Projektiranje stambeno poslovne zgrade P+5 i P+10 od CLT-a

Gulam, Marija

Gulam_Marija_Diplomski_rad.pdf

by Marija Gulam

Sveučilište u Zagrebu

GRAĐEVINSKI FAKULTET

Marija Gulam

PROJEKTIRANJE STAMBENO POSLOVNE ZGRADE P+5 I P+10 OD CLT-A

DIPLOMSKI RAD

Zagreb, 2024.

Sveučilište u Zagrebu

GRAĐEVINSKI FAKULTET

Marija Gulam

PROJEKTIRANJE STAMBENO POSLOVNE ZGRADE P+5 I P+10 OD CLT-A

DIPLOMSKI RAD

Mentor: prof. dr. sc. Vlatka Rajčić

Komentor: dr. sc. Nikola Perković

Zagreb, 2024.

University of Zagreb

FACULTY OF CIVIL ENGINEERING

Marija Gulam

DESIGN OF THE RESIDENT – OFFICE BUILDING FORM CLT – P+5 AND P+10

MASTER THESIS

Supervisor: prof. dr. sc. Vlatka Rajčić

Co-supervisor: dr. sc. Nikola Perković

Zagreb, 2024.

ZAHVALE

SAŽETAK

Tema ovog rada je projekt stambeno polsovnog kompleksa koji se sastoji od dva objekta katnosti P+10 (zgrada A) i P+5 (zgrada B) od križno lameliranog drva sa zajedničkom garažom. Konstrukcija je proračunata na granično stanje nosivosti, granično stanje nosivosti u slučaju požara te na granično stanje uporabivosti. Pri proračunu konstrukcije korišteni su software-i *Dlubal RFEM i Calculatis*. Osim projektnog zadatka, dan je i uvid u korištene materijale, križno lamelirano drvo i lijepljeno lamelirano drvo, te prednosti gradnje drvenih konstrukcija. Projekt je u skladu sa skupom europskih normi Eurocode.

Ključne riječi: križno lamelirano drvo, projektiraje drvene konstrukcije, održiva gradnja, prirodni materijali

SUMMARY

The subject of this paper is the design of the resident – office building complex consisting of two buildings P+10 (Building A) and P+5 (Building B), made of cross-laminated timber, with a shared garage. The structural analysis was conducted for the ultimate limit state, the ultimate limit state in case of fire, and the serviceability limit state. The software tools Dlubal RFEM and Calculatis were used for design and structural calculations. In addition to the project, the paper also presents an overview of the materials used, cross laminated timber and glue laminated timber, along with the benefits of timber construction. The project complies with the set of European standards Eurocode.

Key words: Cross Laminated Timber, timber structures design, sustainable construction, natural materials

SADRŽAJ

ZAHVALE i
SAŽETAK ii
SUMMARY iii
SADRŽAJ iv
1 UVOD 1
2 PROJEKTNI ZADATAK 9
2.1 Idejno arhitektonsko rješenje 9
2.2 Tehnički opis 11
2.3 Analiza opterećenja 13
2.3.1 Vlastita težina nosivih i ne nosivih dijelova konstrukcije 13
2.3.2 Uporabno opterećenje 13
2.3.3 Opterećenje snijegom 13
2.3.4 Opterećenje vjetrom 14
2.3.5 Potresno opterećenje 24
2.4 Statički proračun 25
2.4.1 Proračun zgrade A (P+10) 25
2.4.2 Proračun zgrade B (P+5) 63
2.5 Dimenzioniranje nosivih dijelova konstrukcije 96
2.5.1 Krovna ploča 97
2.5.2 Međukatna konstrukcija 125
2.5.3 Čelična greda 149
2.5.4 Zid s otvorom 156
2.5.5 Stupovi 165
2.6 Dimenzioniranje karakterističnih spojeva 171
2.6.1 Spoj CLT zida s betonskom pločom 171
2.6.2 Spoj CLT zidova 178
2.6.3 Spoj CLT zida s CLT pločom 183
2.6.4 Spoj zid – ploča – zid 187
2.6.5 Nastavak ploče 191
2.6.6 Spoj CLT ploče i čelične grede 196
2.7 Iskaz materijala 201
3 ZAKLJUČAK 208

POPIS LITERATURE 209
POPIS SLIKA 210
POPIS TABLICA 212
PRILOZI 213

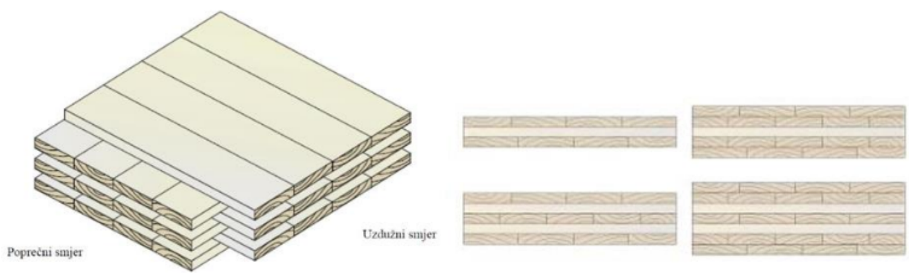
1 UVOD

Drvo je jedan od najstarijih i najčešće korištenih materijala u graditeljstvu. Tradicionalne drvene konstrukcije izvodile su se kao lagani okvirni sustavi s linijskim elementima od punog drva i ograničenih raspona. U 20. stoljeću drvo je zamijenjeno čelikom i betonom zbog ekonomičnosti i mogućnosti gradnje visokih zgrada.

Zanimanje za drvene konstrukcije ponovno je poraslo u drugoj polovici 20. stoljeća s razvojem novih tehnologija i materijala na bazi drva. Prvi pločasti proizvodi, kao što su LVL i OSB, koristili su se kao sekundarni elementi. Lijepljeno lamelirano drvo (LLD) i križno lamelirano drvo (*eng. Cross Laminated Timber* – CLT) omogućili su gradnju viših, kompleksnijih objekata, što je otvorilo vrata za primjenu drva u suvremenom graditeljstvu.

Križno lamelirano drvo (CLT) relativno je novi pločasti proizvod na bazi drva. Patentiran u Europi u 90-ima, vrlo brzo se našao u primjeni i van granica Europe zbog svojih seizmičkih i požarnih svojstava. Zemlje poput SAD, Kanade, Japana i Kine sve češće koriste proizvode od CLT-a.

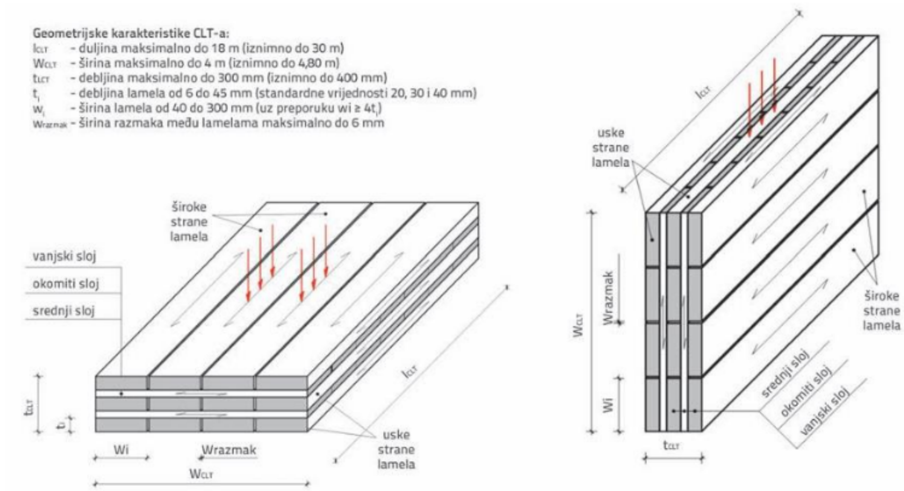
CLT predstavlja kruti pločasti proizvod sastavljen od odgovarajućeg broja slojeva (uglavnom neparnog 3, 5 ili 7), gdje je svaki sloj načinjen od lamela položenih jedna do druge pri čemu su susjedni slojevi lijepljeni okomito jedan na drugi. [1]



Slika 1. Slaganje lamela unutar jednog panela

Uslojena struktura omogućuje nosivost u ravnini i okomito na ravninu elementa s primjenom u obliku zidnih nosača i stropnih ploča. Mala gustoća drva (400-500 kg/m^3) čini proizvod relativno lagan, a paneli postižu jako dobre karakteristike čvrstoće i krutosti. Mala vlastita težina olakšava temeljenje i omogućuje primjenu u seizmički aktivnim područjima. S obzirom da se radi o predgotovljenim elementima, CLT se odlikuje i brzinom montaže.

Zbog svojih prednosti, CLT je sve popularniji u visokogradnji i mostogradnji te u zemljama izloženim potresima.

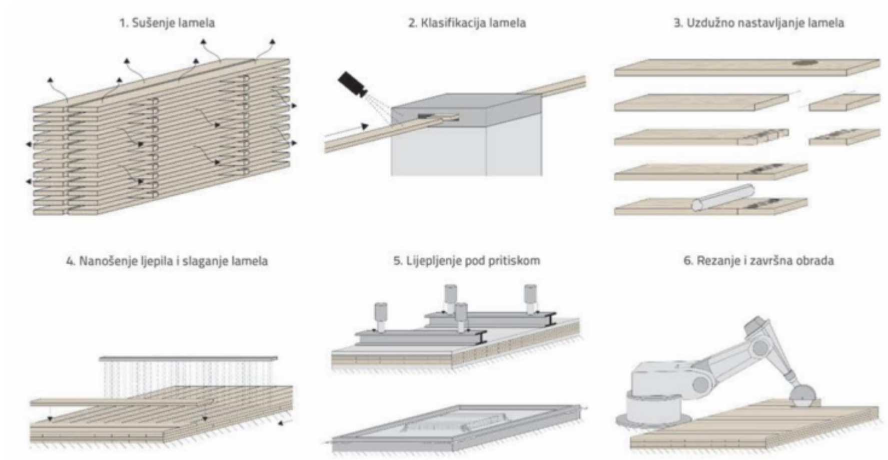


Slika 2. Geometrijske karakteristike CLT elemenata za djelovanje okomito na ravninu (lijevo) i djelovanje u ravnini (desno)

Širina jednog panela obično iznosi do 4 metra uz mogućnost postizanja i većih širina (do 4,8 m), dok u duljinu paneli idu do 18 metara, iznimno i više. Debljina pojedine lamele kreće se u rasponu 16-51 mm, a širine su 60-240 mm.

Za proizvodnju panela najčešće se koristi meko drvo, klase C24. Dopušteno je kombiniranje sa slabijim klasama drva, C16/C18, u okomitim slojevima, iako nije uobičajeno.

Postupak proizvodnje panela možemo podijeliti na dva osnovna dijela; priprema i obrada osnovnog materijala te slaganje i lijepljenje osnovnog materijala. Postupak započinje sušenjem i klasifikacijom lamela. Pojava pukotina se sprječava održavanjem vlage u granicama 9%-15%. Slijedi slaganje i lijepljenje lamela jednokomponentnim poliuretanskim ljepilom (1K-PUR) ili melanim-urea-fomaldehidom (MUF). Nakon lijepljenja paneli su izloženi hidrauličkom pritisku ili pritisku u vakuumu. U zadnjem koraku proizvodnje korigira se geometrija panela te se paneli režu na zahtijevane dimenzije, za što se danas koriste CNC strojevi. Završna obrada panela ovisi o potrebama i mjestu gdje se panel ugrađuje. Na slici 3. prikazan je postupak proizvodnje CLT panela.



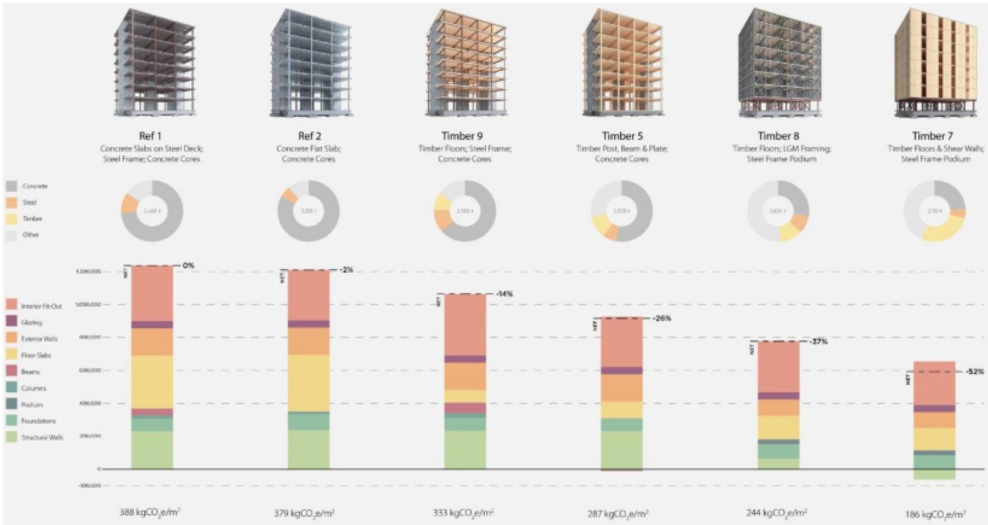
Slika 3. Postupak proizvodnje CLT panela

U europskoj normi za CLT, EN 16351, reguliraju se ograničenja vezana za proizvodnju i izvedbu CLT panela (zahtjevi za ljepila, kontrola proizvodnje/kvalitete), ali još uvijek nisu dani jedinstveni postupci proračuna istih. Postupke proračuna moguće je pronaći u raznim tehničkim propisima i specifikacijama izdanim od strane proizvođača. Također, postoje i priručnici i smjernice pojedinih nacionalnih tijela koji daju preporuke za projektiranje zgrada.

Još jedna prednost CLT-a su njegove toplinske karakteristike. Ima izvrsna izolacijska svojstva, što znači da može pomoći u održavanju zgrada toplima zimi i hladnima ljeti. To može dovesti do značajnih energetskih ušteda.

Dok drveće raste, ono upija ugljikov dioksid (dalje CO_2) i skladišti ga. Iako se CO_2 emitira tijekom obrade drva, proizvodnja betona mnogo je intenzivnija po pitanju emisija. Na primjer, samo u proizvodnji jedne tone cementa emitira se oko pola tone CO_2.[4] Razne studije pokazale su da CLT može smanjiti emisije CO_2 kod velikih zgrada za 40% u odnosu na druge građevinske materijale. [3] Pregled emisija zgrada od različitog materijala možemo vidjeti na slici 4.

Drvo može biti ponovno upotrebljeno i nakon rušenja zgrada, primjerice za proizvodnju namještaja. Ako drvo dolazi iz održivih šuma, gdje se stabla zamjenjuju nakon sječe, te se reciklira nakon životnog vijeka konstrukcije, CLT može biti moćno rješenje za smanjenje emisija i borbu protiv klimatskih promjena.

