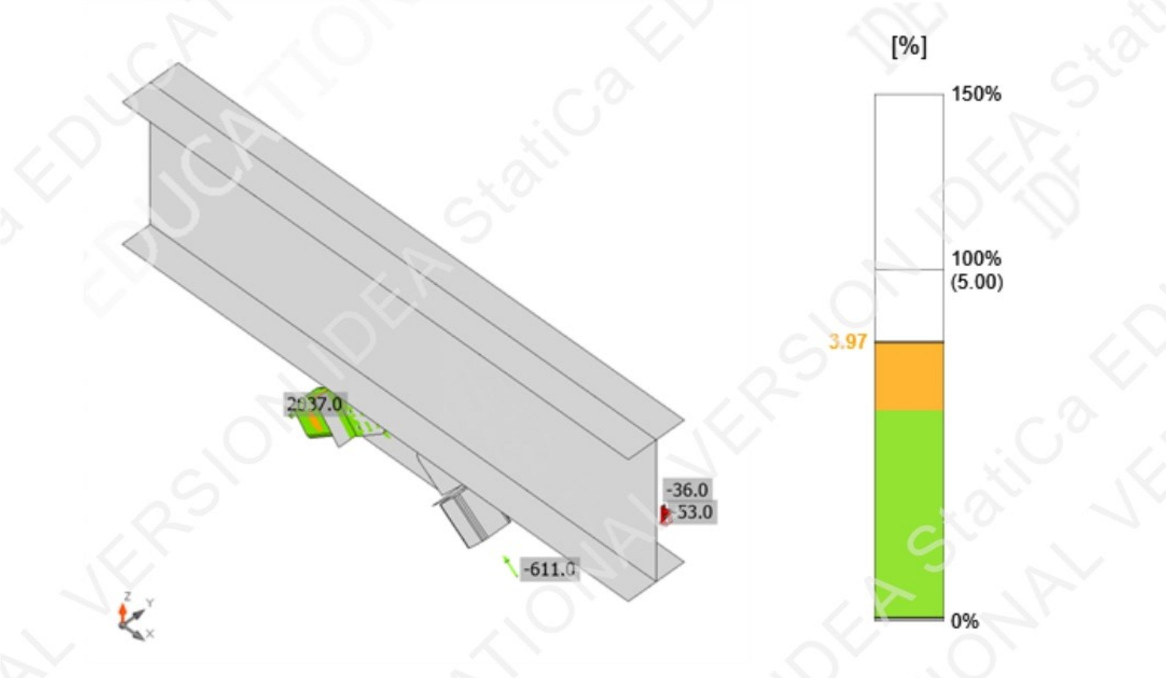
Loc. deformation

Name	d_0 [mm]	Loads	δ [mm]	$δ_{lim}$ [mm]	$δ/d_0$ [%]	Check status
D1	160	LE1	0	5	0.0	OK
D2	160	LE1	1	5	0.9	OK

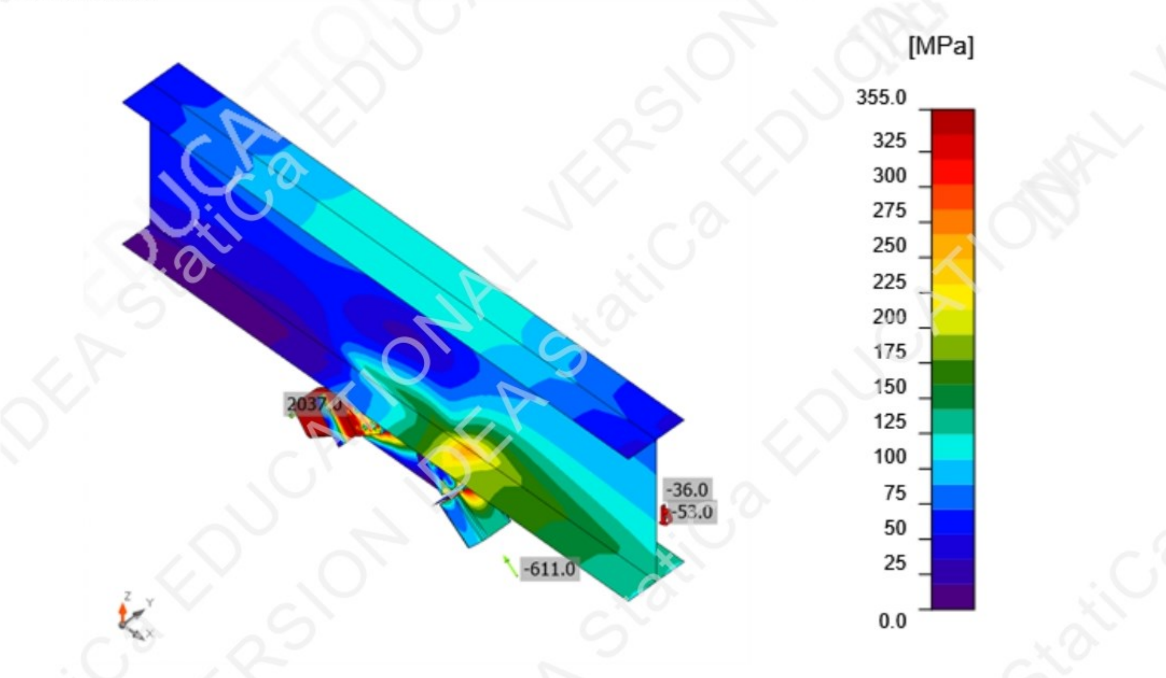


Overall check, LE1

Project:
Project no:
Author:



Strain check, LE1



Equivalent stress, LE1

Project:
Project no:
Author:

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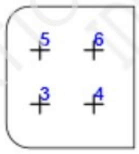
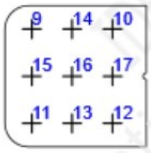
Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B3	M24 10.9 - 1	LE1	6.3	72.3	517.4	2.5	51.2	53.0	OK	OK
	B4	M24 10.9 - 1	LE1	2.3	71.5	401.3	0.9	50.6	51.3	OK	OK
	B5	M24 10.9 - 1	LE1	7.0	81.2	517.4	2.8	57.5	59.5	OK	OK
	B6	M24 10.9 - 1	LE1	2.8	80.8	401.3	1.1	57.2	58.0	OK	OK
	B9	M22 10.9 - 2	LE1	21.7	112.2	263.8	10.0	92.6	99.7	OK	OK
	B10	M22 10.9 - 2	LE1	23.3	111.6	277.5	10.7	92.0	99.7	OK	OK
	B11	M22 10.9 - 2	LE1	21.7	112.2	263.8	9.9	92.6	99.7	OK	OK
	B12	M22 10.9 - 2	LE1	23.3	111.5	294.4	10.7	92.0	99.7	OK	OK
	B13	M22 10.9 - 2	LE1	8.7	117.6	263.8	4.0	97.0	99.8	OK	OK
	B14	M22 10.9 - 2	LE1	8.6	117.6	263.8	3.9	97.0	99.9	OK	OK
	B15	M22 10.9 - 2	LE1	26.5	110.1	263.8	12.1	90.8	99.5	OK	OK
	B16	M22 10.9 - 2	LE1	10.1	116.9	263.8	4.6	96.5	99.8	OK	OK
	B17	M22 10.9 - 2	LE1	27.8	109.5	285.9	12.7	90.3	99.4	OK	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M24 10.9 - 1	254.2	421.1	141.2
M22 10.9 - 2	218.2	609.4	121.2

Detailed result for B3

Tension resistance check (EN 1993-1-8 – Table 3.4)

$$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} = \quad 254.2 \quad \text{kN} \quad \geq \quad F_{t,Ed} = \quad 6.3 \quad \text{kN}$$

Where:

$k_2 = 0.90$ – Factor

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A_s = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} = \quad 421.1 \quad \text{kN} \quad \geq \quad F_{t,Ed} = \quad 6.3 \quad \text{kN}$$

Where:

$d_m = 38$ mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p = 15$ mm – Plate thickness

$f_u = 490.0$ MPa – Ultimate strength

$\gamma_{M2} = 1.25$ – Safety factor

Project:
Project no:
Author:

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 72.3 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 517.4 kN ≥ $F_{b,Ed} =$ 144.7 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 1.00$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 171$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 80$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 26$ mm – Bolt hole diameter

$e_1 = 183$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = \infty$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 24$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.02 ≤ 1,0

Where:

$F_{t,Ed} = 6.3$ kN – Tensile force

$F_{t,Rd} = 254.2$ kN – Tension resistance

$B_{p,Rd} = 421.1$ kN – Punching resistance

Project:
Project no:
Author:

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.51 ≤ 1,0

Where:

$F_{v,Ed} =$ 72.3 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 144.7 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 517.4 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.53 ≤ 1,0

Where:

$F_{v,Ed} =$ 72.3 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 6.3 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B4

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\,f_{ub}\,A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 2.3 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\,d_m\,t_p\,f_u}{\gamma_{M2}} =$ 421.1 kN ≥ $F_{t,Ed} =$ 2.3 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 15 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Project:
Project no:
Author:

Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 71.5 kN

Where:

$\beta_p = 1.00$	– Reduction factor for packing
$\alpha_v = 0.50$	– Reduction factor for shear stress
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$A = 353$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 401.3 kN ≥ $F_{b,Ed} =$ 142.9 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.78$	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 = 123$ mm	– Distance to the plate edge perpendicular to the shear force
$p_2 = 80$ mm	– Distance between bolts perpendicular to the shear force
$d_0 = 26$ mm	– Bolt hole diameter
$e_1 = 233$ mm	– Distance to the plate edge in the direction of the shear force
$p_1 = 80$ mm	– Distance between bolts in the direction of the shear force
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$f_u = 490.0$ MPa	– Ultimate strength of the plate
$d = 24$ mm	– Nominal diameter of the fastener
$t = 22$ mm	– Thickness of the plate
$\gamma_{M2} = 1.25$	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.01 ≤ 1,0

Where:

$F_{t,Ed} = 2.3$ kN	– Tensile force
$F_{t,Rd} = 254.2$ kN	– Tension resistance
$B_{p,Rd} = 421.1$ kN	– Punching resistance

Project:
Project no:
Author:

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.51 ≤ 1,0

Where:

$F_{v,Ed} =$ 71.5 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 142.9 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 401.3 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.51 ≤ 1,0

Where:

$F_{v,Ed} =$ 71.5 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 2.3 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B5

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\,f_{ub}\,A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 7.0 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\,d_m\,t_p\,f_u}{\gamma_{M2}} =$ 421.1 kN ≥ $F_{t,Ed} =$ 7.0 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 15 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 81.2 kN

Where:

$\beta_p = 1.00$	– Reduction factor for packing
$\alpha_v = 0.50$	– Reduction factor for shear stress
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$A = 353$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 517.4 kN ≥ $F_{b,Ed} =$ 162.4 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 1.00$	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 = 109$ mm	– Distance to the plate edge perpendicular to the shear force
$p_2 = 80$ mm	– Distance between bolts perpendicular to the shear force
$d_0 = 26$ mm	– Bolt hole diameter
$e_1 = 121$ mm	– Distance to the plate edge in the direction of the shear force
$p_1 = \infty$ mm	– Distance between bolts in the direction of the shear force
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$f_u = 490.0$ MPa	– Ultimate strength of the plate
$d = 24$ mm	– Nominal diameter of the fastener
$t = 22$ mm	– Thickness of the plate
$\gamma_{M2} = 1.25$	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.03 ≤ 1,0

Where:

$F_{t,Ed} = 7.0$ kN	– Tensile force
$F_{t,Rd} = 254.2$ kN	– Tension resistance
$B_{p,Rd} = 421.1$ kN	– Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.57 ≤ 1,0

Where:

$F_{v,Ed} =$ 81.2 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 162.4 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 517.4 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 0.59 ≤ 1,0

Where:

$F_{v,Ed} =$ 81.2 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 7.0 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B6

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 254.2 kN ≥ $F_{t,Ed} =$ 2.8 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 353 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 421.1 kN ≥ $F_{t,Ed} =$ 2.8 kN

Where:

$d_m =$ 38 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 15 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 141.2 kN ≥ $F_{v,Ed} =$ 80.8 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 353$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 401.3 kN ≥ $F_{b,Ed} =$ 161.7 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.50$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.78$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 124$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 80$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 26$ mm – Bolt hole diameter

$e_1 = 169$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = 80$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 24$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.01 ≤ 1,0

Where:

$F_{t,Ed} = 2.8$ kN – Tensile force

$F_{t,Rd} = 254.2$ kN – Tension resistance

$B_{p,Rd} = 421.1$ kN – Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.57 ≤ 1,0

Where:

$F_{v,Ed} =$ 80.8 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{b,Ed} =$ 161.7 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 401.3 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 0.58 ≤ 1,0

Where:

$F_{v,Ed} =$ 80.8 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 141.2 kN – Shear resistance

$F_{t,Ed} =$ 2.8 kN – Tensile force

$F_{t,Rd} =$ 254.2 kN – Tension resistance

Detailed result for B9

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 21.7 kN

Where:

$k_2 = 0.90$ – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 21.7 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} = 1.25$ – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 112.2 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 303$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 263.8 kN ≥ $F_{b,Ed} =$ 224.4 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.58$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 144$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 70$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 24$ mm – Bolt hole diameter

$e_1 = 151$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = 60$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 22$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.10 ≤ 1,0

Where:

$F_{t,Ed} = 21.7$ kN – Tensile force

$F_{t,Rd} = 218.2$ kN – Tension resistance

$B_{p,Rd} = 609.4$ kN – Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.93 ≤ 1,0

Where:

$F_{v,Ed} =$ 112.2 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 224.4 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 263.8 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 1.00 ≤ 1,0

Where:

$F_{v,Ed} =$ 112.2 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 21.7 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Detailed result for B10

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 23.3 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 23.3 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 111.6 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 303$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\ \alpha_b\ f_u\ dt}{\gamma_{M2}} =$ 277.5 kN ≥ $F_{b,Ed} =$ 223.1 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.61$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 69$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 70$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 24$ mm – Bolt hole diameter

$e_1 = 44$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = \infty$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 22$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.11 ≤ 1,0

Where:

$F_{t,Ed} = 23.3$ kN – Tensile force

$F_{t,Rd} = 218.2$ kN – Tension resistance

$B_{p,Rd} = 609.4$ kN – Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.92 ≤ 1,0

Where:

$F_{v,Ed} =$ 111.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 223.1 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 277.5 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 1.00 ≤ 1,0

Where:

$F_{v,Ed} =$ 111.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 23.3 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Detailed result for B11

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 21.7 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 21.7 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 112.2 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 303$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 263.8 kN ≥ $F_{b,Ed} =$ 224.4 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.58$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 78$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 70$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 24$ mm – Bolt hole diameter

$e_1 = 166$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = 60$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 22$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.10 ≤ 1,0

Where:

$F_{t,Ed} = 21.7$ kN – Tensile force

$F_{t,Rd} = 218.2$ kN – Tension resistance

$B_{p,Rd} = 609.4$ kN – Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.93 ≤ 1,0

Where:

$F_{v,Ed} =$ 112.2 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 224.4 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 263.8 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 1.00 ≤ 1,0

Where:

$F_{v,Ed} =$ 112.2 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 21.7 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Detailed result for B12

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 23.3 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0,6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 23.3 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 111.5 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 303$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 294.4 kN ≥ $F_{b,Ed} =$ 223.1 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.65$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 73$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 70$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 24$ mm – Bolt hole diameter

$e_1 = 47$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = \infty$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 22$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.11 ≤ 1,0

Where:

$F_{t,Ed} = 23.3$ kN – Tensile force

$F_{t,Rd} = 218.2$ kN – Tension resistance

$B_{p,Rd} = 609.4$ kN – Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.92 ≤ 1,0

Where:

$F_{v,Ed} =$ 111.5 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 223.1 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 294.4 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 1.00 ≤ 1,0

Where:

$F_{v,Ed} =$ 111.5 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 23.3 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Detailed result for B13

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 8.7 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 8.7 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

Project:
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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 117.6 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 303$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 263.8 kN ≥ $F_{b,Ed} =$ 235.1 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.58$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 118$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 70$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 24$ mm – Bolt hole diameter

$e_1 = 107$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = 60$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 22$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.04 ≤ 1,0

Where:

$F_{t,Ed} = 8.7$ kN – Tensile force

$F_{t,Rd} = 218.2$ kN – Tension resistance

$B_{p,Rd} = 609.4$ kN – Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.97 ≤ 1,0

Where:

$F_{v,Ed} =$ 117.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 235.1 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 263.8 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 1.00 ≤ 1,0

Where:

$F_{v,Ed} =$ 117.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 8.7 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Detailed result for B14

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 8.6 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 8.6 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p\ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 117.6 kN

Where:

$\beta_p = 1.00$	– Reduction factor for packing
$\alpha_v = 0.50$	– Reduction factor for shear stress
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$A = 303$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1\ \alpha_b\ f_u\ dt}{\gamma_{M2}} =$ 263.8 kN ≥ $F_{b,Ed} =$ 235.2 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.58$	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 = 107$ mm	– Distance to the plate edge perpendicular to the shear force
$p_2 = 70$ mm	– Distance between bolts perpendicular to the shear force
$d_0 = 24$ mm	– Bolt hole diameter
$e_1 = 104$ mm	– Distance to the plate edge in the direction of the shear force
$p_1 = 60$ mm	– Distance between bolts in the direction of the shear force
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$f_u = 490.0$ MPa	– Ultimate strength of the plate
$d = 22$ mm	– Nominal diameter of the fastener
$t = 22$ mm	– Thickness of the plate
$\gamma_{M2} = 1.25$	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.04 ≤ 1,0

Where:

$F_{t,Ed} = 8.6$ kN	– Tensile force
$F_{t,Rd} = 218.2$ kN	– Tension resistance
$B_{p,Rd} = 609.4$ kN	– Punching resistance

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Author:

Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.97 ≤ 1,0

Where:

$F_{v,Ed} =$ 117.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 235.2 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 263.8 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 1.00 ≤ 1,0

Where:

$F_{v,Ed} =$ 117.6 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 8.6 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Detailed result for B15

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 26.5 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 26.5 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 110.1 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 303$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 263.8 kN ≥ $F_{b,Ed} =$ 220.1 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.58$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 146$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 70$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 24$ mm – Bolt hole diameter

$e_1 = 166$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = 60$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 22$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.12 ≤ 1,0

Where:

$F_{t,Ed} = 26.5$ kN – Tensile force

$F_{t,Rd} = 218.2$ kN – Tension resistance

$B_{p,Rd} = 609.4$ kN – Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.91 ≤ 1,0

Where:

$F_{v,Ed} =$ 110.1 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 220.1 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 263.8 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.99 ≤ 1,0

Where:

$F_{v,Ed} =$ 110.1 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 26.5 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Detailed result for B16

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 10.1 kN

Where:

$k_2 =$ 0.90 – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\,\pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 10.1 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 116.9 kN

Where:

$\beta_p = 1.00$	– Reduction factor for packing
$\alpha_v = 0.50$	– Reduction factor for shear stress
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$A = 303$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 263.8 kN ≥ $F_{b,Ed} =$ 233.8 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.58$	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 = 161$ mm	– Distance to the plate edge perpendicular to the shear force
$p_2 = 70$ mm	– Distance between bolts perpendicular to the shear force
$d_0 = 24$ mm	– Bolt hole diameter
$e_1 = 106$ mm	– Distance to the plate edge in the direction of the shear force
$p_1 = 60$ mm	– Distance between bolts in the direction of the shear force
$f_{ub} = 1000.0$ MPa	– Ultimate tensile strength of the bolt
$f_u = 490.0$ MPa	– Ultimate strength of the plate
$d = 22$ mm	– Nominal diameter of the fastener
$t = 22$ mm	– Thickness of the plate
$\gamma_{M2} = 1.25$	– Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.05 ≤ 1,0

Where:

$F_{t,Ed} = 10.1$ kN	– Tensile force
$F_{t,Rd} = 218.2$ kN	– Tension resistance
$B_{p,Rd} = 609.4$ kN	– Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.96 ≤ 1,0

Where:

$F_{v,Ed} =$ 116.9 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 233.8 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 263.8 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 1.00 ≤ 1,0

Where:

$F_{v,Ed} =$ 116.9 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 10.1 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Detailed result for B17

Tension resistance check (EN 1993-1-8 – Table 3.4)

$F_{t,Rd} = \frac{k_2\, f_{ub}\, A_s}{\gamma_{M2}} =$ 218.2 kN ≥ $F_{t,Ed} =$ 27.8 kN

Where:

$k_2 = 0.90$ – Factor

$f_{ub} =$ 1000.0 MPa – Ultimate tensile strength of the bolt

$A_s =$ 303 mm^2 – Tensile stress area of the bolt

$\gamma_{M2} =$ 1.25 – Safety factor

Punching resistance check (EN 1993-1-8 – Table 3.4)

$B_{p,Rd} = \frac{0{,}6\, \pi\, d_m\, t_p\, f_u}{\gamma_{M2}} =$ 609.4 kN ≥ $F_{t,Ed} =$ 27.8 kN

Where:

$d_m =$ 36 mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p =$ 23 mm – Plate thickness

$f_u =$ 490.0 MPa – Ultimate strength

$\gamma_{M2} =$ 1.25 – Safety factor

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Shear resistance check (EN 1993-1-8 – Table 3.4)

$F_{v,Rd} = \frac{\beta_p \ \alpha_v f_{ub} A}{\gamma_{M2}} =$ 121.2 kN ≥ $F_{v,Ed} =$ 109.5 kN

Where:

$\beta_p = 1.00$ – Reduction factor for packing

$\alpha_v = 0.50$ – Reduction factor for shear stress

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$A = 303$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 – Table 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 285.9 kN ≥ $F_{b,Ed} =$ 219.0 kN

Where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) = 2.38$ – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) = 0.63$ – Factor for end distance and bolt spacing in direction of load transfer

$e_2 = 131$ mm – Distance to the plate edge perpendicular to the shear force

$p_2 = 70$ mm – Distance between bolts perpendicular to the shear force

$d_0 = 24$ mm – Bolt hole diameter

$e_1 = 46$ mm – Distance to the plate edge in the direction of the shear force

$p_1 = \infty$ mm – Distance between bolts in the direction of the shear force

$f_{ub} = 1000.0$ MPa – Ultimate tensile strength of the bolt

$f_u = 490.0$ MPa – Ultimate strength of the plate

$d = 22$ mm – Nominal diameter of the fastener

$t = 22$ mm – Thickness of the plate

$\gamma_{M2} = 1.25$ – Safety factor

Utilization in tension

$\frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 0.13 ≤ 1,0

Where:

$F_{t,Ed} = 27.8$ kN – Tensile force

$F_{t,Rd} = 218.2$ kN – Tension resistance

$B_{p,Rd} = 609.4$ kN – Punching resistance

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Utilization in shear

$\max(\frac{F_{v,Ed}}{F_{v,Rd}}; \frac{F_{b,Ed}}{F_{b,Rd}}) =$ 0.90 ≤ 1,0

Where:

$F_{v,Ed} =$ 109.5 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{b,Ed} =$ 219.0 kN – Bearing force (for decisive plate)

$F_{b,Rd} =$ 285.9 kN – Bearing resistance

Interaction of tension and shear (EN 1993-1-8 – Table 3.4)

$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\,F_{t,Rd}} =$ 0.99 ≤ 1,0

Where:

$F_{v,Ed} =$ 109.5 kN – Shear force (in decisive shear plane)

$F_{v,Rd} =$ 121.2 kN – Shear resistance

$F_{t,Ed} =$ 27.8 kN – Tensile force

$F_{t,Rd} =$ 218.2 kN – Tension resistance

Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
CH-bfl 1	SP1	◢ 12.0 ◣	729	LE1	427.1	0.1	154.1	-154.1	-170.7	98.0	64.3	OK	OK
		◢ 12.0 ◣	729	LE1	427.1	0.1	154.2	154.1	170.7	98.0	64.3	OK	OK
CPL1a	CPL1b	-	180	-	-	-	-	-	-	-	-	OK	OK
CPL1a	CPL1c	-	180	-	-	-	-	-	-	-	-	OK	OK
CPL2a	CPL2b	-	100	-	-	-	-	-	-	-	-	OK	OK
CPL2a	CPL2b	-	100	-	-	-	-	-	-	-	-	OK	OK
CPL2a	CPL2c	-	100	-	-	-	-	-	-	-	-	OK	OK
CPL2a	CPL2c	-	100	-	-	-	-	-	-	-	-	OK	OK
CPL1a	D1-w 1	-	674	-	-	-	-	-	-	-	-	OK	OK
CPL2a	D2-w 1	-	674	-	-	-	-	-	-	-	-	OK	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	490.0	0.90	435.6	352.8

Project:
Project no:
Author:

Detailed result for CH-bfl 1 / SP1 - 1

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 427.1 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}\ =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 154.1 MPa

where:

$f_u = 490.0$ MPa – Ultimate strength

$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:

$\sigma_{w,Ed} = 427.1$ MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance

$\sigma_\perp = 154.1$ MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

Detailed result for CH-bfl 1 / SP1 - 2

Weld resistance check (EN 1993-1-8 – Cl. 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 427.1 MPa

$\sigma_{\perp,Rd} = 0,9\ f_u\ /\ \gamma_{M2}\ =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 154.2 MPa

where:

$f_u = 490.0$ MPa – Ultimate strength

$\beta_w = 0.90$ – Correlation factor EN 1993-1-8 – Tab. 4.1

$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 0.98 ≤ 1,0

Where:

$\sigma_{w,Ed} = 427.1$ MPa – Maximum normal stress transverse to the axis of the weld

$\sigma_{w,Rd} = 435.6$ MPa – Equivalent stress resistance

$\sigma_\perp = 154.2$ MPa – Normal stress perpendicular to the throat

$\sigma_{\perp,Rd} = 352.8$ MPa – Perpendicular stress resistance

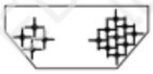
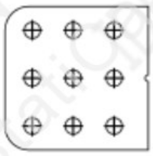
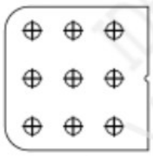
Detailed result for CPL1a / CPL1b - 1

Butt welds are not checked. Their resistance is assumed to be the same as that of the welded member.