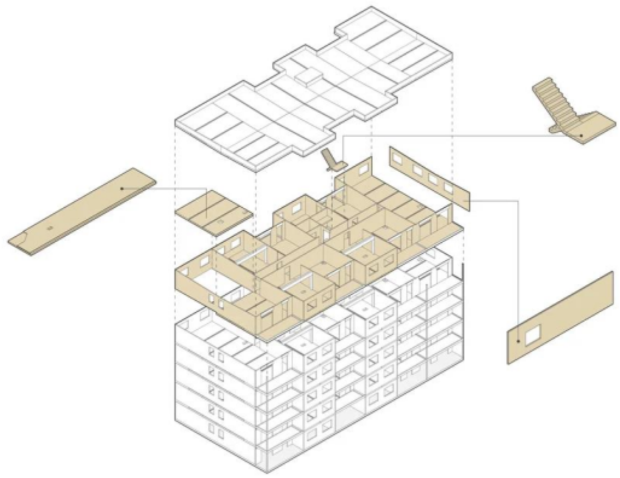


Slika 4. Pregled emisije ugljikovog dioksida za zgrade od različitih materijala

U zadnjih 15-ak godina u svijetu je izgrađeno na desetke višeetažnih drvenih zgrada te hibridnih sustava drvo – beton i drvo – čelik u kojima drvo tvori okvire i međukatne konstrukcije, a beton i čelik čine jezgru.

Kada je riječ o gradnji drvom, postoje dva načina gradnje – lagana i masivna gradnja. Lagana gradnja izvodi se okvirnim sustavima s linijskim elementima, dok se masivna gradnja izvodi s pločastim elementima. Dva popularna izbora materijala čine križno lamelirano drvo (CLT) i lijepljeno lamelirano drvo (LLD).

Mogućnosti uporabe ploča od CLT-a u stambenoj gradnji odlikuje raznolikost proizvoda i konstrukcijskih elemenata. Primjenjuju se u izvedbi konstrukcija stropova, vanjskih i unutarnjih zidova i pokrovnih elemenata velikih dimenzija, ali i za konstrukcije ploča stubišta i balkona, te kao nosivi elementi plošnog tipa za nadvoje i stupove. Za raspone veće od 6 m i više zidne elemente bez dodatnih potpora preporučuju se ploče s rebrastim ojačanjima od lijepljenih lameliranih greda. Prikaz načina gradnje s CLT panelima prikazan je na slici 5.

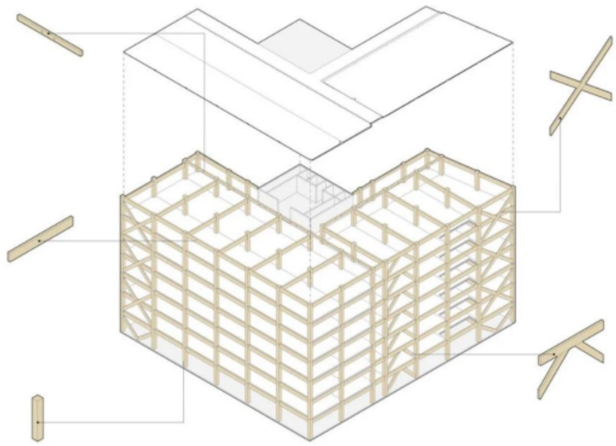


Slika 5. Shematski prikaz gradnje s CLT panelima

Međusobno spajanje ploča od CLT-a u karakterističnim spojevima i prijenos opterećenja uglavnom se odvija točkasto, npr. vijcima za drvo, ulijepljenim navojnim šipkama, čavlima, trnovima, vijcima i drugim mehaničkim spajalima .

Za razliku od CLT-a, LLD ima slojeve orijentirane u jednom smjeru te primarno nosi u jednoj ravnini. Kao takav pogodan je za linijske elemente, odnosno grede i stupove za koje nije bitna nosivost van glavne ravnine elementa. LLD se najčešće koristi pri svladavanju velikih raspona kao što su krovne konstrukcije različitih oblika, okvirne konstrukcije hala i mostovi.

Prednost okvirne gradnje s linijskim elementima je mogućnost ostvarivanja velikih otvorenih planova u dizajnu, primjerice uredi i komercijalne zgrade. LLD je jeftiniji od CLT-a jer je utrošak materijala manji. Prikaz načina gradnje s LLD gredama i stupovima prikazan je na slici 6.

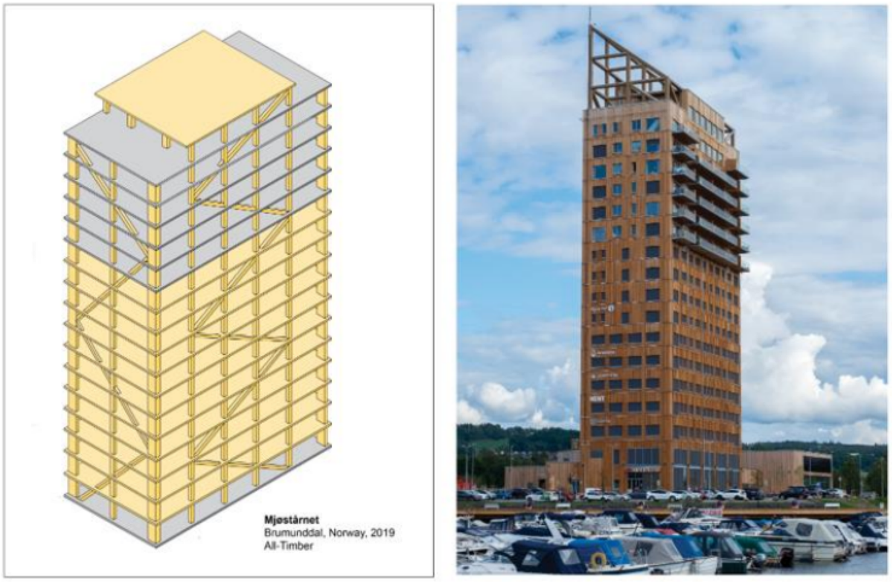


Slika 6. Shematski prikaz gradnje sa LLD stupovima i gredama

Često se izvode građevine koje kombiniraju oba sustava gradnje, maksimalno koristeći sve njihove prednosti, gdje se LLD koristi za mrežu stupova i greda, a CLT se koristi za međukatne konstrukcije i zidove.

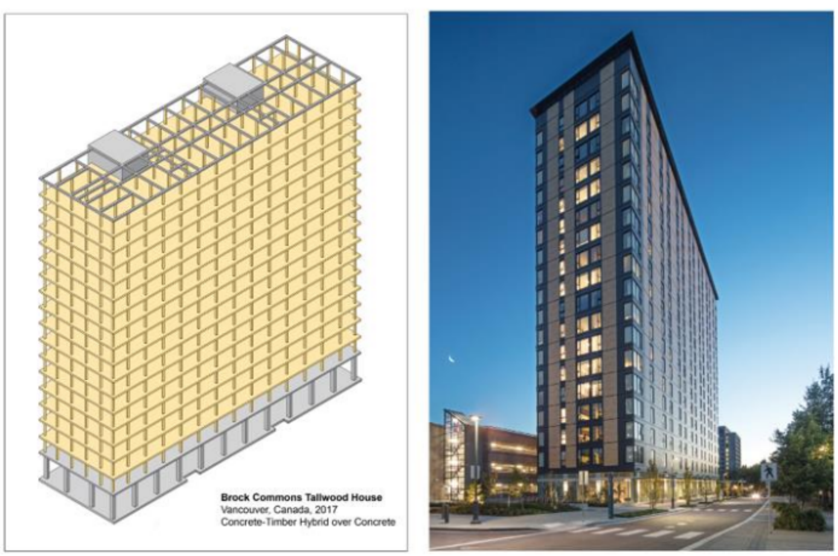
U zadnjih 15-ak godina u svijetu je izgrađeno na desetke višeetažnih drvenih zgrada te hibridnih sustava drvo – beton i drvo – čelik u kojima drvo tvori okvire i međukatne konstrukcije, a beton i čelik čine jezgru.

Jedna od najznačajnijih visokih zgrada od drva je Mjøstårnet u Norveškoj (Slika 7.), zgrada sa 18 etaža, izgrađena koristeći CLT, LLD i LVL, a na sedam najviših etaža korištene su betonske ploče kako bi se povećala težina i smanjio utjecaj horizontalnih djelovanja.



Slika 7. Mjøstårnet, Norveška

Još jedan primjer je i zgrada Brock Commons Tallwood House u Kanadi (Slika 8.), također sa 18 etaža, izgrađena je za manje od 70 dana. Nosivu konstrukciju čine LLD stupovi sa CLT pločama, prizemlje i dvije jezgre su betonske, a krovna konstrukcija je od čeličnih greda.

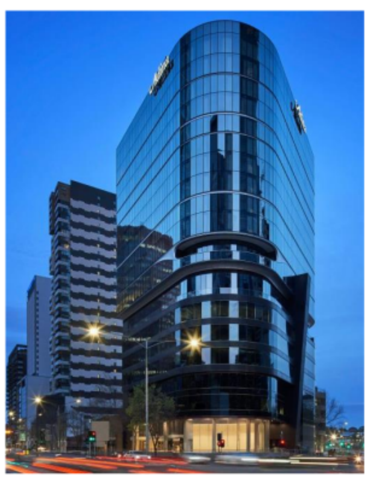


Slika 8. Brock Commons Tallwood House, Vancouver, Kanada

Zgrada Ascent, SAD, visine 86,6 metara, najviša je zgrada od drva u svijetu (Slika 9.). Sastoji se od 25 etaža, od čega su dvije jezgre i prvih 5 etaža izvedene od armiranog betona, a ostalih 18 etaža izvedene su u kombinaciji CLT-a i LLD-a.

Slika 9. Ascent, SAD

CLT ima i veliku primjenu u nadogradnji postojećih objekata zbog lakog spajanja s drugim materijalima, poput čelika, betona i stakla. Jedan takav primjer nadogradnje je zgrada *55 Southbank Boulevard u Melbourne-u* (Slika 10.) gdje je, na već postojeću betonsku zgradu, bila predviđena nadogradnja 5 katova u betonu, ali korištenjem CLT-a, čija je težina pet puta manja od težine betona, nadograđeno je ukupno 10 dodatnih katova.



Slika 10. 55 Southbank Boulevard, Melbourne, Australia

2 PROJEKTNI ZADATAK

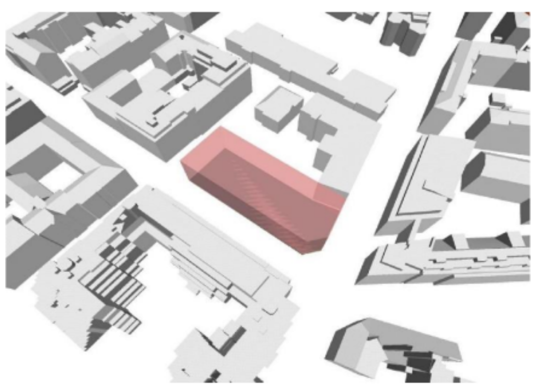
2.1 Idejno arhitektonsko rješenje

Podloga ovog diplomskog rada bio je projektni zadatak u sklopu studentskog natjecanja *proHolz Student Trophy 24,* čija je tema bila istraživanje mogućnosti širenja i jačanja urbanih središta korištenjem drva kao građevinskog materijala. Urbana područja proširivala su se i nadograđivala u interakciji s već izgrađenim objektima.

Zadaci su bili podijeljeni na tri građevinske lokacije u Beču te su uključivali proširenje školske zgrade, dodatak uz rub bloka te vertikalnu nadogradnju postojeće zgrade. (Slika 11.)

Slika 11. Situacija

Natjecanje je zamišljeno kao suradnja studenata građevinskog i arhitektonskog fakulteta. Zajedno s kolegama odlučili smo da će naš projekt biti dodatak uz rub bloka. (Slika 12)



Slika 12. Mikrolokacija postojećeg bloka

Koncept projekta temelji se na prilagodbi parceli na sjeverozapadnom rubu bloka. Dvije zgrade u obliku slova „L" omogućuju prolaz i stvaraju zelenu, aktivnu okolinu namijenjenu javnoj upotrebi. Idejni prikaz projekta prikazan je na slikama 13.-15.

Slika 13. Pogled na zgradu - sjeverozapad

Slika 14. Pogled na zgradu - sjeveroistok

Slika 15. Pogled na zgradu - sjeveroistok

2.2 Tehnički opis

Ovim radom predviđen je projekt drvene nosive konstrukcije stambeno poslovnog kompleksa od križno lameliranog drva (dalje CLT) i lijepljenog lameliranog drva (dalje LLD) u Zagrebu. Kompleks se sastoji od dvije zgrade katnosti P+10 (zgrada A) i P+5 (zgrada B) sa zajedničkom garažom. Zgrada se jednim zidom naslanja na već postojeću građevinu unutar bloka.

Armiranobetonska konstrukcija (dalje AB), koja obuhvaća garažu, jezgru stubišta i dizala te temeljnu ploču, bit će obrađena kroz pretpostavljene dimenzije, ali se neće detaljno proračunavati.

Konstrukcija zgrade A je nepravilnog oblika, tlocrtnih dimenzija 40x13,3 m na etažama P do 4. kata, tlocrtne dimenzije etaža od 5. do 10. kata su 18,4x13,3 m sa zaobljenim rubovima Φ1,5 m. Na etaži 5. kata nalazi se krovna terasa, a na posljednjoj etaži je neprohodan krov. Ukupna visina je 33,3 m.

Konstrukcija zgrade B je pravilnog oblika, tlocrtnih dimenzija 13,3x27,14 m. Ukupna visina objekta je 18,3 m. Na posljednjoj etaži nalazi se krovna terasa.

Temelji ispod garaže izvedeni su kao trake širine 80 i dubine 100 cm ispod zidova, dok se ispod stupova nalaze temeljne stope dimenzija 2,0x2,0 m i dubine 1,0 m. Preko njih je položena AB temeljna ploča debljine 30 cm. Temeljno tlo je kruta glina i spada u tip C temeljnog tla.

Garaža te jezgra stubišta i dizala izvedene su od AB klase C35/45, dok su svi ostali elementi izvedeni od LLD-a i CLT-a . Kvaliteta CLT-a je C24, dok je kvaliteta LLD-a GL32h. Garaža je u potpunosti ukopana, a sastoji se od AB zidova debljine 30 cm i stupova dimenzija 25x25 cm na koje su povezane AB grede dimenzija b/h=30/30 cm. Visina garaže je 3 m, strop garaže izveden je kao AB ploča debljine 25 cm na koju se spajaju elementi od CLT-a i LLD-a. Etaže od prizemlja do 10. kata izvedene su kombinacijom LLD stupova, zidnih i stropnih panela od CLT-a te čeličnih greda kvalitete S355. Visina prizemlja je 3,3 m, dok je visina ostalih etaža 3 m.

CLT paneli koji će se koristiti u izvedbi su od proizvođača *Stora Enso*. Paneli za izvedbu zidnih elemenata su CLT 140 L5s (debljina 140 mm, sastoji se od 5 slojeva lamela, od kojih su 3 u dominantom smjeru opterećenja). Paneli za izvedbu međukatnih konstrukcija ovise o statičkom sustavu, za kontinuirano oslonjene panele korišten je CLT 200 L5s (debljina 200 mm, sastoji se od 5 slojeva lamela), dok se za ploče na velikim rasponima koristi CLT 160 L5s (debljina 160 mm, sastoji se od 5 slojeva lamela) sa čeličnom gredom na sredini raspona

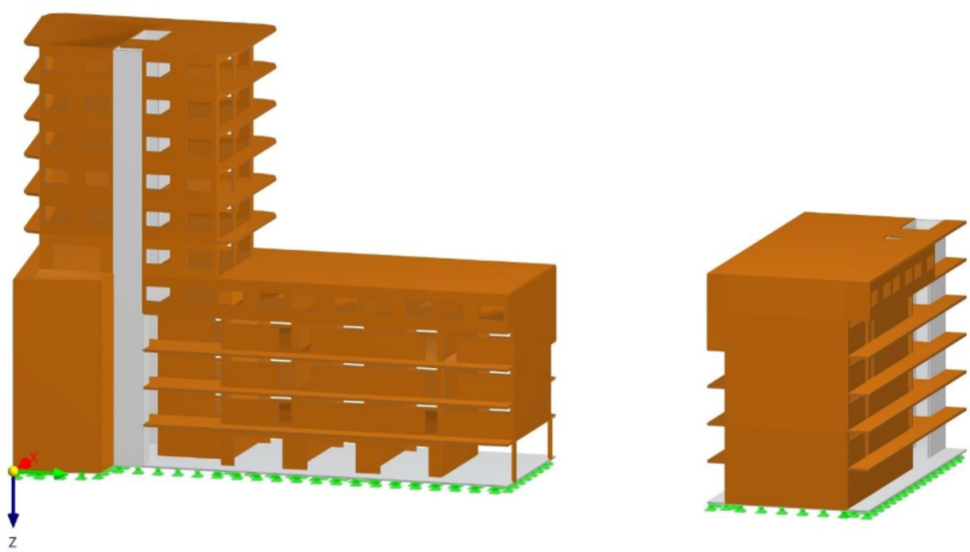
HE 280 A. Klasa drva korištena za lamele u panelima je C24. Stupovi od LLD-a su dimenzija 200x200 mm.

Požarna otpornost vertikalnih elemenata (zidova) je R90, dok su horizontalni elementi (međukatne i krovne ploče) R60.

Paneli te stupovi i grede spajaju se spojnim sredstvima proizvođača Rothoblaas. Korišteni su kutnici za spojeve zidova s pločama, dok su kod spoja ploča korišteni vijci pod kutom 45°.

Projektom su predviđene sve standardne instalacije koje podrazumijeva stambeni objekt (vodovod i kanalizacija, električne instalacije, klimatizacija, protupožarne instalacije, cijevi itd.). Konstrukcija je projektirana tako da zadovolji granična stanja nosivosti i uporabivosti te požarnu otpornost i vibracije. U statički proračun uzeta su sva opterećenja koja propisuje Eurocode s pripadajućim nacionalnim dodacima. Provedena je i dinamička (potresna) analiza te je dokazana otpornost konstrukcije na vršno ubrzanje tla vjerojatnosti premašaja od 10% u 50 godina (povratni period od 475 godina).

Prilikom proračuna su primijenjene sljedeće norme iz pojedinih Eurokodova: HRN EN 1990, HRN EN 1991, HRN EN 1993, HRN EN 1995 i HRN EN 1998 te pripadajući nacionalni dodaci za RH i Sloveniju. Za potrebe cjelokupnog proračuna korišteni su programi *Dlubal RFEM 6* te *Calculatis – Stora Enso.*



Slika 16. Prikaz modela zgrade – Dlubal RFEM

2.3 Analiza opterećenja

2.3.1 Vlastita težina nosivih i ne nosivih dijelova konstrukcije

Vlastita težina svih nosivih elemenata uzima se u programskom paketu Dlubal RFEM njegovim automatskim proračunom.

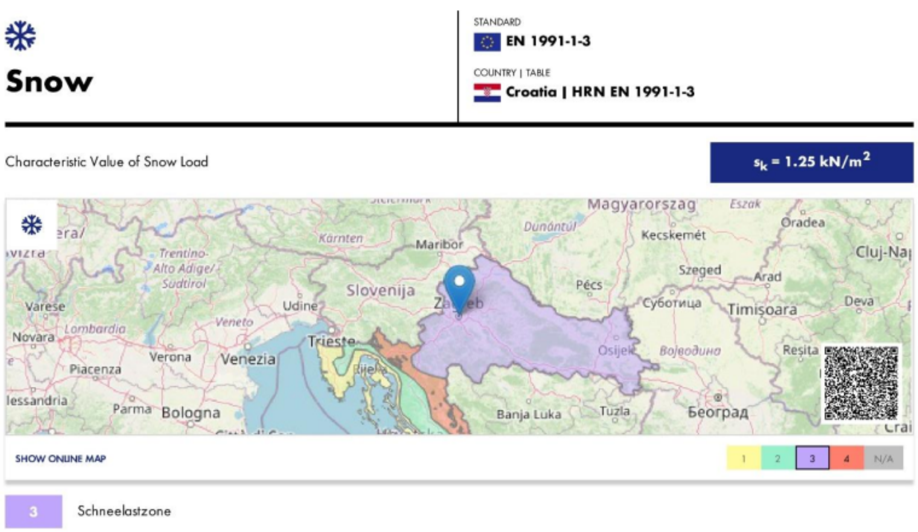
Dodatno stalno opterećenje od ne nosivih dijelova konstrukcije iznosi $1{,}5\ kN/m^2$.

2.3.2 Uporabno opterećenje

Prema HRN EN 1991-1-1:2012 i HRN EN 1991-1-1:2012/NA:2012 uporabno opterećenje iznosi:

- stropovi $q_k = 2{,}0\ kN/m^2$
- balkoni $q_k = 2{,}5\ kN/m^2$
- krovne terase $q_k = 4{,}0\ kN/m^2$
- neprohodan krov $q_k = 0{,}6\ kN/m^2$

2.3.3 Opterećenje snijegom



Slika 17. Karakteristična vrijednost opterećenja snijegom na tlo za lokaciju Zagreb

Prema HRN EN 1991-1-3:2012 i HRN EN 1991-1-3:2012/NA:2012 opterećenje snijegom na krovu dobiva se prema izrazu:

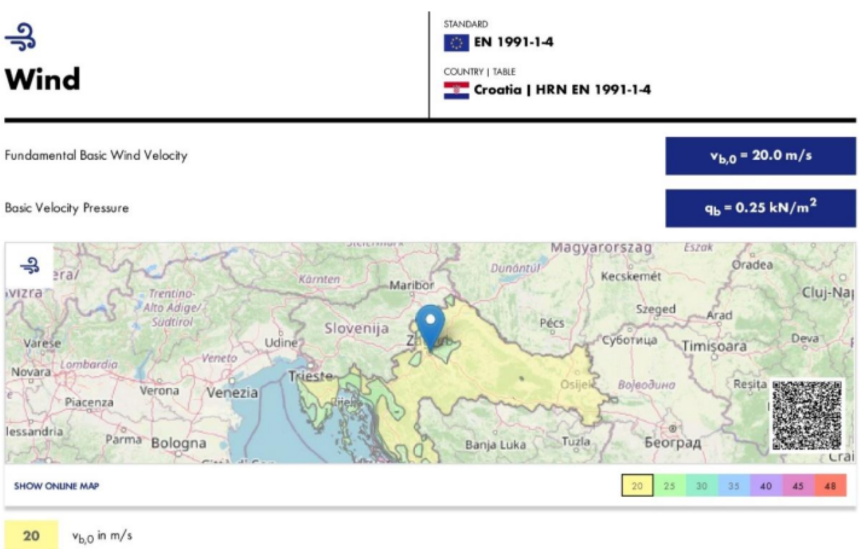
$$s = \mu_i \cdot C_e \cdot C_t \cdot s_k$$

- građevina se nalazi u Zagrebu (158 m n.m.) ; područje 3 – $s_k = 1{,}25\ kN/m^2$
- koeficijent izloženosti $C_e = 1{,}0$; preporučena vrijednost prema HRN EN 1991-1-3:2012/NA
- toplinski koeficijent zbog zagrijavanja građevine $C_t = 1{,}0$; preporučena vrijednost prema HRN EN 1991-1-3:2012/NA
- koeficijent oblika opterećenja snijegom na krovu μ_i ovisi o nagibu i tipu krova, te ovisi o mogućnosti klizanja snijega s krova; za ovaj slučaj iznosi $\mu_i = 0{,}8$

Opterećenje snijegom na krovu iznosi:

$$s = 0{,}8 \cdot 1{,}0 \cdot 1{,}0 \cdot 1{,}25 = 1{,}0\, kN/m^2$$

2.3.4 Opterećenje vjetrom



Slika 18. Osnovna brzina vjetra za lokaciju Zagreb

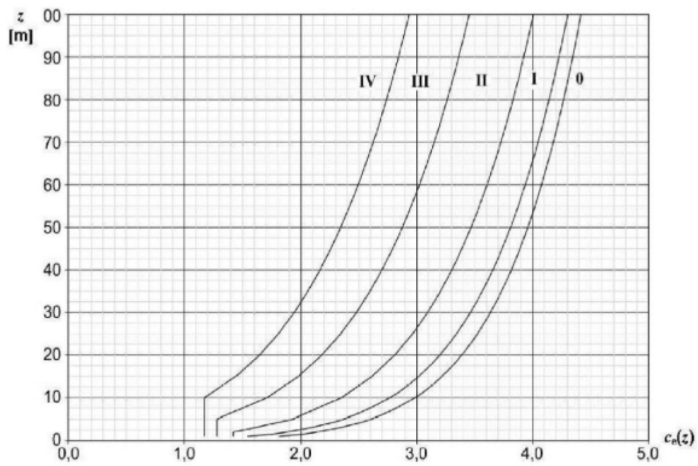
Prema HRN EN 1991-1-4:2012 i HRN EN 1991-1-4:2012/NA:2012 osnovna brzina vjetra dobiva se prema izrazu:

$$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$$

- temeljna vrijednost osnovne brzine vjetra $v_{b,0} = 20\, m/s$

- kategorija terena: IV
- referentna visina zgrade A: $(z_{e,A}) = 33{,}3\ m$
- koeficijent izloženosti krovne plohe zgrade A: $c_e(z_{e,A}) = 2{,}02$ – očitano iz dijagrama
- referentna visina zgrade B: $(z_{e,B}) = 18{,}3\ m$
- koeficijent izloženosti krovne plohe zgrade B: $c_e(z_{e,B}) = 1{,}57$ – očitano iz dijagrama
- faktor smjera vjetra $c_{dir} = 1{,}0$; preporučena vrijednost prema HRN EN 1991-1-4:2012/NA
- faktor godišnjeg doba $c_{season} = 1{,}0$; preporučena vrijednost prema HRN EN 1991-1-4:2012/NA

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



Slika 19. Koeficijent izloženosti

Tlak pri osnovnoj brzini vjetra određuje se prema izrazu:

$$q_b = 0{,}5 \cdot \rho \cdot v_b^2$$

- gustoća zraka $\rho = 1{,}25\ kg/m^3$

$$q_b = 0{,}5 \cdot 1{,}25 \cdot 20^2 = 250\ N/m^2 = 0{,}25\ kN/m^2$$

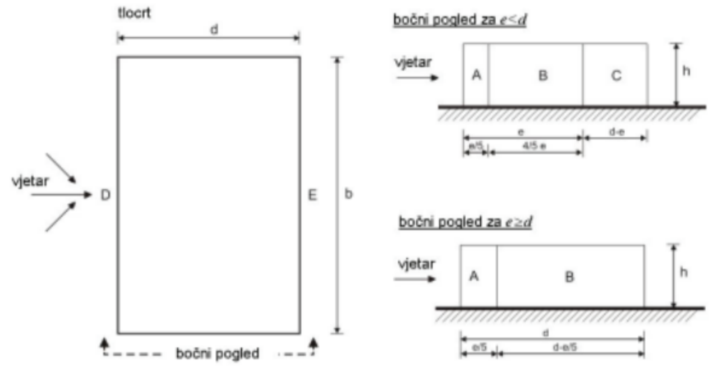
Tlak pri vršnoj brzini na referentnoj visini z_e iznosi

- za zgradu A:

$$q_p(z_{e,A}) = c_e(z_{e,A}) \cdot q_b = 2{,}02 \cdot 0{,}25 = 0{,}505\ kN/m^2$$

- za zgradu B:

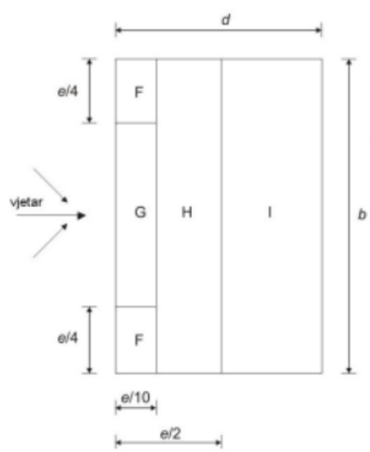
$$q_p(z_{e,B}) = c_e(z_{e,B}) \cdot q_b = 1{,}57 \cdot 0{,}25 = 0{,}393\ kN/m^2$$



Slika 20. Koeficijenti vanjskog tlaka za vertikalne zidove građevina pravokutnog tlocrta

Vrijednosti koeficijenata vanjskog tlaka za vertikalne zidove:

- Područje A: $c_{pe,10,A} = -1{,}2$
- Područje B: $c_{pe,10,B} = -0{,}8$
- Područje C: $c_{pe,10,C} = -0{,}5$
- Područje D: $c_{pe,10,D} = +0{,}8$
- Područje E: $c_{pe,10,E} = -0{,}5$



Slika 21. Koeficijenti vanjskog tlaka za ravne krovove

Vrijednosti koeficijenata vanjskog tlaka za ravne krovove $-5° < \alpha < 5°$:

- Područje F: $c_{pe,10,F} = -1{,}8$
- Područje G: $c_{pe,10,G} = -1{,}2$

- Područje H: $c_{pe,10,H} = -0{,}7$
- Područje I: $c_{pe,10,I,min} = -0{,}2$

  $c_{pe,10,I,max} = +0{,}2$

Vrijednosti koeficijenata unutarnjeg tlaka:

- $c_{pi,min} = -0{,}3$
- $c_{pi,max} = +0{,}2$

Ukupni tlak vjetra određuje se kao zbroj unutarnjeg i vanjskog tlaka:

$$w = w_e + w_i$$

2.3.4.1 Određivanje ukupnog tlaka vjetra po površinama za zgradu A

Iznosi vanjskog tlaka po površini bočnih ploha:

$w_{e,A} = q_p(z_{e,A}) \cdot c_{pe,10,A} = 0{,}505 \cdot (-1{,}2) = -0{,}61\ kN/m^2$

$w_{e,B} = q_p(z_{e,A}) \cdot c_{pe,10,B} = 0{,}505 \cdot (-0{,}8) = -0{,}40\ kN/m^2$

$w_{e,C} = q_p(z_{e,A}) \cdot c_{pe,10,C} = 0{,}505 \cdot (-0{,}5) = -0{,}25\ kN/m^2$

$w_{e,D} = q_p(z_{e,A}) \cdot c_{pe,10,D} = 0{,}505 \cdot (+0{,}8) = +0{,}40\ kN/m^2$

$w_{e,E} = q_p(z_{e,A}) \cdot c_{pe,10,E} = 0{,}505 \cdot (-0{,}5) = -0{,}25\ kN/m^2$

Iznosi vanjskog tlaka po površini krova:

$w_{e,F} = q_p(z_{e,A}) \cdot c_{pe,10,F} = 0{,}505 \cdot (-1{,}8) = -0{,}91\ kN/m^2$

$w_{e,G} = q_p(z_{e,A}) \cdot c_{pe,10,G} = 0{,}505 \cdot (-1{,}2) = -0{,}61\ kN/m^2$

$w_{e,H} = q_p(z_{e,A}) \cdot c_{pe,10,H} = 0{,}505 \cdot (-0{,}7) = -0{,}35\ kN/m^2$