Project:
Project no:
Author:

Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds Throat thickness [mm]	Length [mm]	Bolts	Nr.
SP1	P22.0x730.0-320.0 (S 355)		1	Double fillet: 12.0	730.0	M24 10.9 M22 10.9	4 9
CPL1	P20.0x180.0-180.0 (S 355)		1	Butt: 10.0 Butt: 15.0	564.2 360.0	M24 10.9	4
	P15.0x190.0-210.0 (S 355)		1				
	P15.0x190.0-210.0 (S 355)		1				
CPL2	P35.0x210.0-210.0 (S 355)		1	Butt: 10.0 Butt: 23.0	564.2 400.0	M22 10.9	9
	P23.0x210.0-210.0 (S 355)		1				
	P23.0x210.0-210.0 (S 355)		1				

Project:
Project no:
Author:

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Double fillet	S 355	12.0	17.0	730.0
Butt	S 355	-	-	360.0
Butt	S 355	-	-	1128.5
Butt	S 355	-	-	400.0

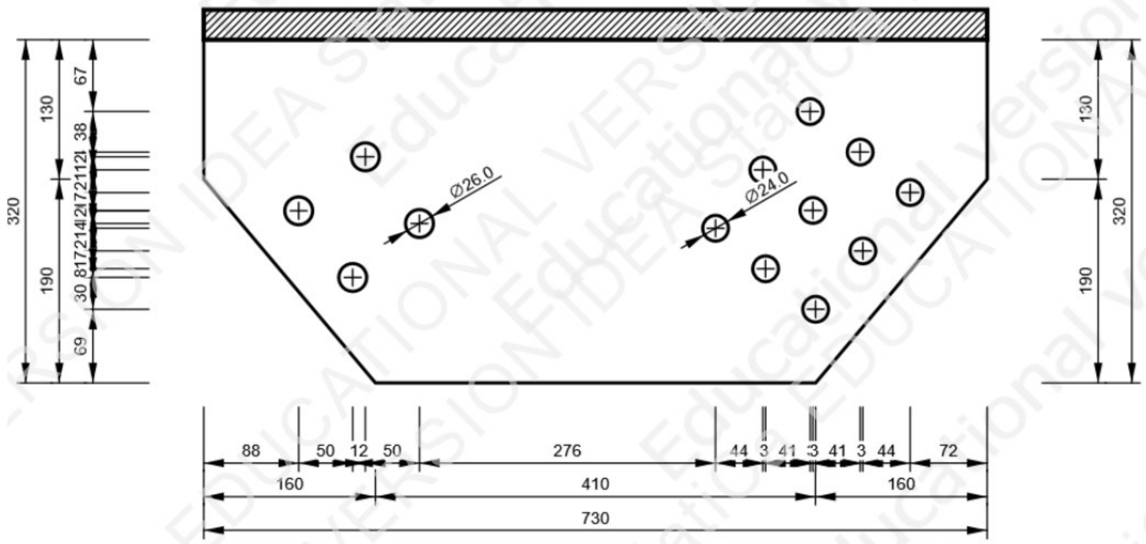
Bolts

Name	Grip length [mm]	Count
M24 10.9	52	4
M22 10.9	68	9

Drawing

SP1

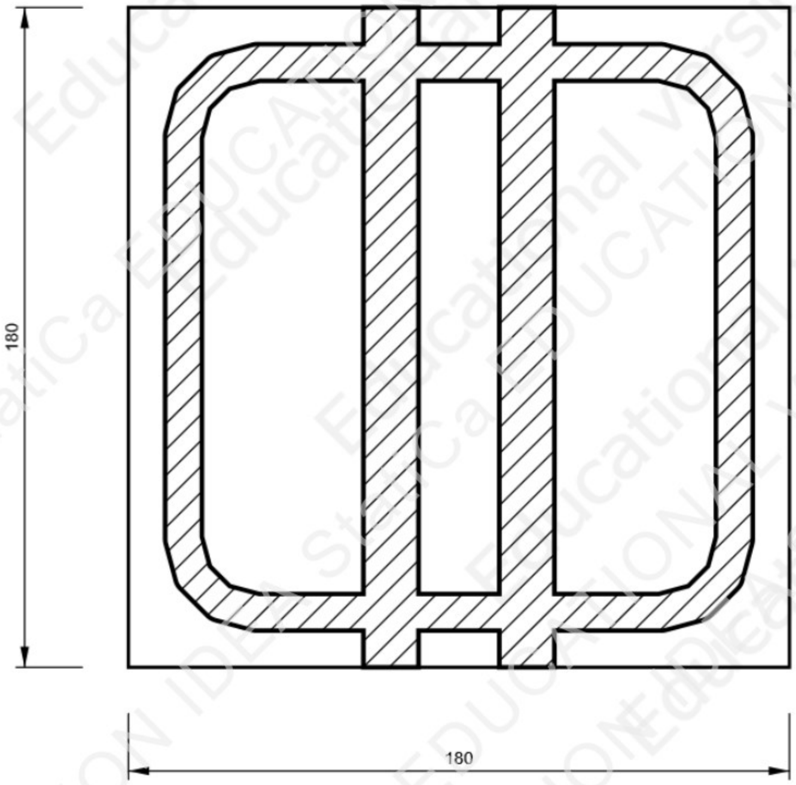
P22.0x320-730 (S 355)



Project:
Project no:
Author:

CPL1 - CPL1a

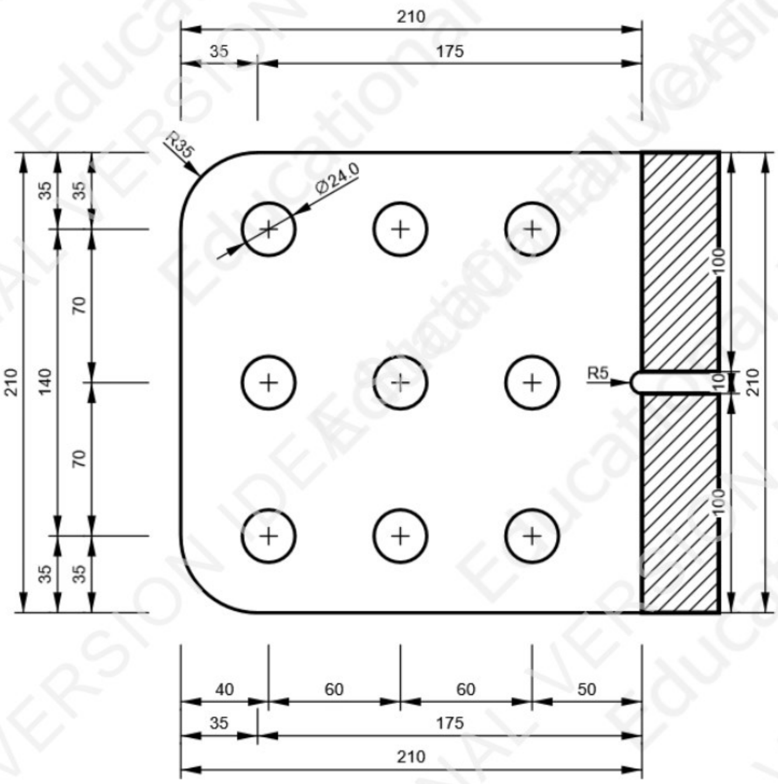
P20.0x180-180 (S 355)



Project:
Project no:
Author:

CPL2 - CPL2c

P23.0x210-210 (S 355)



Project:
Project no:
Author:

Symbol explanation

Symbol	Explanation
t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain
$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4
T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\perp}$	Shear stress perpendicular to weld axis
$\tau_{\parallel}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
◢	Fillet weld
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2
d_0	Cross-section size
δ	Local cross-section deformation
δ_{lim}	Allowed deformation

Project:
Project no:
Author:

IDEA StatiCa® Calculate yesterday's estimates

Code settings

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

15 ISKAZ MATERIJALA

Poz.	Element	Profil	Duljina (m)	Specifična masa (kg/m)	Broj komada	Masa (kg)
S1	Stup	HEA 700	11,0	204	12	26 928
S2	Stup	HEA 450	7,00	140	12	11 760
S3	Stup	HEM 500	18,0	270	12	58 320
G1	U. greda	HEA 400	10,0	125	20	25 000
G2	U. greda	HEA 360	10,0	112	20	22 400
G3	U. greda	HEA 500	10,0	155	20	31 000
G4	U. greda	HEA 600	10,0	178	20	35 600
G5	P. greda	HEA 800	11,57	224	24	62 200
G6	P. greda	HEA 550	11,57	166	12	23 048
G7	P. greda	HEA 450	11,57	140	20	32 396
D1	Dijagonala	140x140/5	6,76	20,5	16	2 217
D2	Dijagonala	140X140/8	6,76	31,4	16	3 396
D3	Dijagonala	160x160/10	8,00	43,7	16	5 594
D4	Dijagonala	180x180/8	8,00	41,5	16	5 312
SN1	Spr. nosač	IPE 330	11,57	49,1	153	86 917
SN2	Spr. nosač	IPE300	11,57	42,2	51	24 901
					Ukupno (kg):	456 962
					Utrošak materijala na priključcima (varovi I vijci):	5%
					Površina zgrade (m^2):	7 000
					Volumen zgrade (m^3)	31 500
					Ukupno s priključcima (kg):	479 810
					Utrošak čelika po m^2 ($^{kg}/_{m^2}$)	68,5
					Utrošak čelika po m^3 ($^{kg}/_{m^3}$)	15,2

POPIS LITERATURE

[1] https://www.kazup.hr/index.php/zupanija/opci-podaci; preuzeto: 20.06.2024

[2] Tehnički propis za čelične konstrukcije; NN br. 112/08, 125/10, 73/12 i 136/12

[3] Tehnički propis za spregnute konstrukcije od čelika i betona; NN br. 119/10, 125/10 i 136/12

[4] HRN EN 1990 Eurocode 0- Osnove projektiranja:

[5] HRN EN 1991 Eurocode 1- Djelovanja na konstrukcije

[6] HRN EN 1993 Eurocode 3- Projektiranje čeličnih konstrukcija

[7] HRN EN 1994 Eurocode 4- Projektiranje spregnutih čelično-betonskih konstrukcija

[8] HRN EN 1998 Eurocode 8- Projektiranje potresne otpornosti konstrukcija

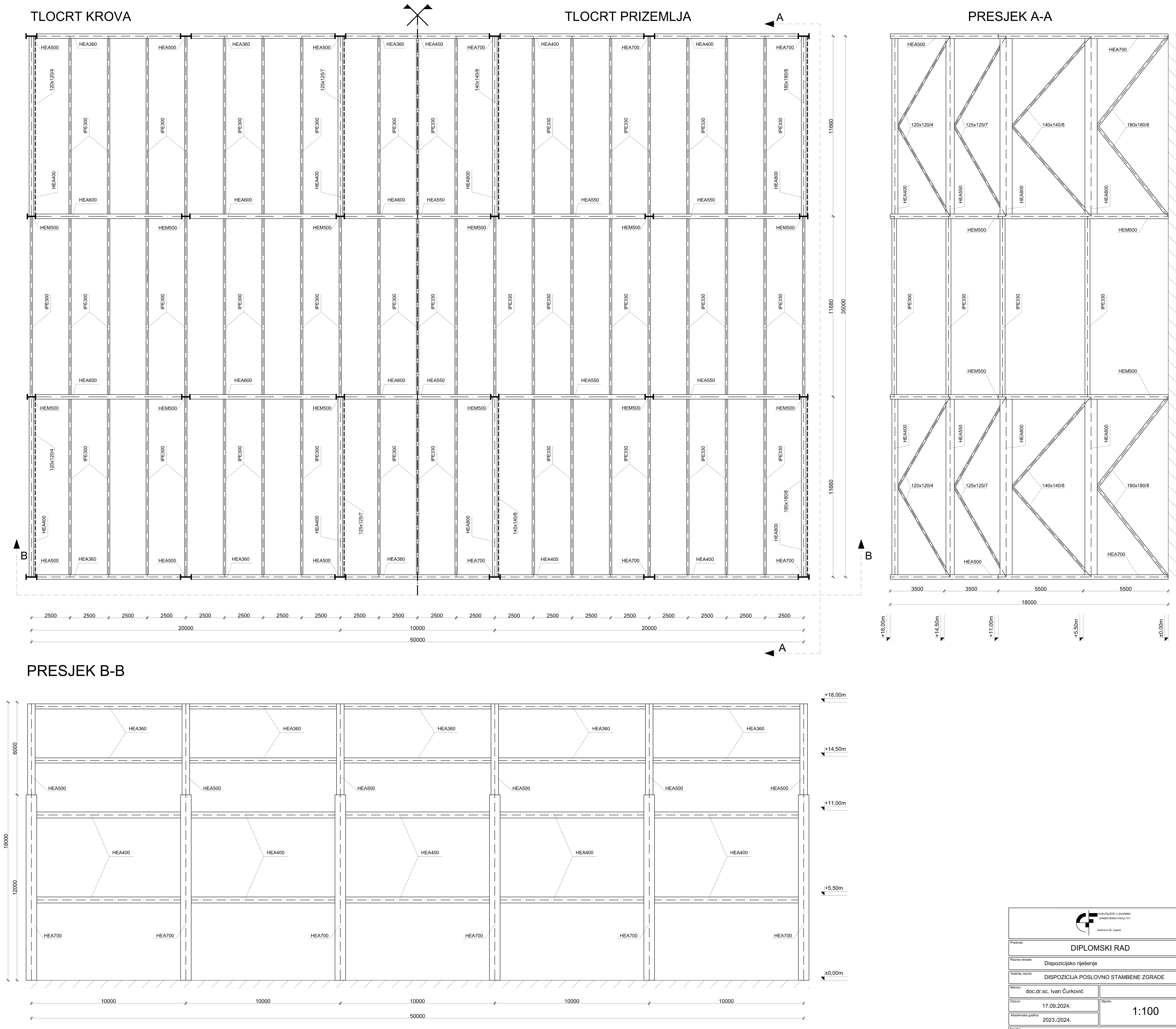
[9] https://www.scribd.com/document/407820929/Analiza-optere%C4%87enja-pdf; preuzeto: 15.5.2023.

[10] Državni hidrometrološki zavod; preuzeto 15.5.2023.

[11] ArcelatorMittal: „*Composite floor decking*“

POPIS SLIKA

POPIS TABLICA



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Razina obrade: Dispozicijsko riješenje	
Sadržaj nacrta: DISPOZICIJA POSLOVNO STAMBENE ZGRADE	
Mentor: doc.dr.sc. Ivan Ćurković	
Datum: 17.09.2024.	Mjerilo: 1:100
Akademska godina: 2023./2024.	
Izradio: Poljak Marija	

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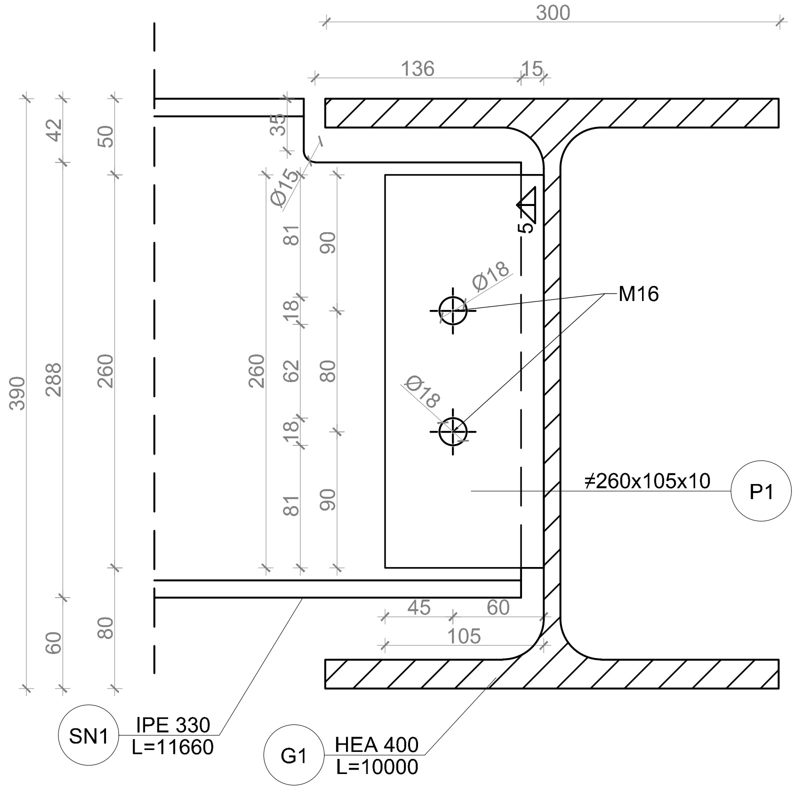

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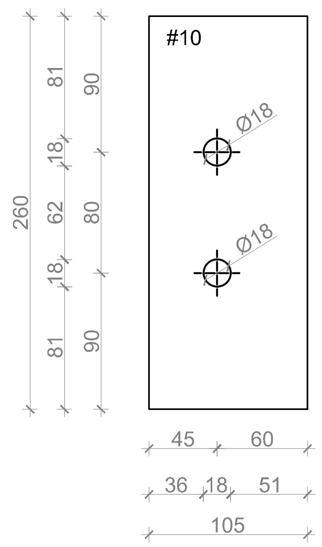

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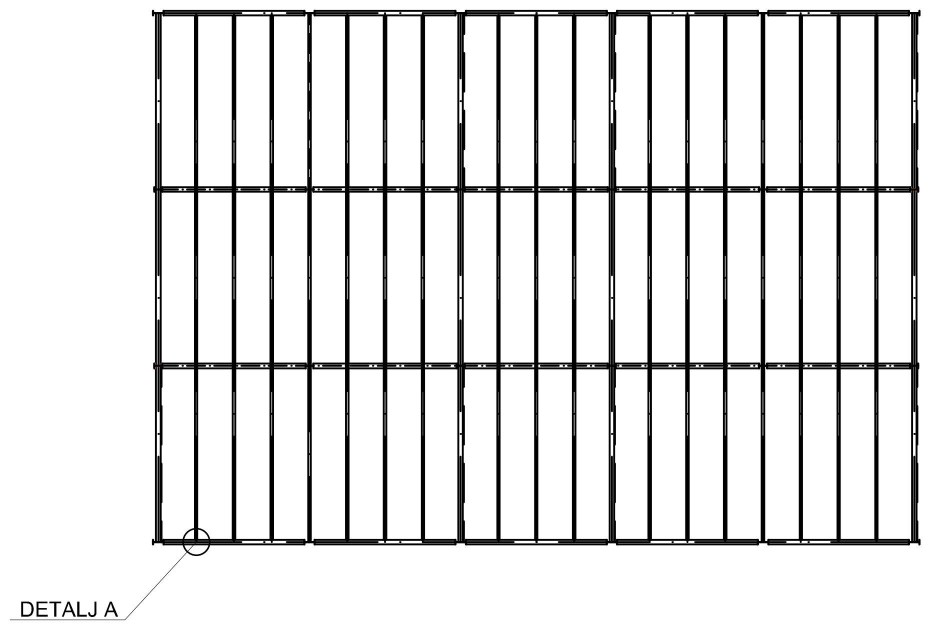

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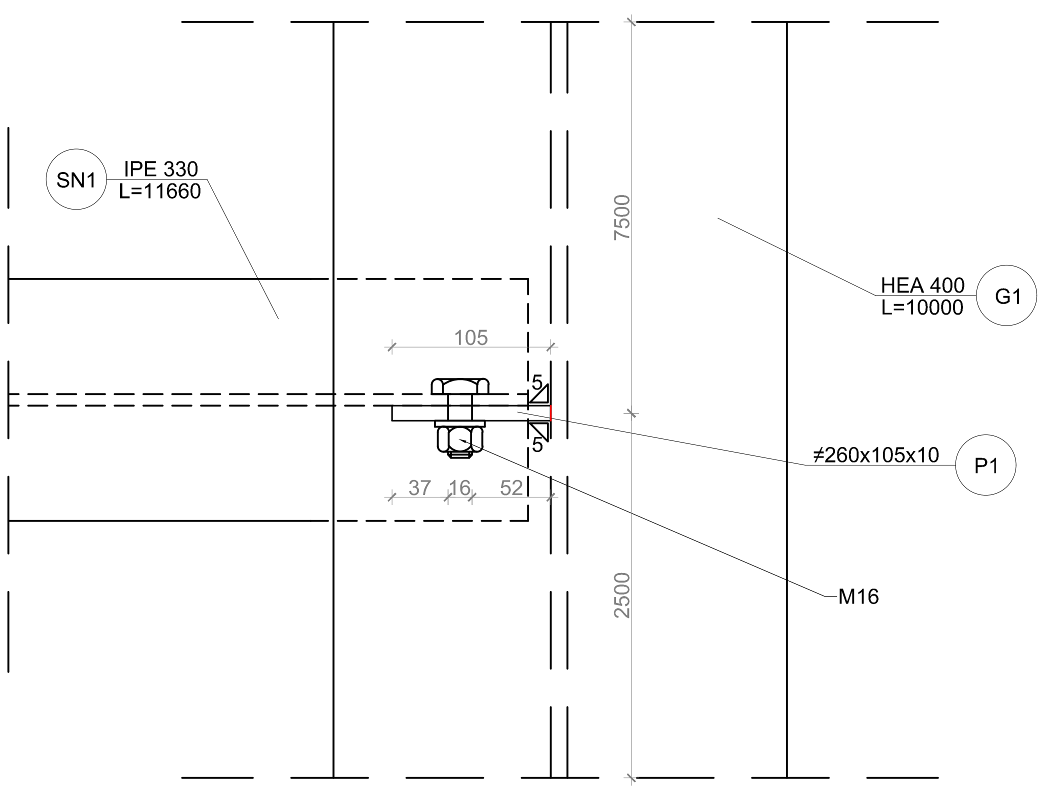

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Razina obrade: Pregledni nacrt	
Sadržaj nacrta: DETALJ A	
Mentor: doc.dr.sc. Ivan Ćurković	
Datum: 17.09.2024.	Mjerilo: 1:5
Akademska godina: 2023./2024.	
Izradio: Poljak Marija	

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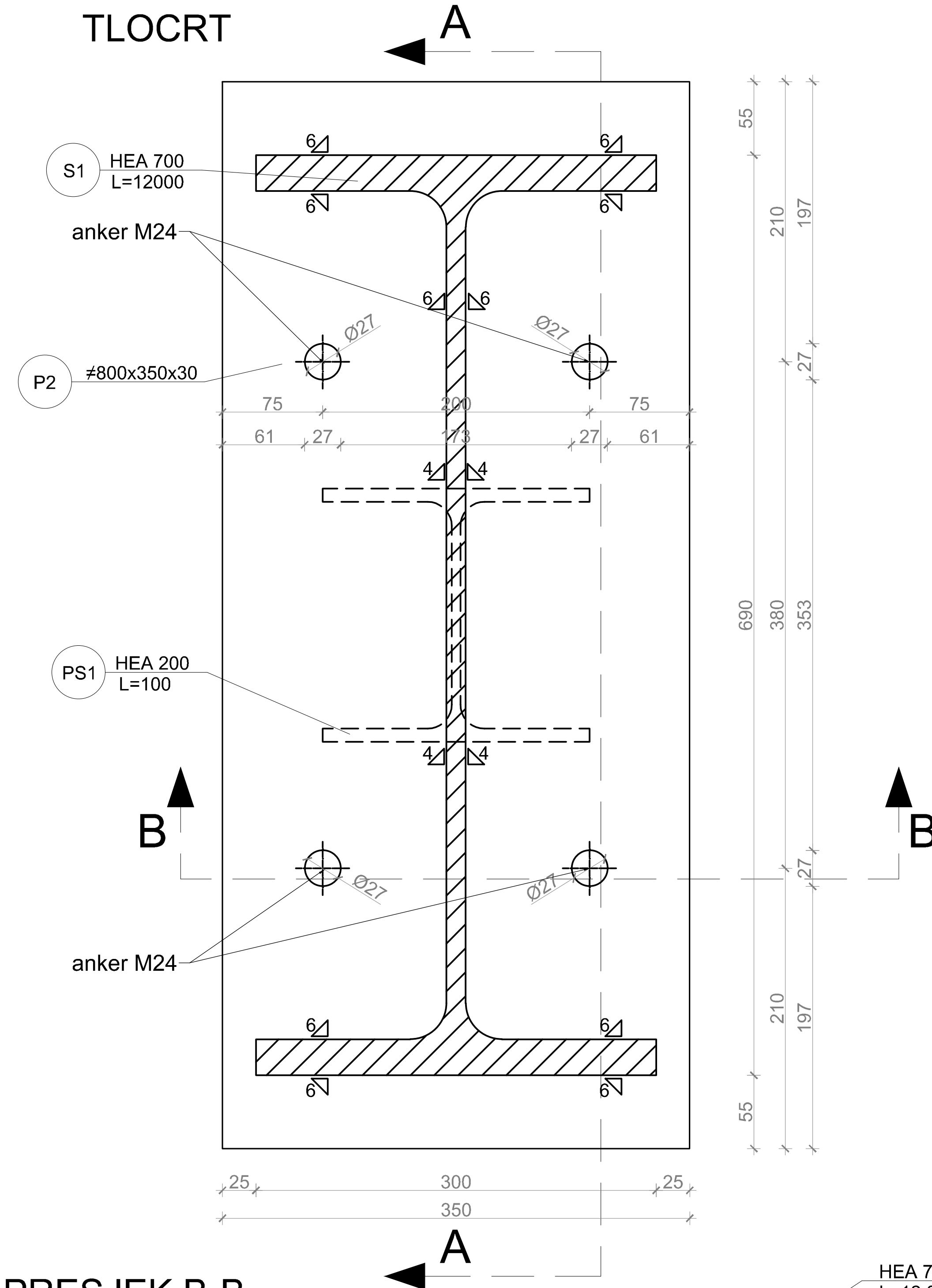