$w_{e,I,min} = q_p(z_{e,A}) \cdot c_{pe,10,I,min} = 0{,}505 \cdot (-0{,}2) = -0{,}10\ kN/m^2$

$w_{e,I,max} = q_p(z_{e,A}) \cdot c_{pe,10,I,max} = 0{,}505 \cdot (+0{,}2) = +0{,}10\ kN/m^2$

Iznosi unutarnjeg tlaka za sve površine:

$w_{i,max} = q_p(z_{i,A}) \cdot c_{pi,max} = 0{,}505 \cdot (+0{,}2) = +0{,}10\ kN/m^2$

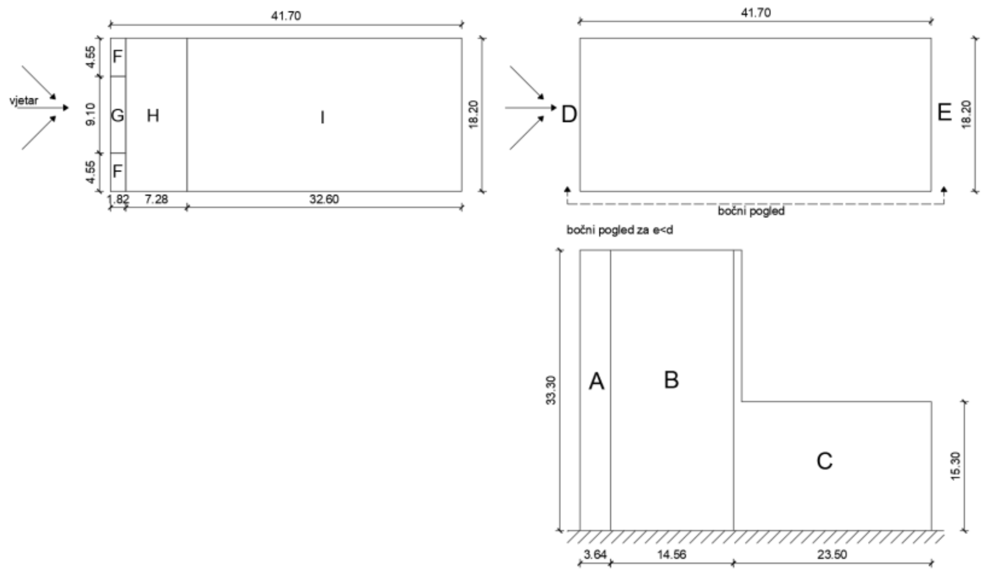
$w_{i,min} = q_p(z_{i,A}) \cdot c_{pi,min} = 0{,}505 \cdot (-0{,}3) = -0{,}15\ kN/m^2$

2.3.4.2 Slučaj 1 – vjetar puše u smjeru 0° (180°), c_{pi} = +0,2

$$h = 33{,}3\ m$$

$$e = \min(b; 2h) = \min(18{,}2; 66{,}6) = 18{,}2$$

$$d = 41{,}7\ m \rightarrow e < d$$



Slika 22. Koeficijenti vanjskog tlaka za zidove i ravne krovove za zgradu A – Slučaj 1 i 2

Ukupni tlak vjetra po površinama:

$$w_A = w_{e,A} + w_{i,max} = -0{,}61 - 0{,}10 = -0{,}71\ \ kN/m^2$$

$$w_B = w_{e,B} + w_{i,max} = -0{,}40 - 0{,}10 = -0{,}50\ \ kN/m^2$$

$$w_C = w_{e,C} + w_{i,max} = -0{,}25 - 0{,}10 = -0{,}35\ \ kN/m^2$$

$$w_D = w_{e,D} + w_{i,max} = +0{,}40 - 0{,}10 = +0{,}30\ \ kN/m^2$$

$$w_E = w_{e,E} + w_{i,max} = -0{,}25 - 0{,}10 = -0{,}35\ \ kN/m^2$$

$$w_F = w_{e,F} + w_{i,max} = -0{,}91 - 0{,}10 = -1{,}01\ \ kN/m^2$$

$$w_G = w_{e,G} + w_{i,max} = -0{,}61 - 0{,}10 = -0{,}71\ \ kN/m^2$$

$$w_H = w_{e,H} + w_{i,max} = -0{,}35 - 0{,}10 = -0{,}45\ \ kN/m^2$$

$$w_{I,min} = w_{e,I,min} + w_{i,max} = -0{,}10 - 0{,}10 = -0{,}20\ \ kN/m^2$$

$$w_{I,max} = w_{e,I,max} + w_{i,max} = +0{,}10 - 0{,}10 = 0{,}00\ \ kN/m^2$$

2.3.4.3 Slučaj 2 – vjetar puše u smjeru 0° (180°), c_{pi} = -0,3

Ukupni tlak vjetra po površinama:

$$w_A = w_{e,A} + w_{i,min} = -0{,}61 + 0{,}15 = -0{,}46\ kN/m^2$$

$$w_B = w_{e,B} + w_{i,min} = -0{,}40 + 0{,}15 = -0{,}25\ kN/m^2$$

$$w_C = w_{e,C} + w_{i,min} = -0{,}25 + 0{,}15 = -0{,}10\ kN/m^2$$

$$w_D = w_{e,D} + w_{i,min} = +0{,}40 + 0{,}15 = +0{,}55\ kN/m^2$$

$$w_E = w_{e,E} + w_{i,min} = -0{,}25 + 0{,}15 = -0{,}10\ kN/m^2$$

$$w_F = w_{e,F} + w_{i,min} = -0{,}91 + 0{,}15 = -0{,}76\ kN/m^2$$

$$w_G = w_{e,G} + w_{i,min} = -0{,}61 + 0{,}15 = -0{,}46\ kN/m^2$$

$$w_H = w_{e,H} + w_{i,min} = -0{,}35 + 0{,}15 = -0{,}20\ kN/m^2$$

$$w_{I,min} = w_{e,I,min} + w_{i,min} = -0{,}10 + 0{,}15 = -0{,}05\ kN/m^2$$

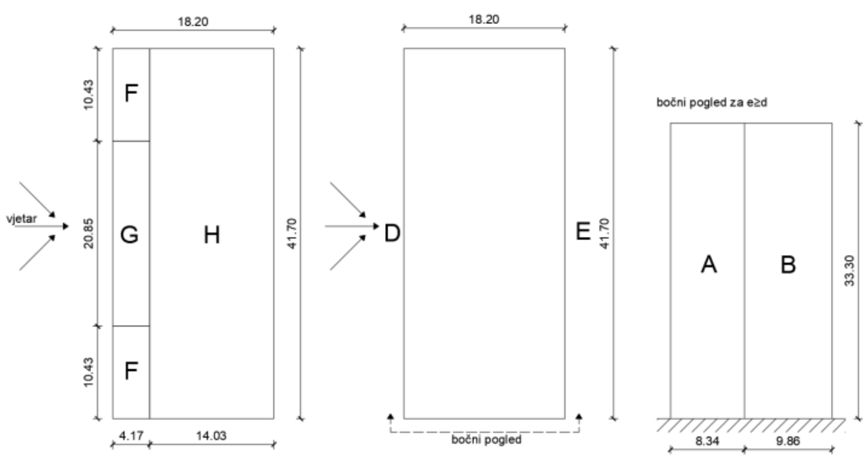
$$w_{I,max} = w_{e,I,max} + w_{i,min} = +0{,}10 + 0{,}15 = +0{,}25\ kN/m^2$$

2.3.4.4 Slučaj 3 – vjetar puše u smjeru 90°, c_{pi} = +0,2

$$h = 33{,}3\ m$$

$$e = \min(b; 2h) = \min(41{,}7; 66{,}6) = 41{,}7$$

$$d = 18{,}2\ m \rightarrow e > d$$



Slika 23. Koeficijenti vanjskog tlaka za zidove i ravne krovove za zgradu A – Slučaj 3 i 4

Ukupni tlak vjetra po površinama:

$w_A = w_{e,A} + w_{i,max} = -0{,}61 - 0{,}10 = -0{,}71\ kN/m^2$

$w_B = w_{e,B} + w_{i,max} = -0{,}40 - 0{,}10 = -0{,}50\ kN/m^2$

$w_D = w_{e,D} + w_{i,max} = +0{,}40 - 0{,}10 = +0{,}30\ kN/m^2$

$w_E = w_{e,E} + w_{i,max} = -0{,}25 - 0{,}10 = -0{,}35\ kN/m^2$

$w_F = w_{e,F} + w_{i,max} = -0{,}91 - 0{,}10 = -1{,}01\ kN/m^2$

$w_G = w_{e,G} + w_{i,max} = -0{,}61 - 0{,}10 = -0{,}71\ kN/m^2$

$w_H = w_{e,H} + w_{i,max} = -0{,}35 - 0{,}10 = -0{,}45\ kN/m^2$

2.3.4.5 Slučaj 4 – vjetar puše u smjeru 90°, c_{pi} = -0,3

Ukupni tlak vjetra po površinama:

$w_A = w_{e,A} + w_{i,min} = -0{,}61 + 0{,}15 = -0{,}46\ kN/m^2$

$w_B = w_{e,B} + w_{i,min} = -0{,}40 + 0{,}15 = -0{,}25\ kN/m^2$

$w_D = w_{e,D} + w_{i,min} = +0{,}40 + 0{,}15 = +0{,}55\ kN/m^2$

$w_E = w_{e,E} + w_{i,min} = -0{,}25 + 0{,}15 = -0{,}10\ kN/m^2$

$w_F = w_{e,F} + w_{i,min} = -0{,}91 + 0{,}15 = -0{,}76\ kN/m^2$

$w_G = w_{e,G} + w_{i,min} = -0{,}61 + 0{,}15 = -0{,}46\ kN/m^2$

$w_H = w_{e,H} + w_{i,min} = -0{,}35 + 0{,}15 = -0{,}20\ kN/m^2$

Slučaj 2 je mjerodavan za pritiskajuće djelovanje vjetra, dok je slučaj 3 mjerodavan za odižuće djelovanje vjetra.

2.3.4.6 Određivanje ukupnog tlaka vjetra po površinama za zgradu B

Iznosi vanjskog tlaka po površini bočnih ploha:

$w_{e,A} = q_p(z_{e,B}) \cdot c_{pe,10,A} = 0{,}393 \cdot (-1{,}2) = -0{,}47\ kN/m^2$

$w_{e,B} = q_p(z_{e,B}) \cdot c_{pe,10,B} = 0{,}393 \cdot (-0{,}8) = -0{,}31\ kN/m^2$

$w_{e,C} = q_p(z_{e,B}) \cdot c_{pe,10,C} = 0{,}393 \cdot (-0{,}5) = -0{,}20\ kN/m^2$

$w_{e,D} = q_p(z_{e,B}) \cdot c_{pe,10,D} = 0{,}393 \cdot (+0{,}8) = +0{,}31\ kN/m^2$

$w_{e,E} = q_p(z_{e,B}) \cdot c_{pe,10,E} = 0{,}393 \cdot (-0{,}5) = -0{,}20\ kN/m^2$

Iznosi vanjskog tlaka po površini krova:

$w_{e,F} = q_p(z_{e,B}) \cdot c_{pe,10,F} = 0{,}393 \cdot (-1{,}8) = -0{,}71\ kN/m^2$

$w_{e,G} = q_p(z_{e,B}) \cdot c_{pe,10,G} = 0{,}393 \cdot (-1{,}2) = -0{,}47\ kN/m^2$

$w_{e,H} = q_p(z_{e,B}) \cdot c_{pe,10,H} = 0{,}393 \cdot (-0{,}7) = -0{,}28\ kN/m^2$

$w_{e,I,min} = q_p(z_{e,B}) \cdot c_{pe,10,I,min} = 0{,}393 \cdot (-0{,}2) = -0{,}08\ kN/m^2$

$w_{e,I,max} = q_p(z_{e,B}) \cdot c_{pe,10,I,max} = 0{,}393 \cdot (+0{,}2) = +0{,}08\ kN/m^2$

Iznosi unutarnjeg tlaka za sve površine:

$w_{i,max} = q_p(z_{i,A}) \cdot c_{pi,max} = 0{,}393 \cdot (+0{,}2) = +0{,}08\ kN/m^2$

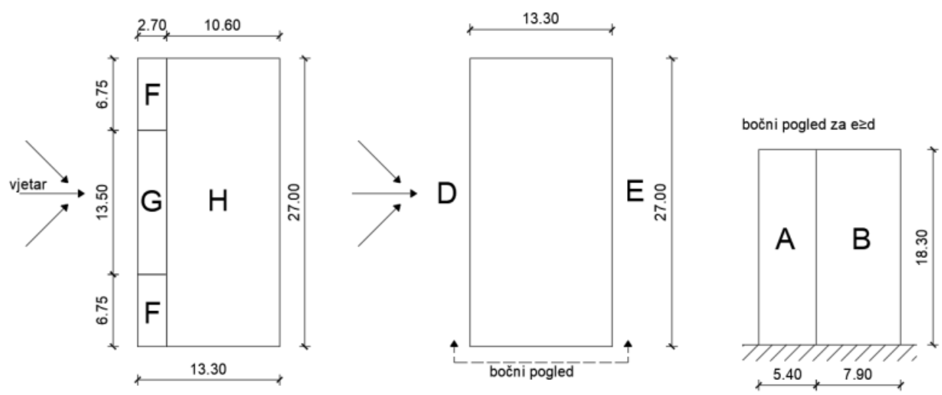
$w_{i,min} = q_p(z_{i,A}) \cdot c_{pi,min} = 0{,}393 \cdot (-0{,}3) = -0{,}12\ kN/m^2$

2.3.4.7 Slučaj 1 – vjetar puše u smjeru 0° (180°), c_{pi} = +0,2

$h = 18{,}3\ m$

$e = \min(b; 2h) = \min(27{,}0; 36{,}6) = 27{,}0$

$d = 13{,}3\ m \rightarrow e > d$



Slika 24. Koeficijenti vanjskog tlaka za zidove i ravne krovove za zgradu B – Slučaj 1 i 2

Ukupni tlak vjetra po površinama:

$w_A = w_{e,A} + w_{i,max} = -0{,}47 - 0{,}08 = -0{,}55\ kN/m^2$

$w_B = w_{e,B} + w_{i,max} = -0{,}31 - 0{,}08 = -0{,}39\ kN/m^2$

$w_D = w_{e,D} + w_{i,max} = +0{,}31 - 0{,}08 = +0{,}23\ kN/m^2$

$w_E = w_{e,E} + w_{i,max} = -0{,}20 - 0{,}08 = -0{,}28 \ kN/m^2$

$w_F = w_{e,F} + w_{i,max} = -0{,}71 - 0{,}08 = -0{,}79 \ kN/m^2$

$w_G = w_{e,G} + w_{i,max} = -0{,}47 - 0{,}08 = -0{,}55 \ kN/m^2$

$w_H = w_{e,H} + w_{i,max} = -0{,}28 - 0{,}08 = -0{,}36 \ kN/m^2$

2.3.4.8 Slučaj 2 – vjetar puše u smjeru 0° (180°), c_{pi} = -0,3

Ukupni tlak vjetra po površinama:

$w_A = w_{e,A} + w_{i,max} = -0{,}47 + 0{,}12 = -0{,}35 \ kN/m^2$

$w_B = w_{e,B} + w_{i,max} = -0{,}31 + 0{,}12 = -0{,}19 \ kN/m^2$

$w_D = w_{e,D} + w_{i,max} = +0{,}31 + 0{,}12 = +0{,}43 \ kN/m^2$

$w_E = w_{e,E} + w_{i,max} = -0{,}20 + 0{,}12 = -0{,}08 \ kN/m^2$

$w_F = w_{e,F} + w_{i,max} = -0{,}71 + 0{,}12 = -0{,}59 \ kN/m^2$

$w_G = w_{e,G} + w_{i,max} = -0{,}47 + 0{,}12 = -0{,}35 \ kN/m^2$

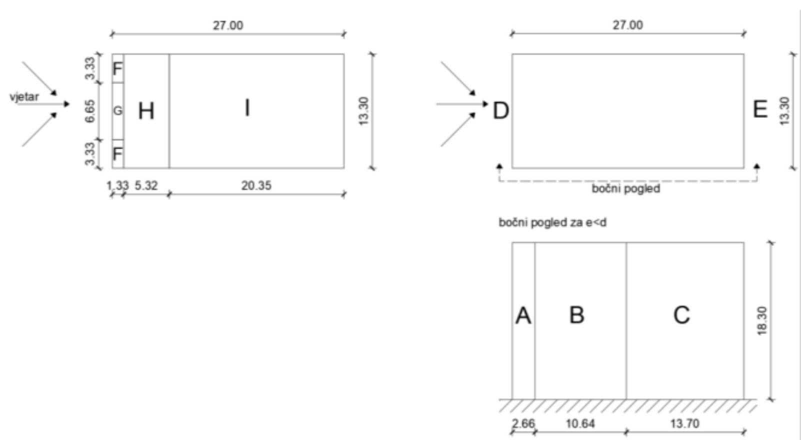
$w_H = w_{e,H} + w_{i,max} = -0{,}28 + 0{,}12 = -0{,}16 \ kN/m^2$

2.3.4.9 Slučaj 3 – vjetar puše u smjeru 90°, c_{pi} = +0,2

$h = 18{,}3 \ m$

$e = \min(b; 2h) = \min(13{,}3; 36{,}6) = 13{,}3$

$d = 27{,}0 \ m \rightarrow e < d$



Slika 25. Koeficijenti vanjskog tlaka za zidove i ravne krovove za zgradu A – Slučaj 3 i 4

Ukupni tlak vjetra po površinama:

$w_A = w_{e,A} + w_{i,max} = -0{,}47 - 0{,}08 = -0{,}55\ kN/m^2$

$w_B = w_{e,B} + w_{i,max} = -0{,}31 - 0{,}08 = -0{,}39\ kN/m^2$

$w_C = w_{e,C} + w_{i,max} = -0{,}20 - 0{,}08 = -0{,}28\ kN/m^2$

$w_D = w_{e,D} + w_{i,max} = +0{,}31 - 0{,}08 = +0{,}23\ kN/m^2$

$w_E = w_{e,E} + w_{i,max} = -0{,}20 - 0{,}08 = -0{,}28\ kN/m^2$

$w_F = w_{e,F} + w_{i,max} = -0{,}71 - 0{,}08 = -0{,}79\ kN/m^2$

$w_G = w_{e,G} + w_{i,max} = -0{,}47 - 0{,}08 = -0{,}55\ kN/m^2$

$w_H = w_{e,H} + w_{i,max} = -0{,}28 - 0{,}08 = -0{,}36\ kN/m^2$

$w_{I,min} = w_{e,I,min} + w_{i,max} = -0{,}08 - 0{,}08 = -0{,}16\ kN/m^2$

$w_{I,max} = w_{e,I,max} + w_{i,max} = +0{,}08 - 0{,}08 = 0{,}00\ kN/m^2$

2.3.4.10 Slučaj 4 – vjetar puše u smjeru 90°, c_{pi} = -0,3

Ukupni tlak vjetra po površinama:

$w_A = w_{e,A} + w_{i,max} = -0{,}47 + 0{,}12 = -0{,}35\ kN/m^2$

$w_B = w_{e,B} + w_{i,max} = -0{,}31 + 0{,}12 = -0{,}19\ kN/m^2$

$w_C = w_{e,C} + w_{i,max} = -0{,}20 + 0{,}12 = -0{,}08\ kN/m^2$

$w_D = w_{e,D} + w_{i,max} = +0{,}31 + 0{,}12 = +0{,}43\ kN/m^2$

$w_E = w_{e,E} + w_{i,max} = -0{,}20 + 0{,}12 = -0{,}08\ kN/m^2$

$w_F = w_{e,F} + w_{i,max} = -0{,}71 + 0{,}12 = -0{,}59\ kN/m^2$

$w_G = w_{e,G} + w_{i,max} = -0{,}47 + 0{,}12 = -0{,}35\ kN/m^2$

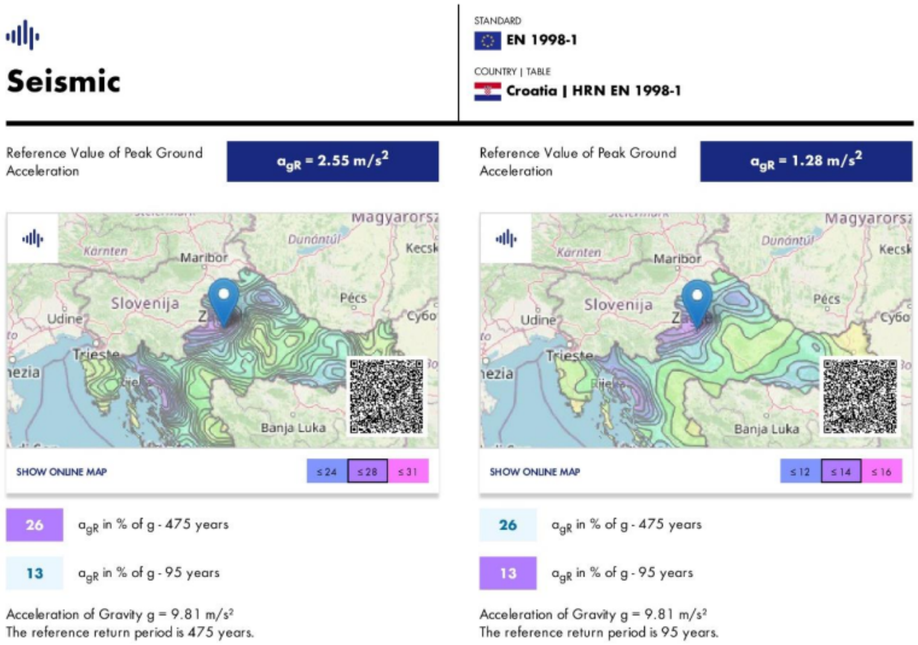
$w_H = w_{e,H} + w_{i,max} = -0{,}28 + 0{,}12 = -0{,}16\ kN/m^2$

$w_{I,min} = w_{e,I,min} + w_{i,max} = -0{,}08 + 0{,}12 = +0{,}04\ kN/m^2$

$w_{I,max} = w_{e,I,max} + w_{i,max} = +0{,}08 + 0{,}12 = +0{,}20\ kN/m^2$

Slučaj 1 je mjerodavan za odižuće djelovanje vjetra, dok je slučaj 4 mjerodavan za pritiskajuće djelovanje vjetra.

2.3.5 Potresno opterećenje



Slika 26. Prikaz povratnih perioda i ubrzanja tla za Zagreb

- tip tla: C
- tip spektra: 1
- faktor tla: $S = 1{,}0$
- donja granica perioda s granom konstantnog spektralnog ubrzanja: $T_B = 0{,}05\ s$
- gornja granica perioda s granom konstantnog spektralnog ubrzanja: $T_C = 0{,}15\ s$
- vrijednost perioda koja definira početak konstantnog spektralnog pomaka: $T_D = 1{,}0\ s$
- horizontalno vršno ubrzanje tla za povreatno razdoblje $T_p = 475\ god$: $a_{g,R} = 0{,}255$
- proračunsko vršno ubrzanje tla: $a_g = a_{g,R} \cdot \gamma_i = 0{,}255\ m/s^2$
- faktor ponašanja: $q = 2{,}5$
- klasa važnosti: II – obične zgrade koje ne pripadaju drugim skupinama
- $\gamma_i = 1{,}0$

2.4 Statički proračun

2.4.1 Proračun zgrade A (P+10)

Marija Gulam

Dlubal

Model: diplomski_zgradaA1

Date 21.8.2024 Page 1/38
Sheet 1

MODEL

CONTENTS

1 Basic Objects 2
1.1 Materials 2
1.2 Sections 2
1.3 Thicknesses 2
1.3.1 Thicknesses - Layer Info 2
1.3.2 Thicknesses - Layers 2
1.3.3 Thicknesses - Options for CLT 3
1.4 Model, In Axonometric Direction 4
1.5 Model, In Axonometric Direction 5
1.6 Model, In Axonometric Direction 6
1.7 Model, In Axonometric Direction 7

2 Special Objects 8
2.1 Nodal Releases 8

3 Types for Surfaces 8
3.1 Surface Supports 8

4 Types for Special Objects 8
4.1 Nodal Release Types 8
4.2 8

5 Load Cases & Combinations 8
5.1 Load Cases 8
5.2 Static Analysis Settings 9
5.3 Modal Analysis Settings 10
5.4 Spectral Analysis Settings 11
5.5 Combination Wizards 11
5.5.1 Combination Wizards - Initial State Items 12
A LC2: Loading, In Axonometric Direction 13
B LC3: Loading, In Axonometric Direction 14
C LC5: Loading, In Axonometric Direction 15
D LC4: Loading, In Axonometric Direction 16
E LC6: Loading, In Axonometric Direction 17
F LC7: Loading, In Axonometric Direction 18

6 Dynamic Loads 19
6.1 Response Spectra 19
6.1.1 Response Spectra - Parameters 19
6.2 Response Spectra | Diagram 19

7 Static Analysis Results 19
7.1 CO10: Basic Internal Forces m_x, In Axonometric Axonometric Direction 20
7.2 CO10: Basic Internal Forces m_y, In Axonometric Axonometric Direction 21
7.3 CO10: Basic Internal Forces n_x, In Axonometric Direction 22
7.4 CO10: Basic Internal Forces n_y, In Axonometric Direction 23
7.5 CO57: Global Deformations |u|, In Axonometric Direction 24
7.6 CO104: Global Deformations |u|, In Axonometric Direction 25
7.7 CO10: Forces n, In Axonometric Direction 26
7.8 CO10: Forces v_y, In Axonometric Direction 27
7.9 CO10: Forces v_z, In Axonometric Direction 28

8 Modal Analysis Results 29
8.1 Natural Frequencies 29
8.2 Effective Modal Masses 29
8.3 Effective Modal Masses - Equivalent Mass per Unit Length 30
8.4 LC9: Mode Shape |u|, In Axonometric Direction 31
8.5 LC9: Mode Shape |u|, In Axonometric Direction 32
8.6 LC9: Mode Shape |u|, In Axonometric Direction 33
8.7 LC9: Mode Shape |u|, In Axonometric Direction 34
8.8 LC9: Mode Shape |u|, In Axonometric Direction 35
8.9 LC9: Mode Shape |u|, In Axonometric Direction 36
G LC10: Envelope Values - Max and Min Values, Global Deformations |u|, In Axonometric Direction 37
H LC10: Envelope Values - Max and Min Values, Global Deformations |u|, In Axonometric Direction 38

www.dlubal.com | RFEM 6.07.0002 - General 3D structures solved using FEM

1 Basic Objects

1.1 MATERIALS

Legend
- Concrete Settings
- Stiffness modification

Material No.	Material Name	Material Type	Analysis Model	Options
1	C24 BBS XL | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	
2	C24 BBS XL | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	
3	GL32h | Isotropic | Linear Elastic	Timber	Isotropic | Linear Elastic	
4	C35/45 | Isotropic | Linear Elastic	Concrete	Isotropic | Linear Elastic	

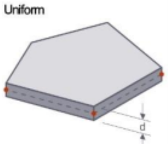
1.2 SECTIONS

Section No.	Material No.	Section Type	Manufacturing Type	I_t [cm⁴] A [cm²]	I_y [cm⁴] A_y [cm²]	I_z [cm⁴] A_z [cm²]	Overall Dimensions b [mm]	h [mm]
1	R_M1 200/200 | 3 - GL32h							
	3	Parametric - Massive I		22533.33	13333.33	13333.33	200.0	200.0
				400.00	333.33	333.33		

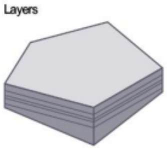
R_M1
200/200

1.3 THICKNESSES

Uniform



Layers



Thick. No.	Type	Assigned to Surface No.	Material	Thickness Symbol	Value	Unit	Nodes	Direction
1	Layers | d : 220.0 mm | Layers: 7							
	Layers	11,12,20,71,73,75,77,97-99,116,118,154-157,171-192,204-206,212-214,221-223,229-231,267-273,298-304,343,408-410,413-415,418-420,423-425,526						
2	Layers | d : 140.0 mm | Layers: 5							
	Layers	1-10,13,14,21-31,43-53,70,72,74,76,78,100-104,106-114,117,120-129,139-142,159-170,208-211,216-220,225-228,233-236,257,258,262-266,315-342,348-364,366-381,383-407,411,412,416,417,421,422,426,427						
3	Uniform | d : 200.0 mm | 4 - C35/45							
	Uniform	32-42,59-69,115,119,143-153,158,193-203,207,215,224,232,274-296,305	4	d	200.0	mm		

1.3.1 THICKNESSES - LAYER INFO

Thick. No.	Total Thickness d [mm]	Total Weight g [N/m²]	Direction of Main Thickness	Comment
1	220.0	990.0	0.00	
2	140.0	630.0	0.00	

1.3.2 THICKNESSES - LAYERS

Thick. No.	Layer No.	Object	Material	Thickness t [mm]	Rotation β [deg]	Number of Int. Points	Spec. W. g_i [N/m³]	Weight g [N/m²]
1	1	Directly	1	40.0	0.00	9	4500.0	180.0
	2	Directly	2	40.0	90.00	9	4500.0	180.0
	3	Directly	1	20.0	0.00	9	4500.0	90.0
	4	Directly	2	20.0	90.00	9	4500.0	90.0
	5	Directly	1	20.0	0.00	9	4500.0	90.0
	6	Directly	2	40.0	90.00	9	4500.0	180.0
	7	Directly	1	40.0	0.00	9	4500.0	180.0
2	1	Directly	1	40.0	0.00	9	4500.0	180.0