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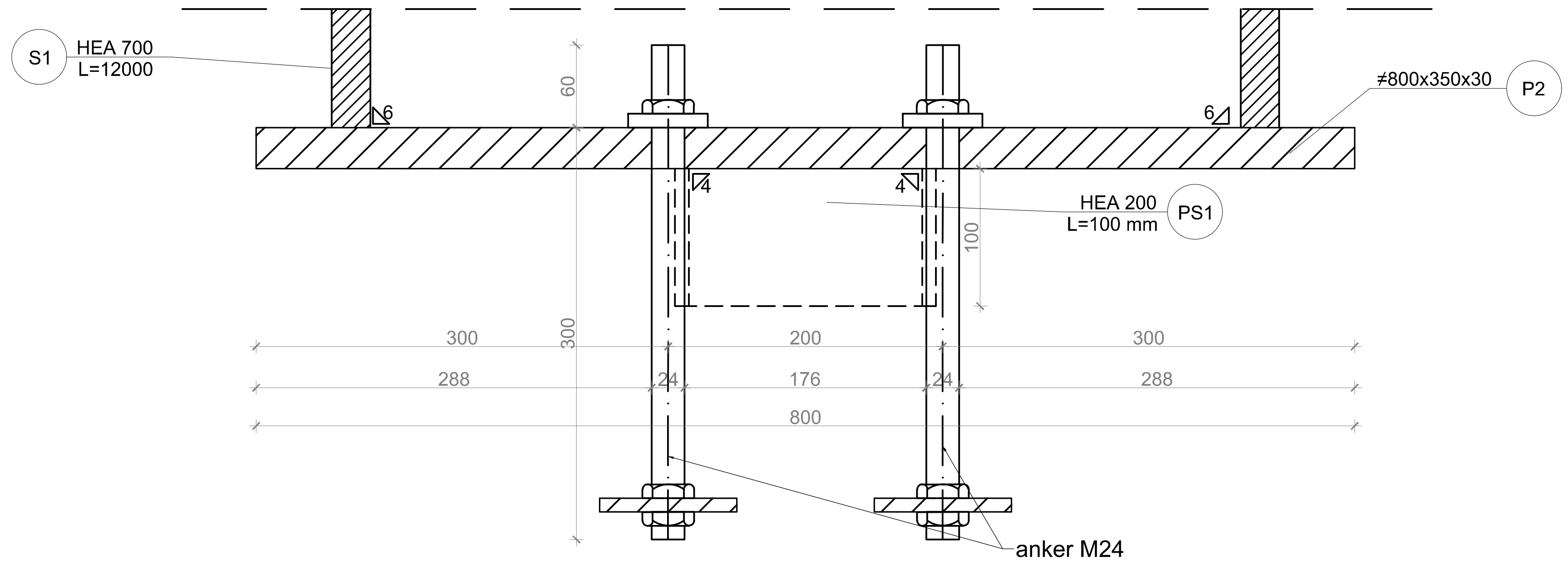

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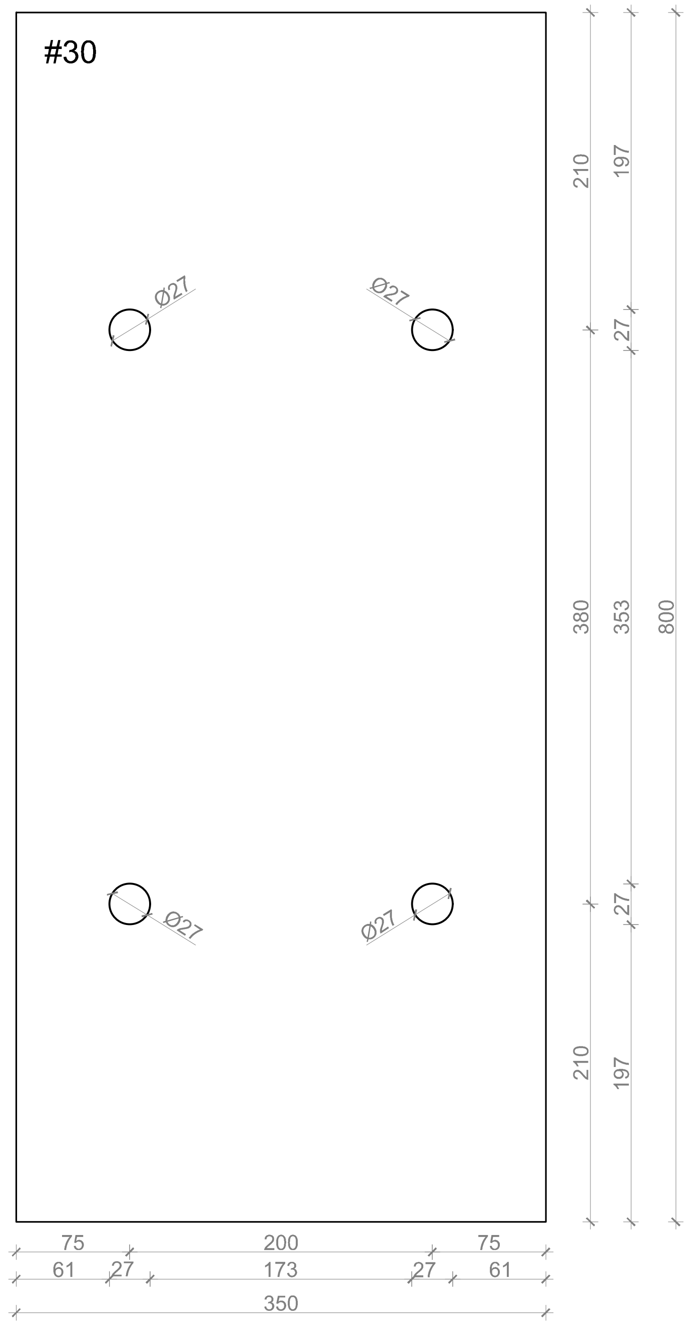

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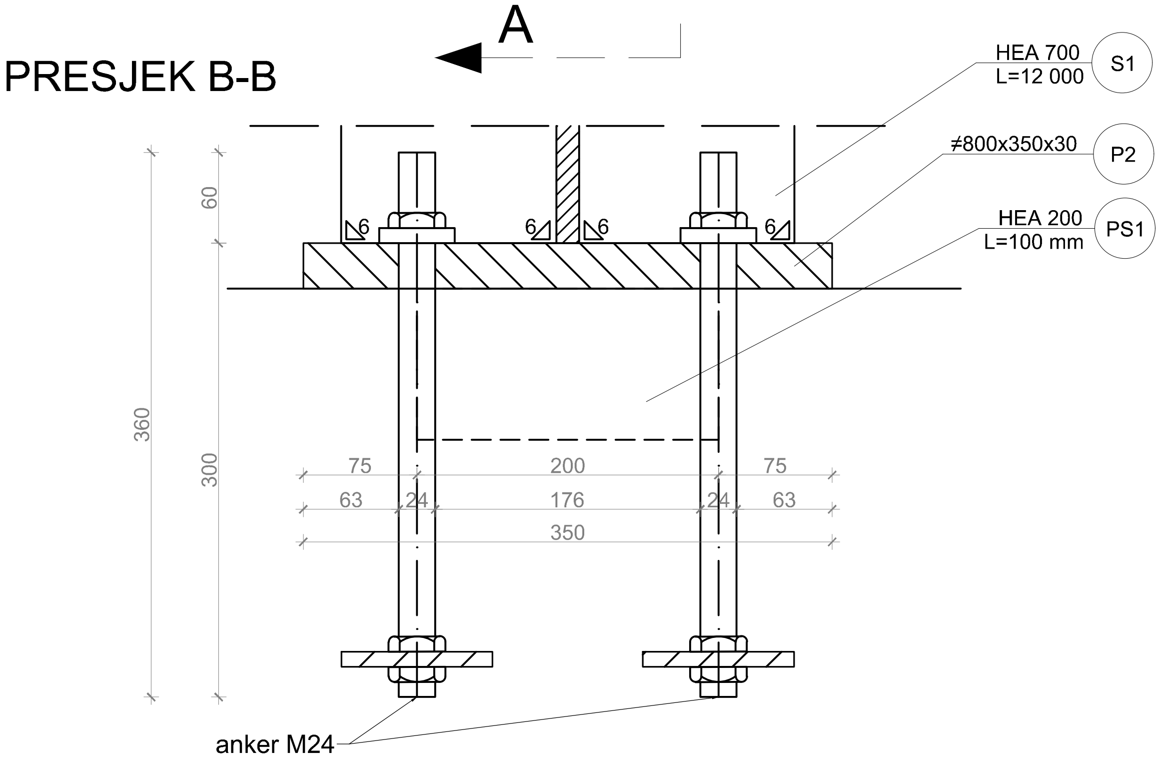

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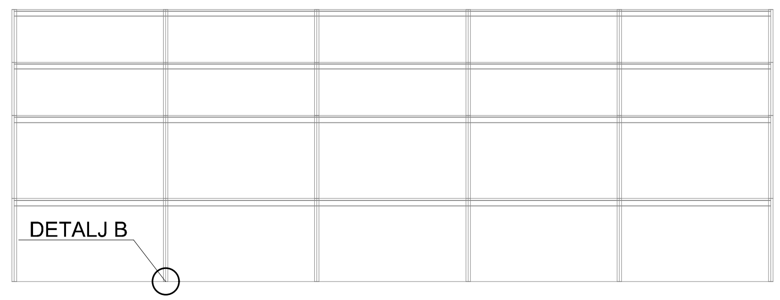

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Sadržaj nacrta:	DETALJ B
Mentor:	doc.dr.sc. Ivan Ćurković
Datum:	17.09.2024.
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Mjerilo:	1:5
Izradio:	Poljak Marija