1.3.2 THICKNESSES - LAYERS

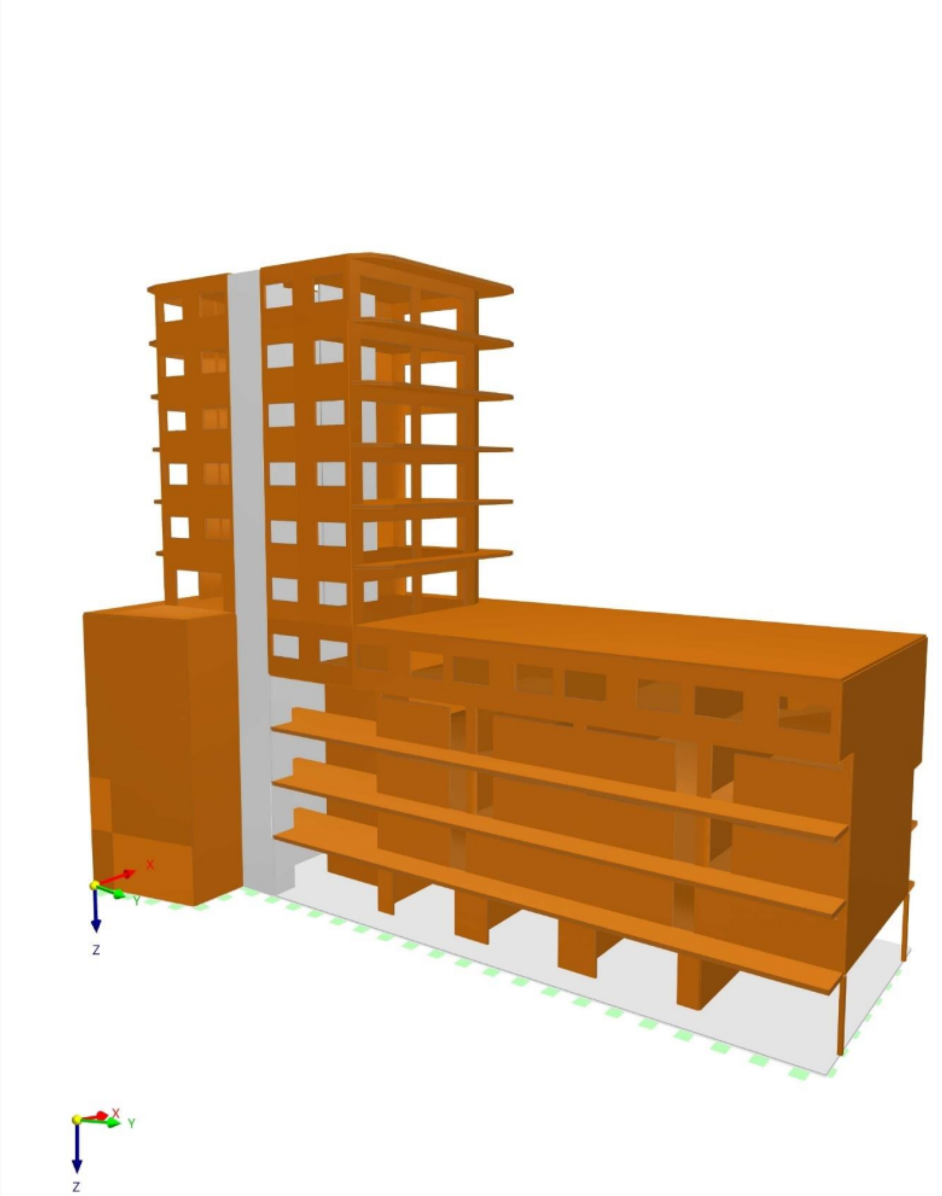
Thick. No.	Layer No.	Object	Material	Thickness t [mm]	Rotation β [deg]	Number of Int. Points	Spec. W. g_i [N/m³]	Weight g [N/m²]
	2	Directly	2	20.0	90.00	9	4500.0	90.0
	3	Directly	1	20.0	0.00	9	4500.0	90.0
	4	Directly	2	20.0	90.00	9	4500.0	90.0
	5	Directly	1	40.0	0.00	9	4500.0	180.0

1.3.3 THICKNESSES - OPTIONS FOR CLT

Thick. No.	Options for CLT Name	Symbol	Value	Unit
1	Design for failure of net section and failure in glued contact surface is enabled.		☐	
2	Design for failure of net section and failure in glued contact surface is enabled.		☐	

1.4 **MODEL, IN AXONOMETRIC DIRECTION**

Visibility mode | In Axonometric Direction



1.5 **MODEL, IN AXONOMETRIC DIRECTION**

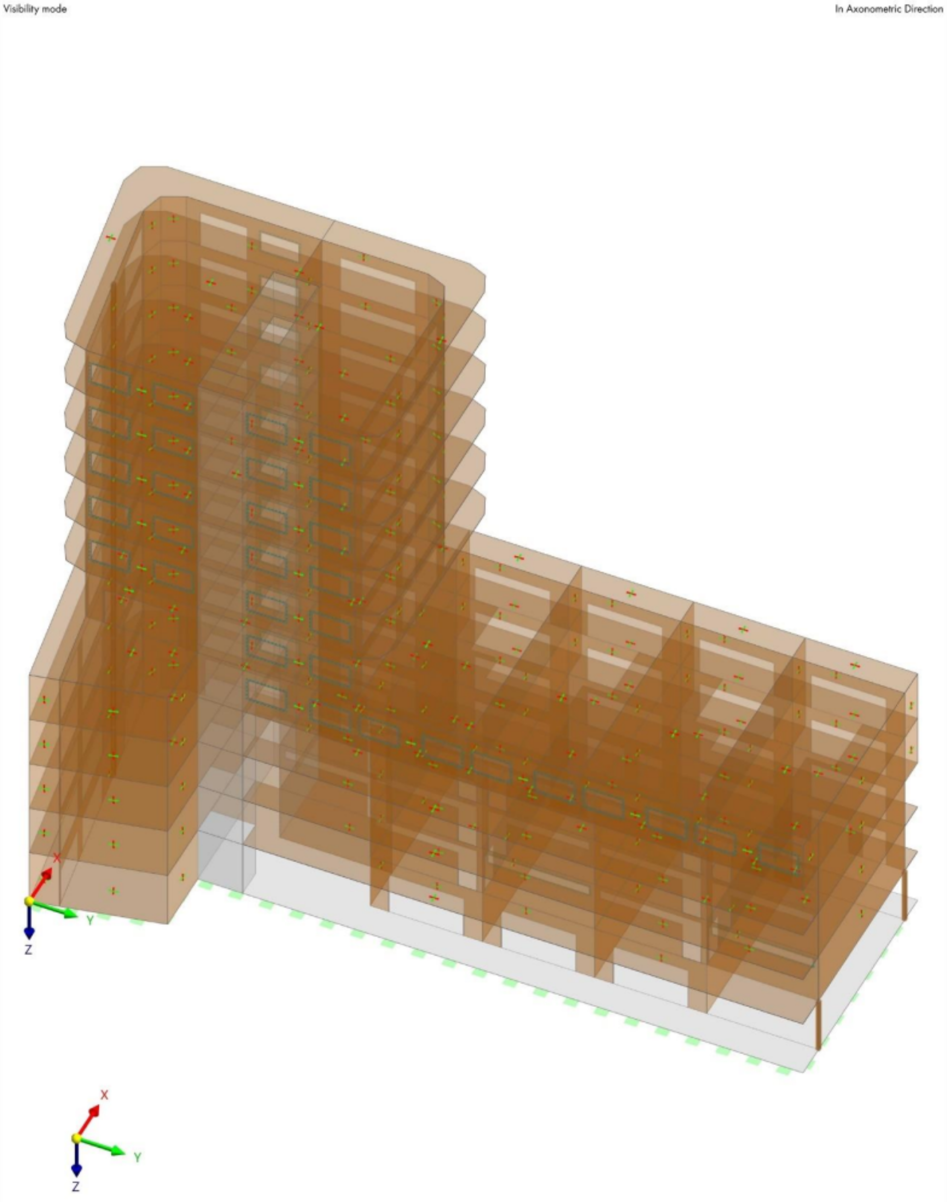
Visibility mode | In Axonometric Direction

1.6 **MODEL, IN AXONOMETRIC DIRECTION**

1.7 **MODEL, IN AXONOMETRIC DIRECTION**

Visibility mode

In Axonometric Direction



2 Special Objects

2.1 NODAL RELEASES

Release No.	Name	Value
1	1 - ☐☐☐ ☐☑☑ | 1 - Global XYZ | Original node (Nodes : 409,1015)	
	Nodes	409,1015
	Nodal Release Type	1 - ☐☐☐ ☐☑☑ | 1 - Global XYZ
	Released Members	1,2
	Released Surfaces	
	Released Solids	
	Release Location	Original node
	Generated released nodes	
	Deactivated	☐

3 Types for Surfaces

3.1 SURFACE SUPPORTS

Support No.	Surfaces No.	Translational Spring $C_{u,x}$ [kN/m³]	$C_{u,y}$ [kN/m³]	$C_{u,z}$ [kN/m³]	Shear Spring $C_{v,xz}$ [kN/m]	$C_{v,yz}$ [kN/m]
1	☑☑☑ ☑☑ | Rigid					
	115,158,207,215,224, 232,274,305	☒	☒	☒	☒	☒

4 Types for Special Objects

4.1 NODAL RELEASE TYPES

Release Type No.	Coordinate System	Local Axis System Object Type	No.	Translation Spring [kN/m] $C_{u,X}$	$C_{u,Y}$	$C_{u,Z}$	Rotation Spring [kNm/rad] $C_{\varphi,X}$	$C_{\varphi,Y}$	$C_{\varphi,Z}$
1	☐☐☐ ☐☑☑ | 1 - Global XYZ								
	1			☐	☐	☐	☐	☒	☒

4.2 LINE RELEASE TYPES

Release No.	Local Axis System Type	No.	In Plane	Translational Spring [kN/m²] $C_{u,x}$	$C_{u,y}$	$C_{u,z}$	Spring Constant $C_{\varphi,x}$ [kNm·rad⁻¹·m⁻¹]	Rot. Angle β [deg]
1	☐☐☐ ☑ | Line Releases: 1-49)							
	Original line			☐	☐	☐	☒	0.00

5 Load Cases & Combinations

5.1 LOAD CASES

LC No.	Settings	Value	Unit	To Solve
1	G Self-weight			
	Analysis type	Static Analysis		☒
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson		
	Action category	G Permanent		
	Self-weight - Factor in direction X	0.000	–	
	Self-weight - Factor in direction Y	0.000	–	
	Self-weight - Factor in direction Z	1.000	–	
	Load duration	Permanent		
	Self-weight mode for geotechnical analysis	Normal		
2	G Dodatno stalno			
	Analysis type	Static Analysis		☒
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson		
	Action category	G Permanent		
	Load duration	Permanent		
	Self-weight mode for geotechnical analysis	Normal		
3	QI A Uporabno			
	Analysis type	Static Analysis		☒

Marija Gulam	Dlubal	Model: diplomski_zgradaA1	Date 21.8.2024 Page 9/38 Sheet 1 LOADS

5.1 LOAD CASES

LC No.	Settings	Value	Unit	To Solve
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson		
	Action category	QI A Imposed loads - category A: domestic, residential areas		
	Load duration	Medium-term		
	Factor Phi	Independently occupied floors		
	Self-weight mode for geotechnical analysis	Normal		
	Imposed load is considered as fatigue	☐		
4	Qs Snijeg			
	Analysis type	Static Analysis		☒
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson		
	Action category	Qs Snow/Ice loads - H <= 1000 m		
	Load duration	Short-term		
	Self-weight mode for geotechnical analysis	Normal		
5	QI A Uporabno krov			
	Analysis type	Static Analysis		☒
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson		
	Action category	QI A Imposed loads - category A: domestic, residential areas		
	Load duration	Medium-term		
	Factor Phi	Roofs		
	Self-weight mode for geotechnical analysis	Normal		
	Imposed load is considered as fatigue	☐		
6	Qw Vjetar			
	Analysis type	Static Analysis		☒
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson		
	Action category	Qw Wind		
	Load duration	Short-term		
	Self-weight mode for geotechnical analysis	Normal		
7	Qw Vjetar odizuci			
	Analysis type	Static Analysis		☒
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson		
	Action category	Qw Wind		
	Load duration	Short-term		
	Self-weight mode for geotechnical analysis	Normal		
9	AE Potres_modalna			
	Analysis type	Modal Analysis		☒
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Modal analysis settings	MOS1 - #30 | Lanczos		
	Import masses from	SE/M CO162		
	Action category	AE Seismic actions		
	Self-weight mode for geotechnical analysis	Normal		
10	AE Potres_spektar			
	Analysis type	Response Spectrum Analysis		☒
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04		
	Spectral analysis settings	SPS1 - SRSS | Scaled Sum 30.00 %		
	Import modal analysis from	AE LC9		
	Action category	AE Seismic actions		
	Load duration	Instantaneous		
	Self-weight mode for geotechnical analysis	Normal		

5.2 STATIC ANALYSIS SETTINGS

Settings No.	Description	Symbol	Value	Unit
1	Geometrically linear | Newton-Raphson			
	Analysis type		Geometrically linear	
	Iterative method for nonlinear analysis		Newton-Raphson	
	Maximum number of iterations		100	
	Number of load increments		1	
	Modify standard precision and tolerance settings		☐	
	Ignore all nonlinearities		☐	
	Modify loading by multiplier factor		☐	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Method for equation system		Direct	

5.2 **STATIC ANALYSIS SETTINGS**

Settings No.	Description	Symbol	Value	Unit
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
	Stability check based on deformation rate		☐	
2	Second-order (P-Δ) | Picard | 100 | 1			
	Analysis type		Second-order (P-Δ)	
	Iterative method for nonlinear analysis		Picard	
	Maximum number of iterations		100	
	Number of load increments		1	
	Modify standard precision and tolerance settings		☐	
	Ignore all nonlinearities		☐	
	Modify loading by multiplier factor		☐	
	Consider favorable effect due to tension in members		☒	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Refer internal forces to deformed structure		☒	
	Refer internal forces to deformed structure for axial forces		☒	
	Refer internal forces to deformed structure for shear forces		☒	
	Refer internal forces to deformed structure for moments		☒	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
	Stability check based on deformation rate		☐	
3	Large deformations | Newton-Raphson | 100 | 1			
	Analysis type		Large deformations	
	Iterative method for nonlinear analysis		Newton-Raphson	
	Maximum number of iterations		100	
	Number of load increments		1	
	Modify standard precision and tolerance settings		☐	
	Ignore all nonlinearities		☐	
	Modify loading by multiplier factor		☐	
	Consider favorable effect due to tension in members		☒	
	Try to calculate unstable structure		☐	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
	Stability check based on deformation rate		☐	

5.3 **MODAL ANALYSIS SETTINGS**

Settings No.	Description	Symbol	Value	Unit
1	#30 | Lanczos			
	Number of modes method		User-Defined	
	Number of modes		30	
	Solution method		Lanczos	
	Mass matrix type		Consistent	
	Acting masses in X-direction enabled	u_X	☒	
	Acting masses in Y-direction enabled	u_Y	☒	
	Acting masses in Z-direction enabled	u_Z	☐	
	Acting masses about X-axis enabled	φ_X	☐	
	Acting masses about Y-axis enabled	φ_Y	☐	
	Acting masses about Z-axis enabled	φ_Z	☐	
	Mass conversion type		Z-components of loads	
	Neglect masses		User-Defined	
2	#10 | Lanczos			
	Number of modes method		User-Defined	
	Number of modes		10	
	Solution method		Lanczos	
	Mass matrix type		Consistent	
	Acting masses in X-direction enabled	u_X	☒	
	Acting masses in Y-direction enabled	u_Y	☒	
	Acting masses in Z-direction enabled	u_Z	☒	
	Acting masses about X-axis enabled	φ_X	☒	

5.3 MODAL ANALYSIS SETTINGS

Settings No.	Description	Symbol	Value	Unit
	Acting masses about Y-axis enabled	φ_Y	☒	
	Acting masses about Z-axis enabled	φ_Z	☒	
	Mass conversion type		Z-components of loads	
	Neglect masses		No neglection	

5.4 SPECTRAL ANALYSIS SETTINGS

Settings No.	Description	Symbol	Value	Unit
1	SRSS | Scaled Sum 30.00 %			
	Combination rule for periodic responses		SRSS	
	Use equivalent linear combination		☐	
	Signed results using dominant mode		☐	
	Save results of all selected modes		☒	
	Combination rule for directional components		Scaled Sum	
	Combination rule for directional components		30.00	%
	Consider independent directions in envelope results		☐	

5.5 COMBINATION WIZARDS

Wizard No.	Settings	Value
1	Load combinations | SA1 - Geometrically linear | Newton-Raphson	
	Assigned to	DS 1-6
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson
	Consider imperfection case	☒
	Consider initial state	☐
	Structure modification enabled	☐
	Generate same combinations without imperfection case	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐
	Assigned to	DS 1-6
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson
	Consider imperfection case	☒
	Consider initial state	☐
	Structure modification enabled	☐
	Generate same combinations without imperfection case	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐
2	Load combinations | SA1 - Geometrically linear | Newton-Raphson	
	Assigned to	
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson
	Consider imperfection case	☐
	Consider initial state	☐
	Structure modification enabled	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐
	Assigned to	
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson
	Consider imperfection case	☐
	Consider initial state	☐
	Structure modification enabled	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐
3	Result combinations	
	Assigned to	DS 7
	Generate combinations	Result combinations (linear analysis)
	Consider imperfection case	☐
	Generate as permanent superposition	☒
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Assigned to	DS 7
	Generate combinations	Result combinations (linear analysis)
	Consider imperfection case	☐

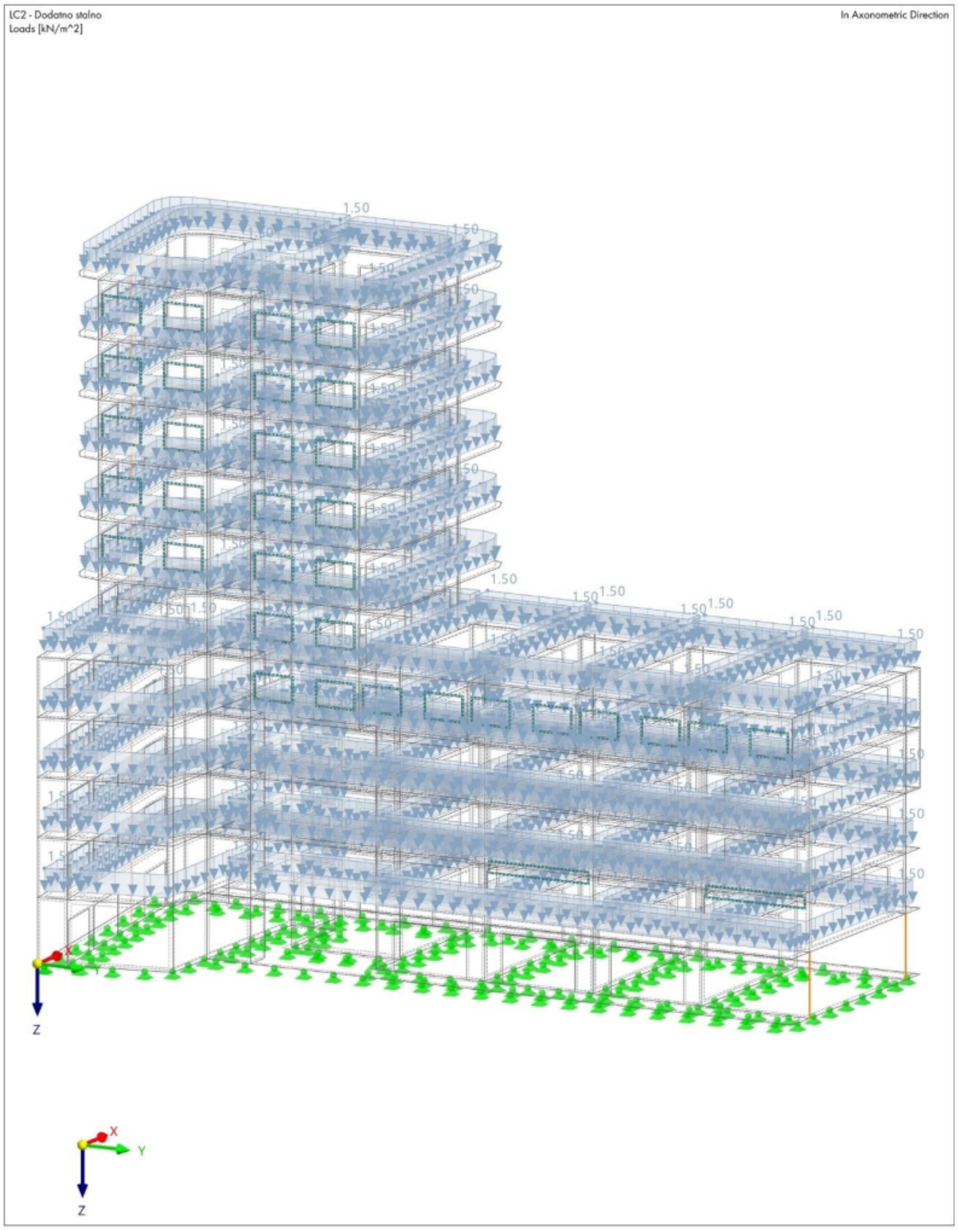
5.5 COMBINATION WIZARDS

Wizard No.	Settings	Value
	User-defined action combinations	☐
	Favorable permanent actions	☐

5.5.1 COMBINATION WIZARDS - INITIAL STATE ITEMS

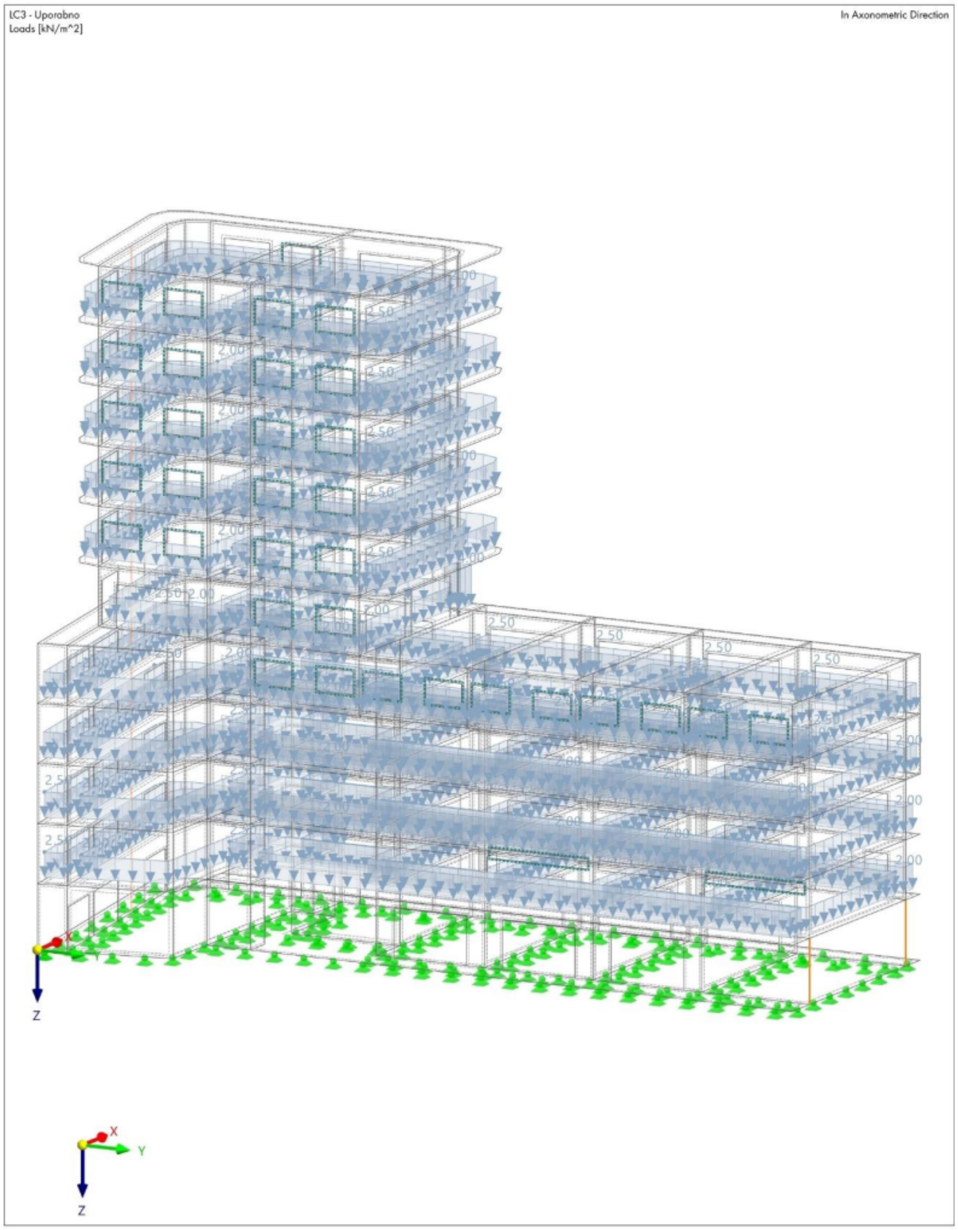
Wizard No.	Definition Type	Case Object
1	Load combinations | SA1 - Geometrically linear | Newton-Raphson	
2	Load combinations | SA1 - Geometrically linear | Newton-Raphson	
3	Result combinations	

A **LC2: LOADING, IN AXONOMETRIC DIRECTION**

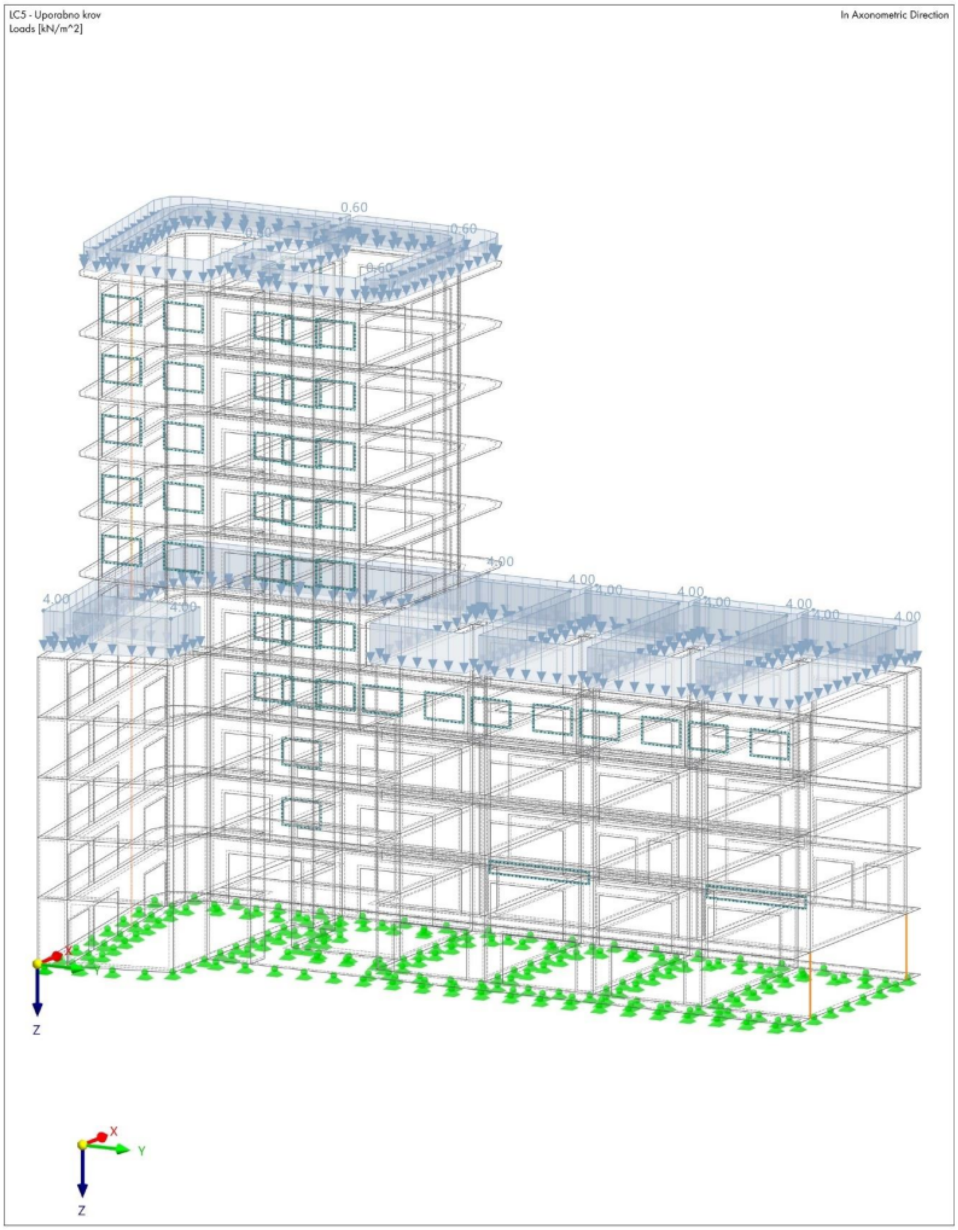


Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024 Page 14/38 Sheet 1
		MODEL

LC3: LOADING, IN AXONOMETRIC DIRECTION

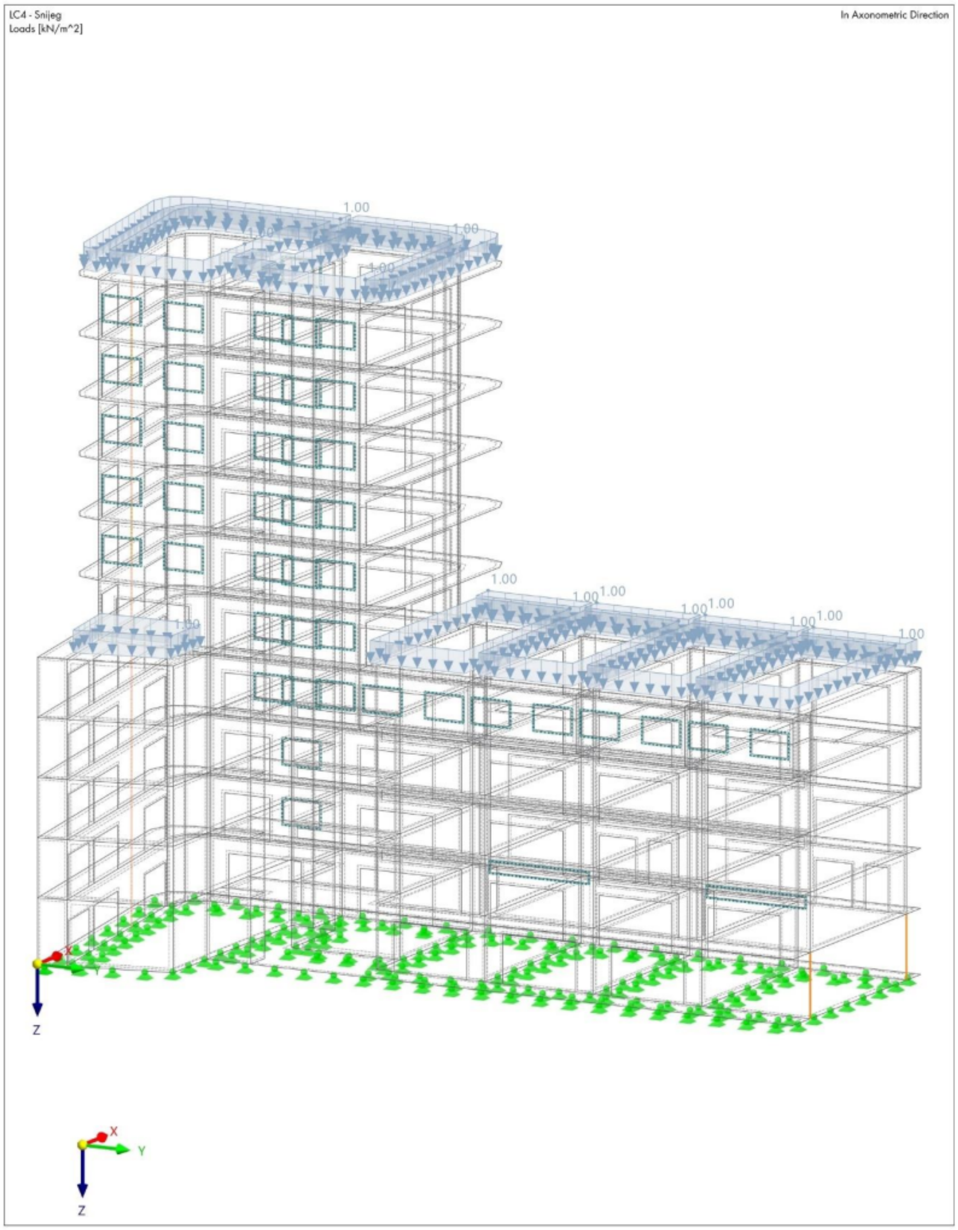


C **LC5: LOADING, IN AXONOMETRIC DIRECTION**



Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024	Page 16/38
			Sheet 1
		MODEL	