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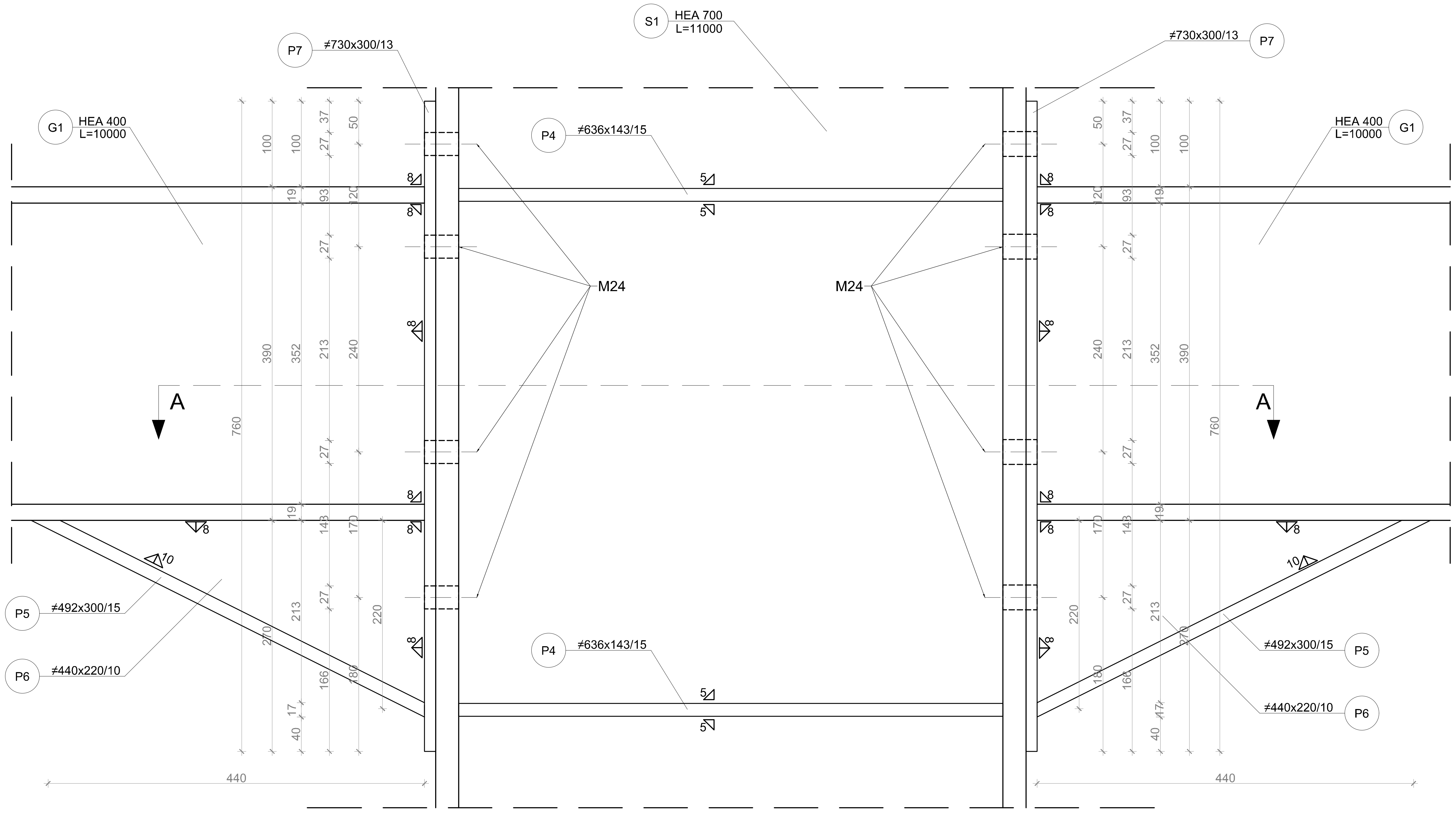

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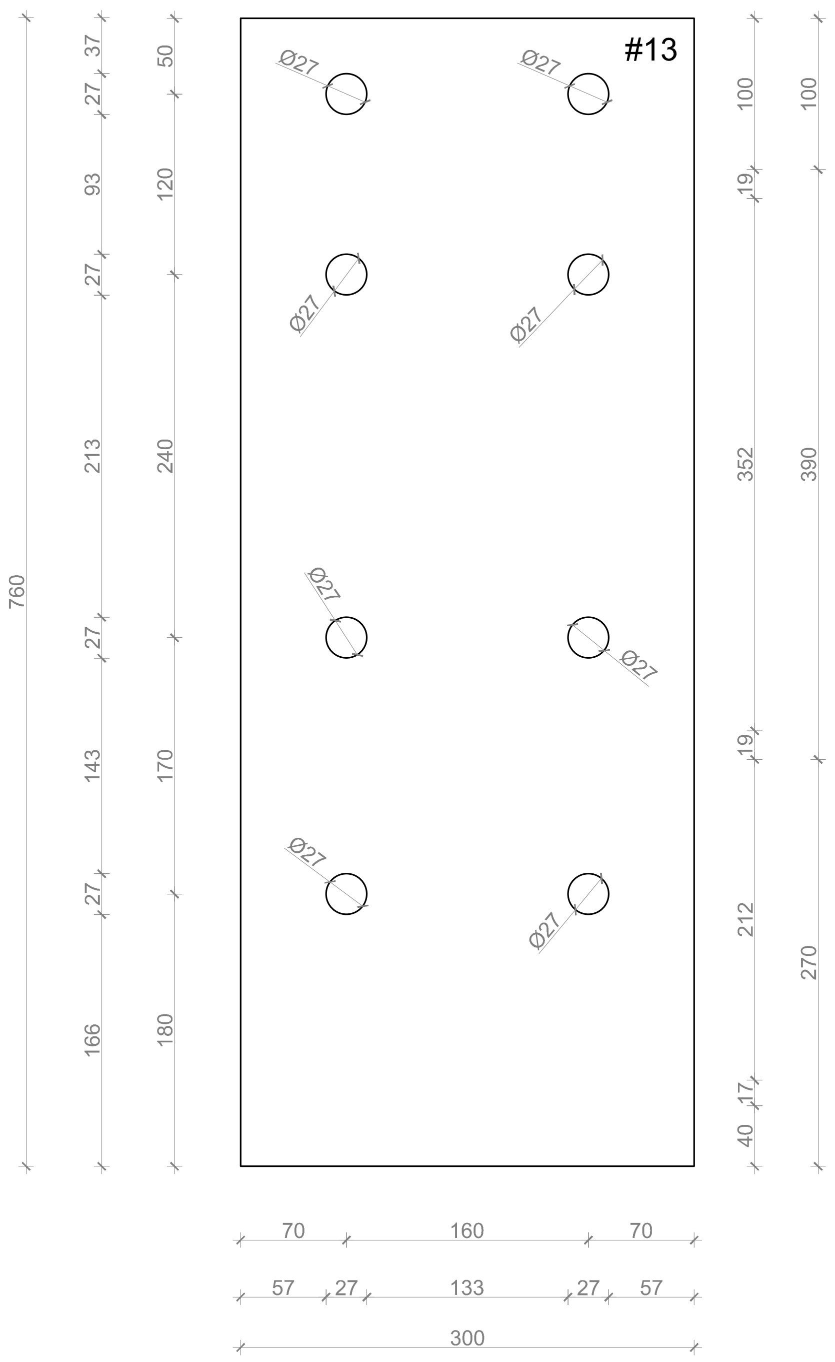

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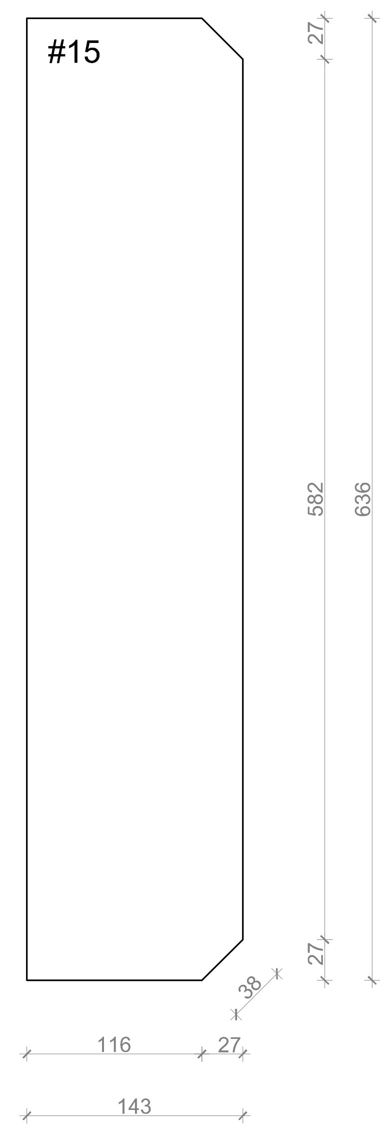

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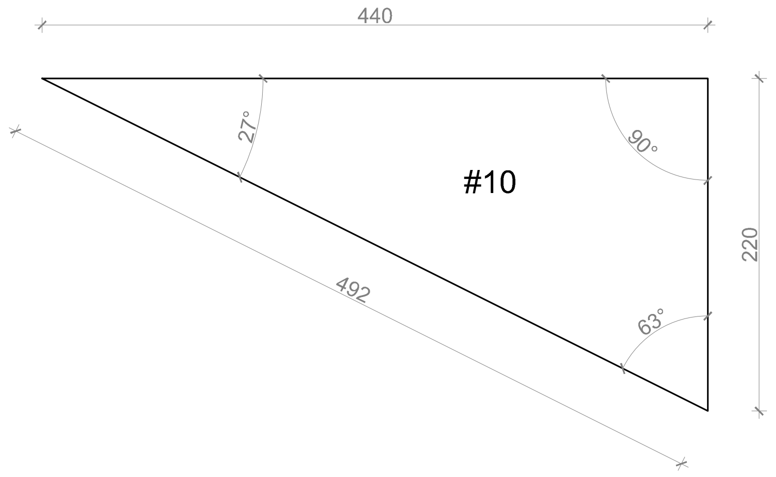

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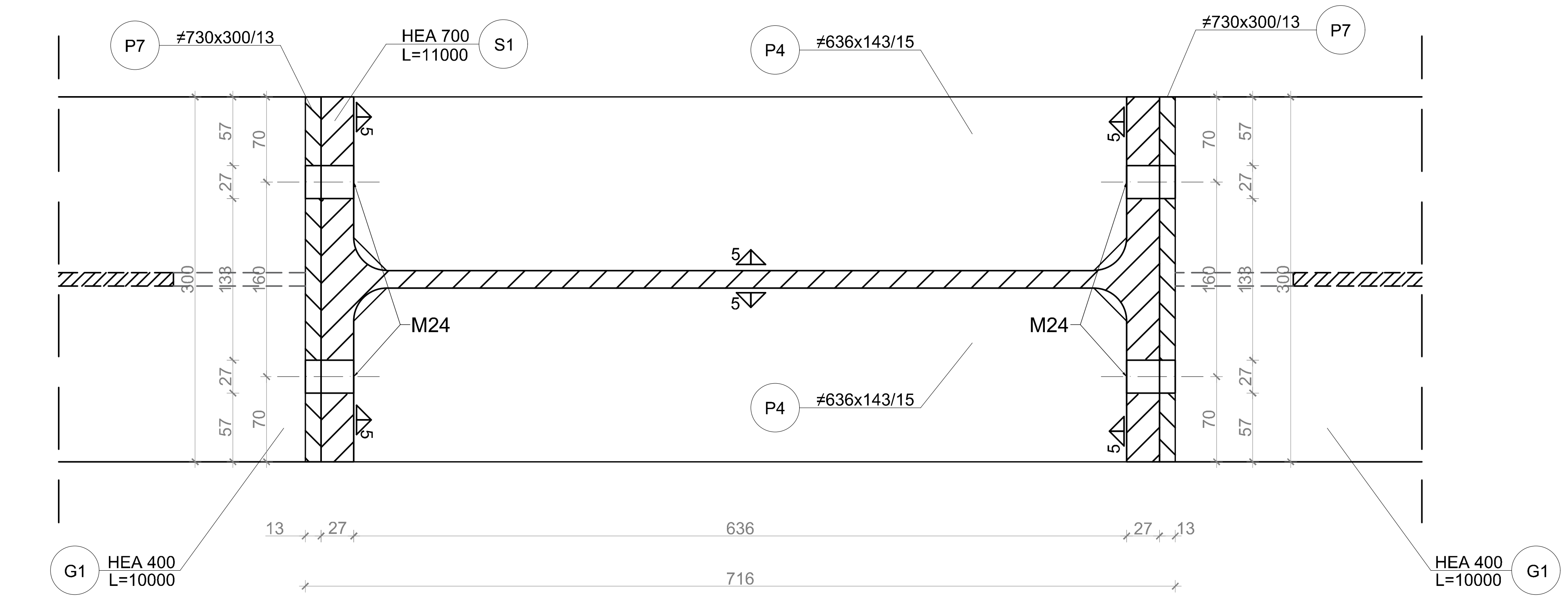

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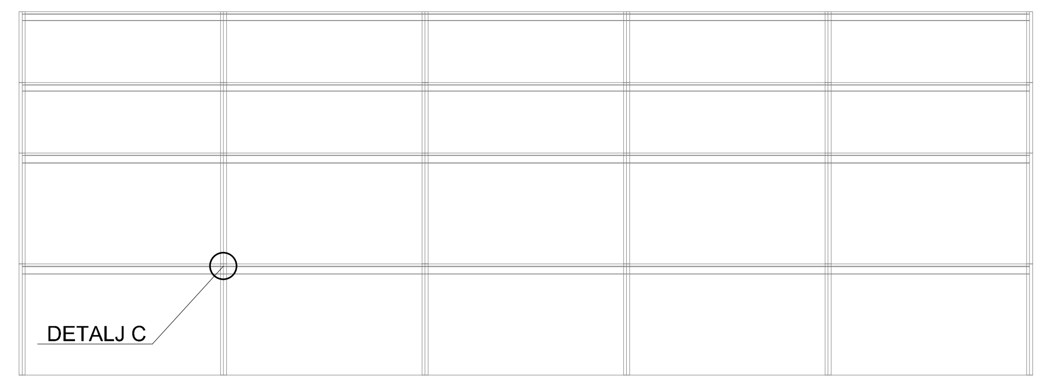

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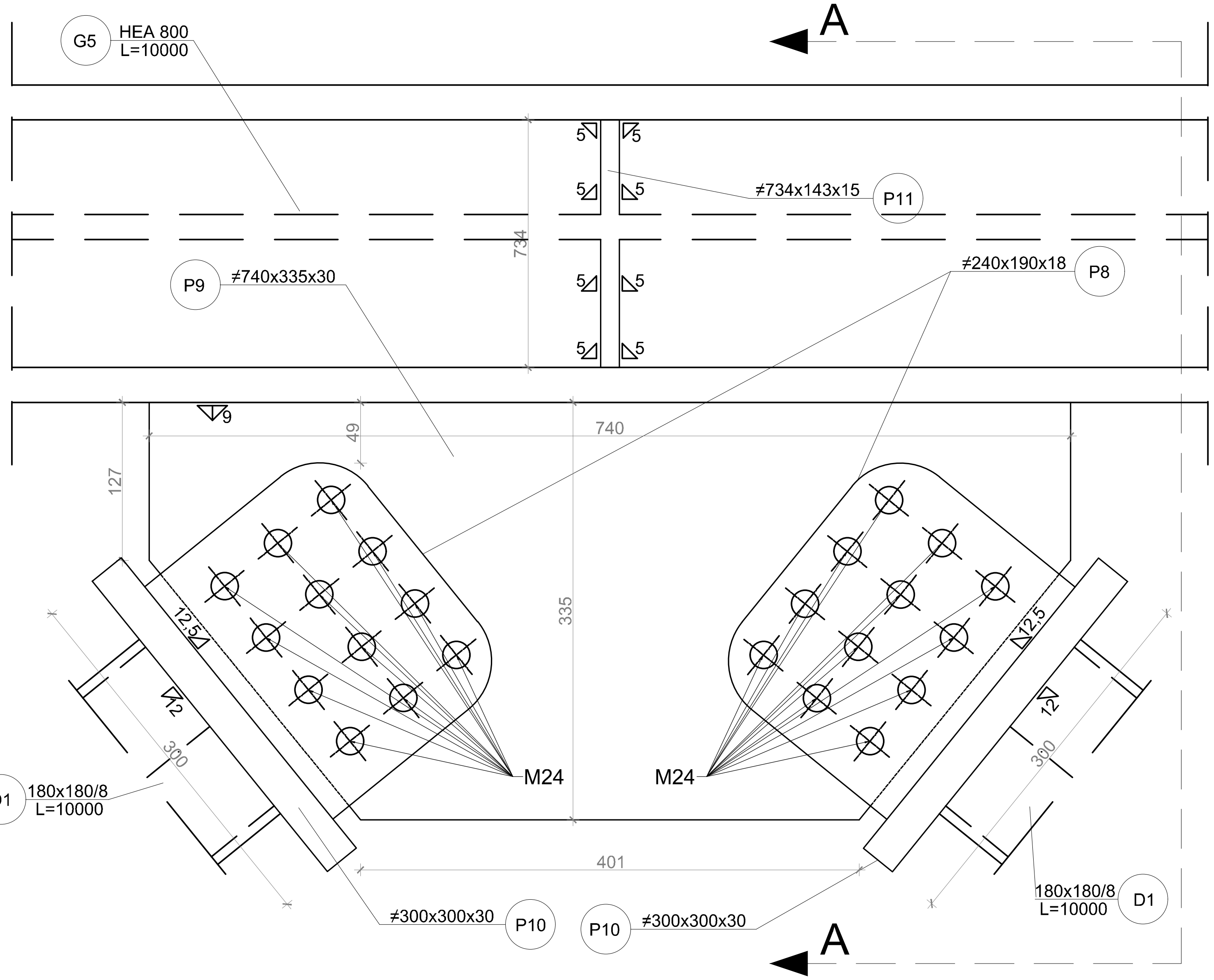

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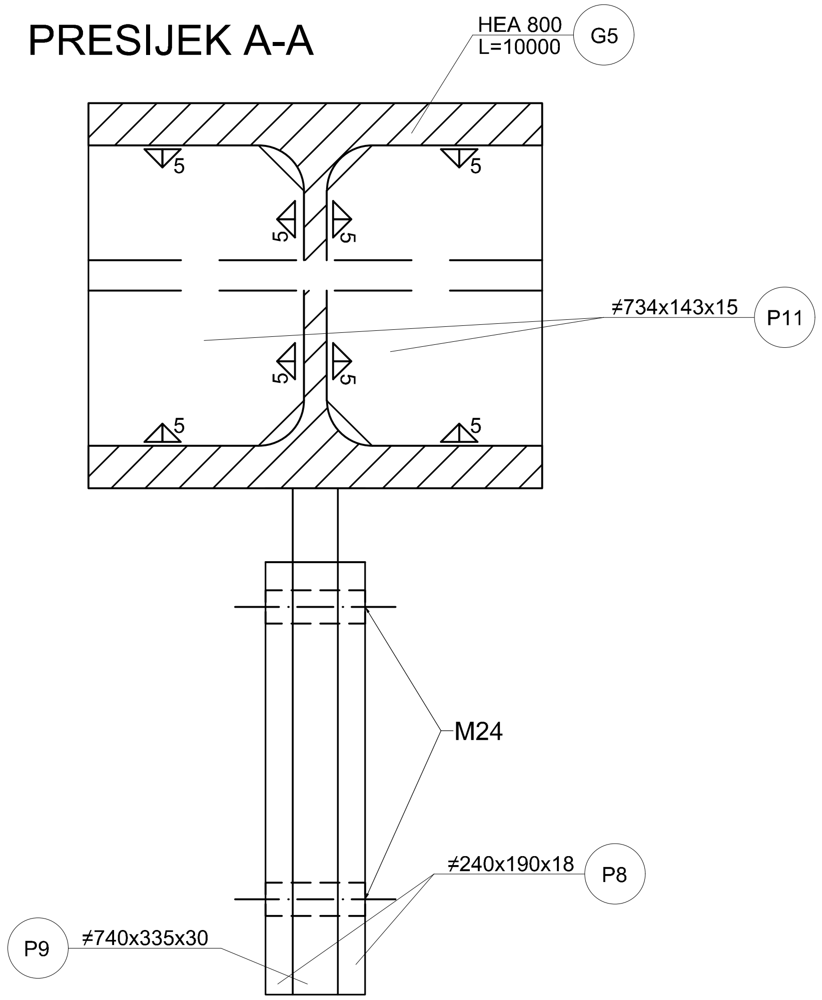

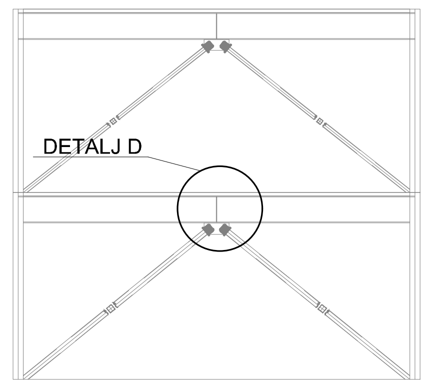

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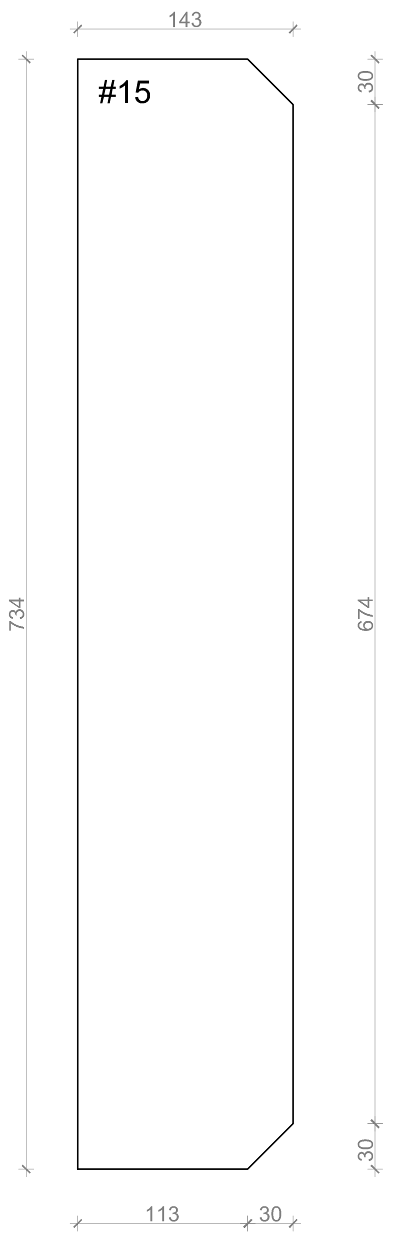

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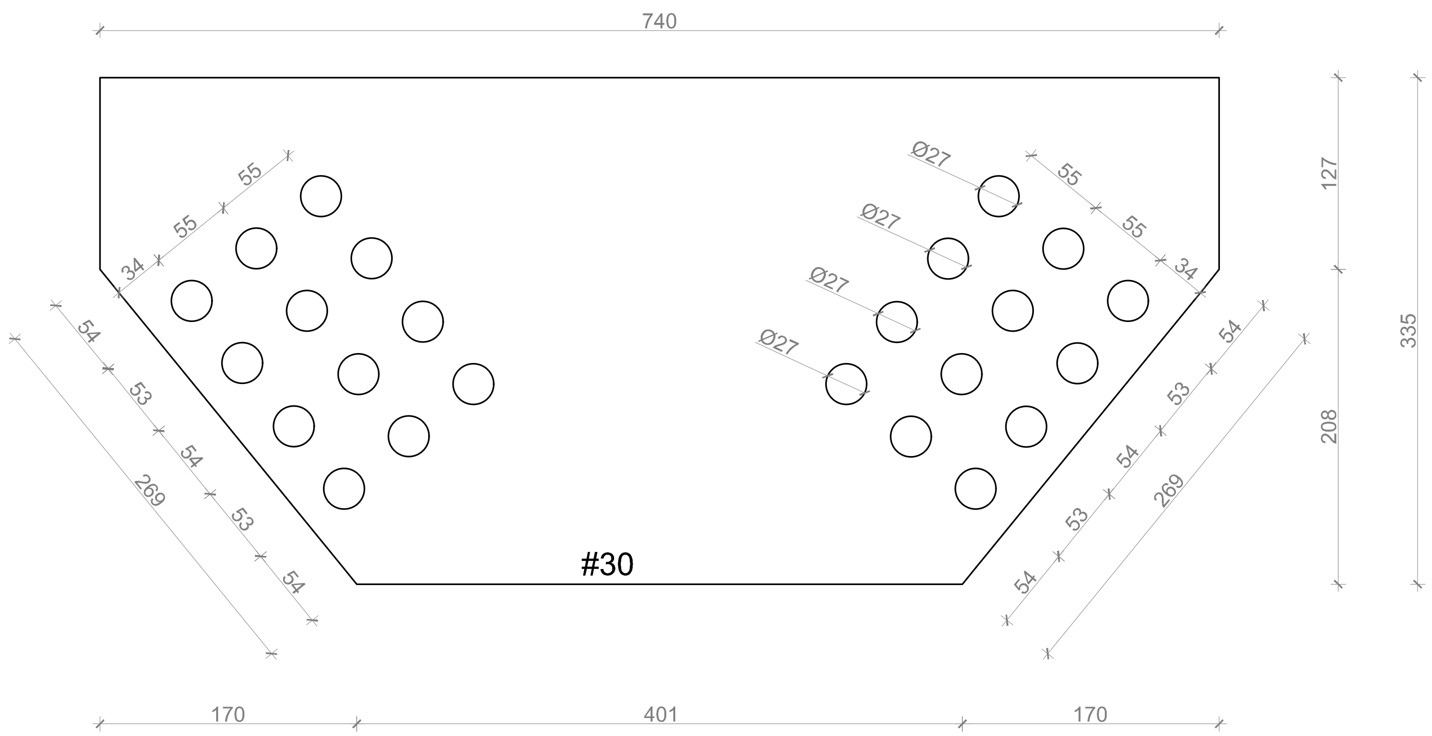

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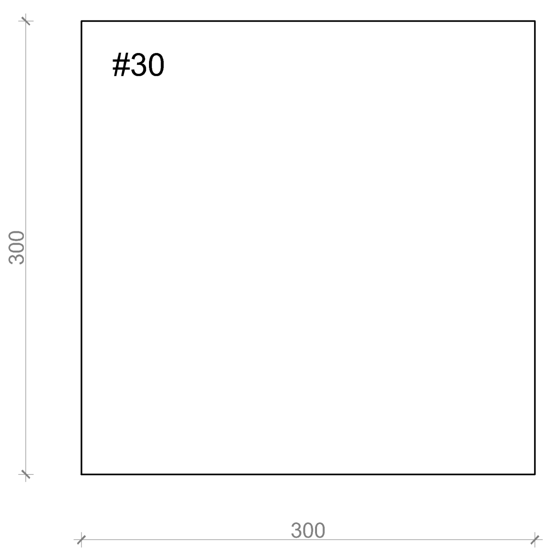

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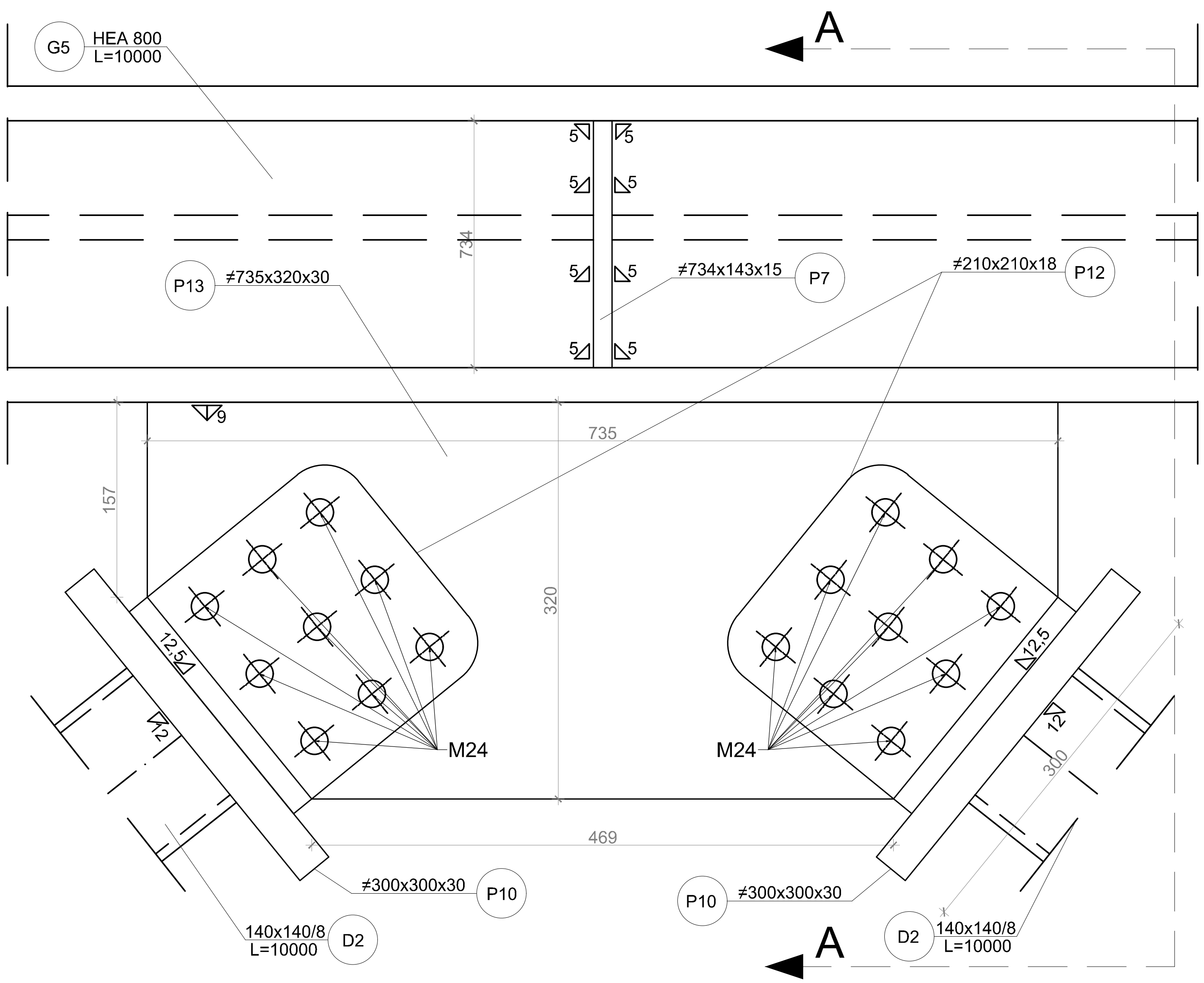

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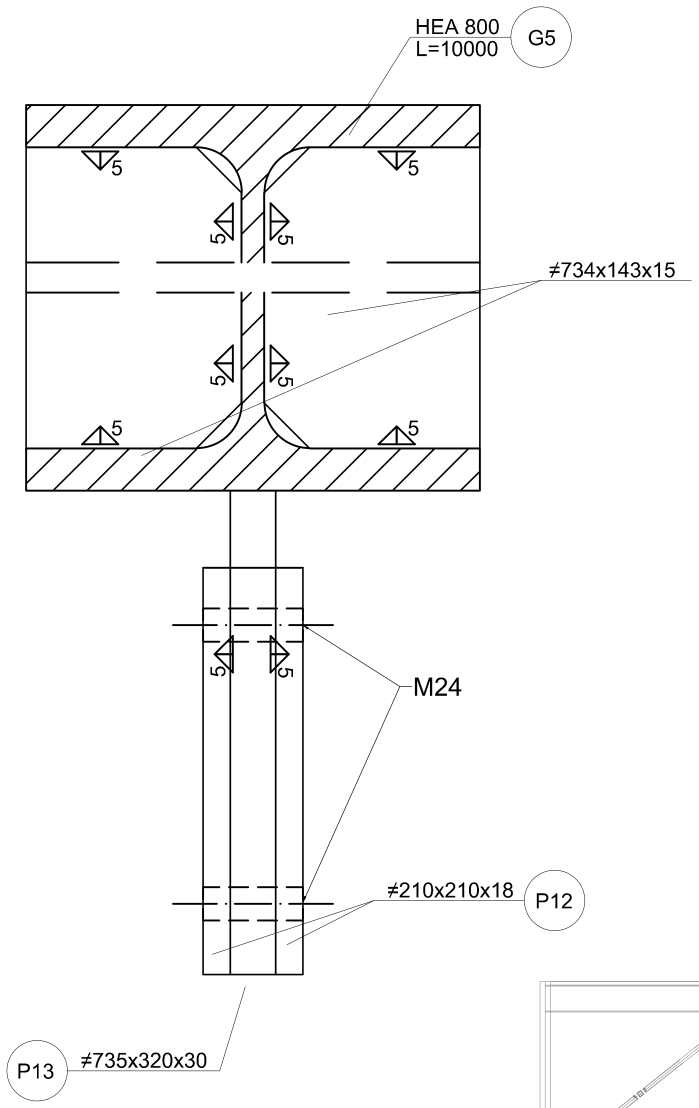

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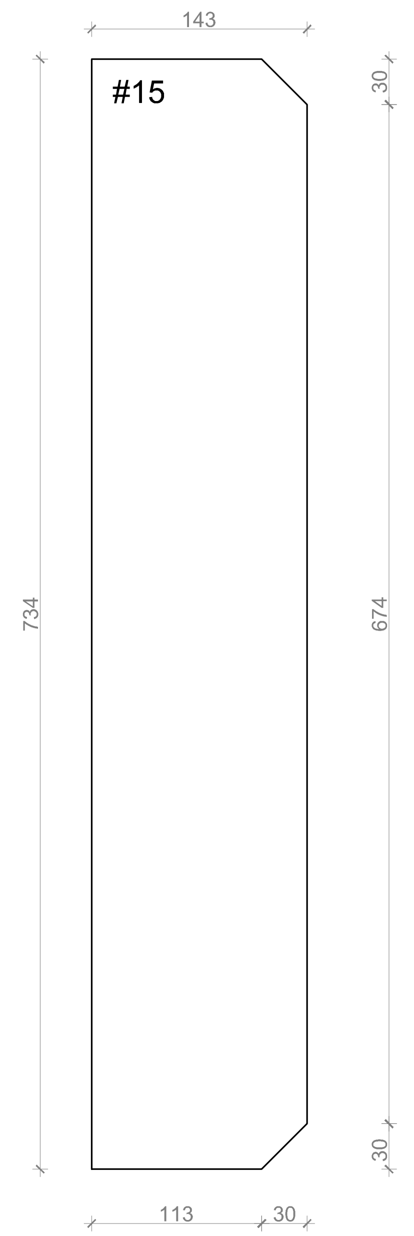

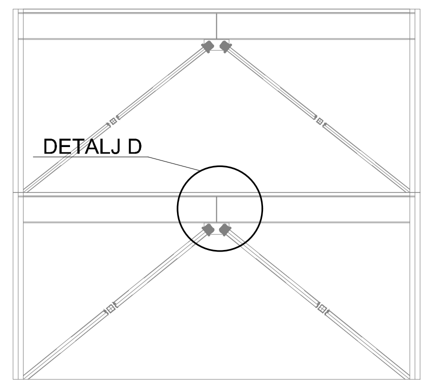

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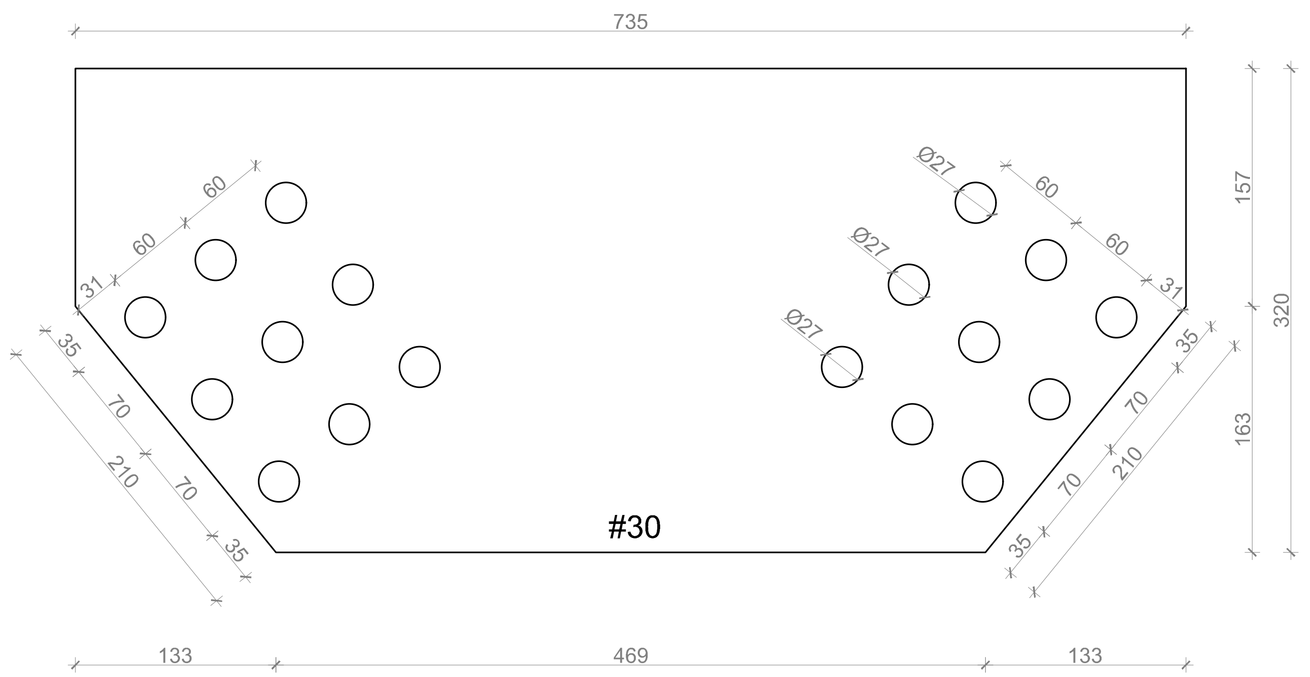

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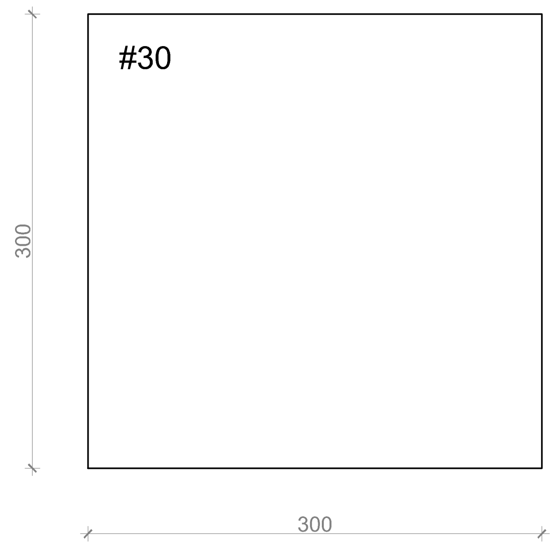

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Sadržaj nacrta:	DETALJ E
Mentor:	doc.dr.sc. Ivan Ćurković
Datum:	17.09.2024.
Mjerilo:	1:5
Akademska godina:	2023./2024.
Izradio:	Poljak Marija