D **LC4: LOADING, IN AXONOMETRIC DIRECTION**

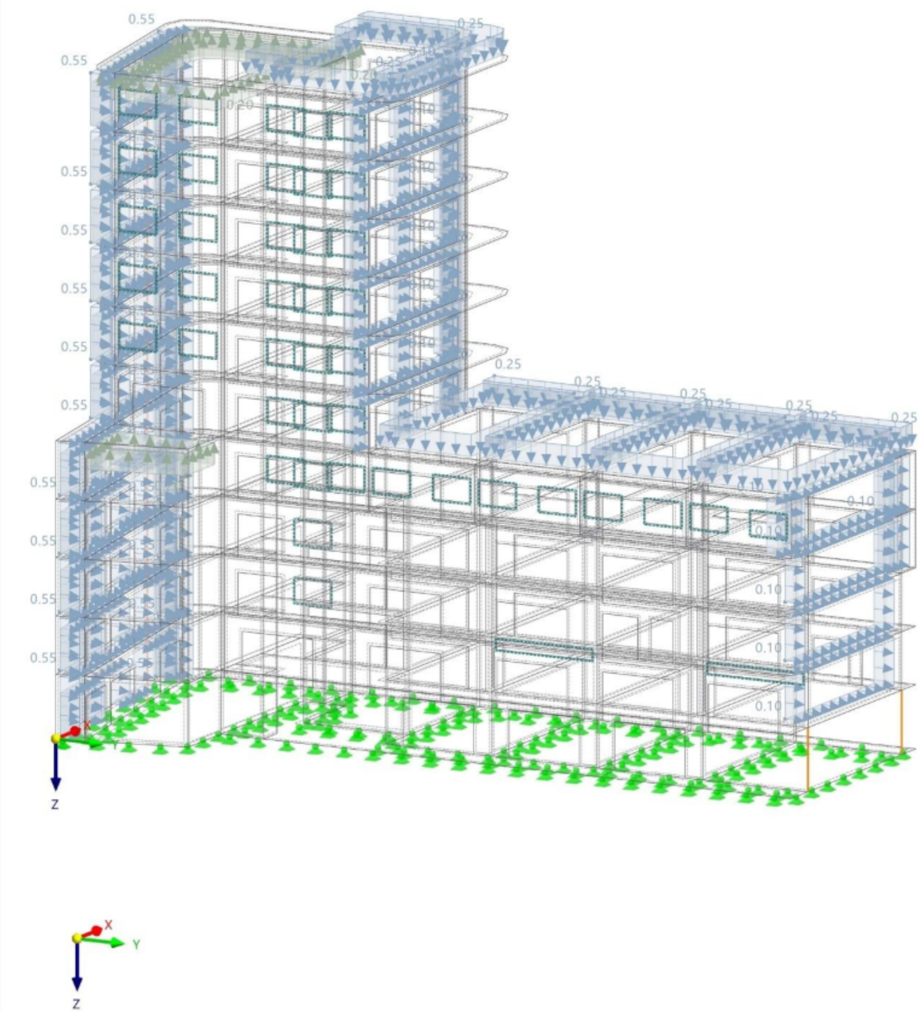


Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024 Page 17/38 Sheet 1
		MODEL

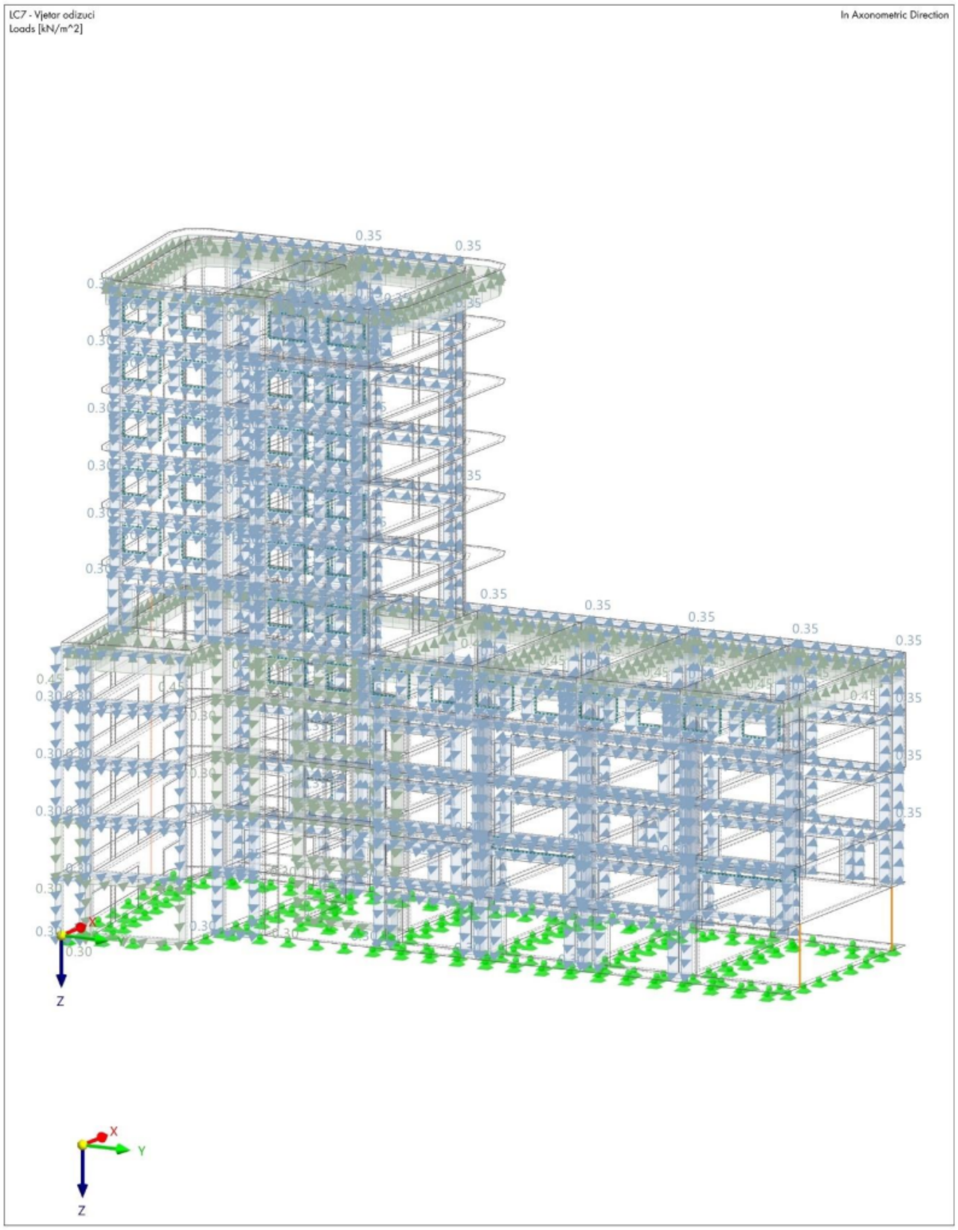
E **LC6: LOADING, IN AXONOMETRIC DIRECTION**

LC6 - Vjetar
Loads [kN/m^2]

In Axonometric Direction



F **LC7: LOADING, IN AXONOMETRIC DIRECTION**



6 Dynamic Loads

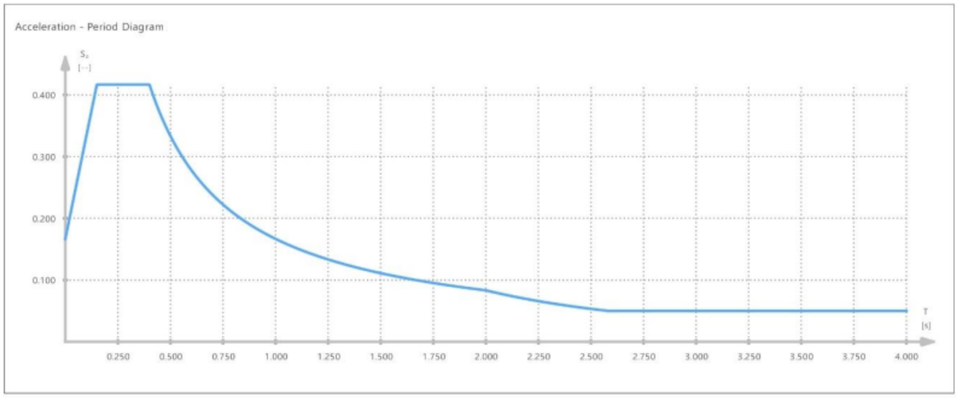
6.1 RESPONSE SPECTRA

RS No.	Definition Type	Comment
1	According to Standard - EN 1998-1 | HRN | 2011-06	

6.1.1 RESPONSE SPECTRA - PARAMETERS

RS No.	Parameter	Symbol	Value	Unit	Reference
1	According to Standard - EN 1998-1 | HRN | 2011-06				
	Type of spectrum				
	Spectrum shape		Design Spectrum		
	Spectrum direction		Horizontal		
	Ground type		A		
	Earthquake action				
	Reference peak ground acceleration	a_{gR}	25.00	%	
	Importance class		II		
		γ_I	1.000	–	4.2.5(5)P
	Design ground acceleration | Horizontal	a_g	0.250	–	
	Factors				
	Behavior factor	q	1.500	–	
	Limit value	β	0.200	–	3.2.2.2(4)P, NA 2.11
	Ground type parameters				
	Soil factor | Ground type A	S	1.000	–	3.2.2.2(2)P, Tab. 3.2
	Control period | Ground type A	T_B	0.150	s	3.2.2.2(2)P, Tab. 3.2
	Control period | Ground type A	T_C	0.400	s	3.2.2.2(2)P, Tab. 3.2
	Control period | Ground type A	T_D	2.000	s	3.2.2.2(2)P, Tab. 3.2
	Maximum period	T_{max}	4.000	s	

6.2 RESPONSE SPECTRA | DIAGRAM



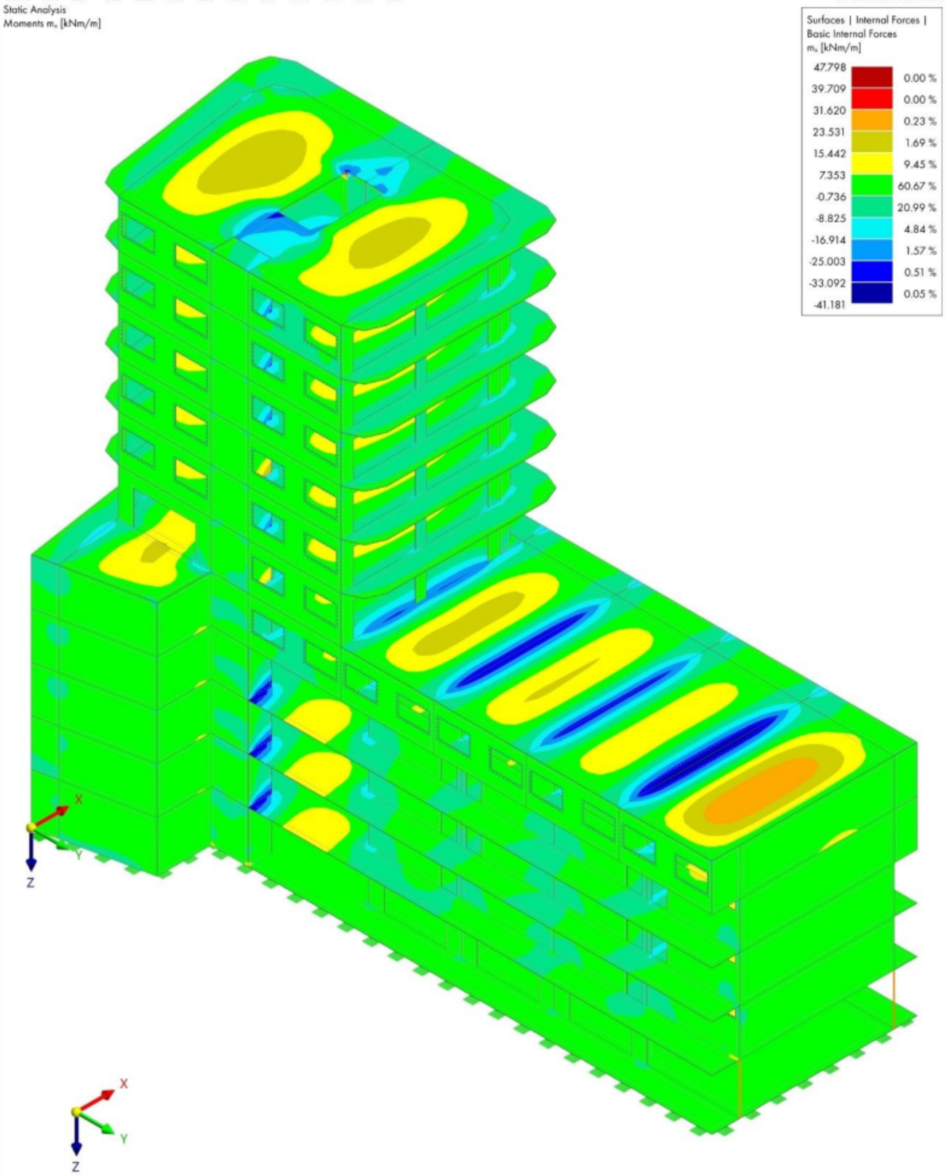
7 Static Analysis Results

Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024 Page 20/38 Sheet 1
		MODEL

7.1 **CO10: BASIC INTERNAL FORCES M_x, IN AXONOMETRIC DIRECTION** **Static Analysis**

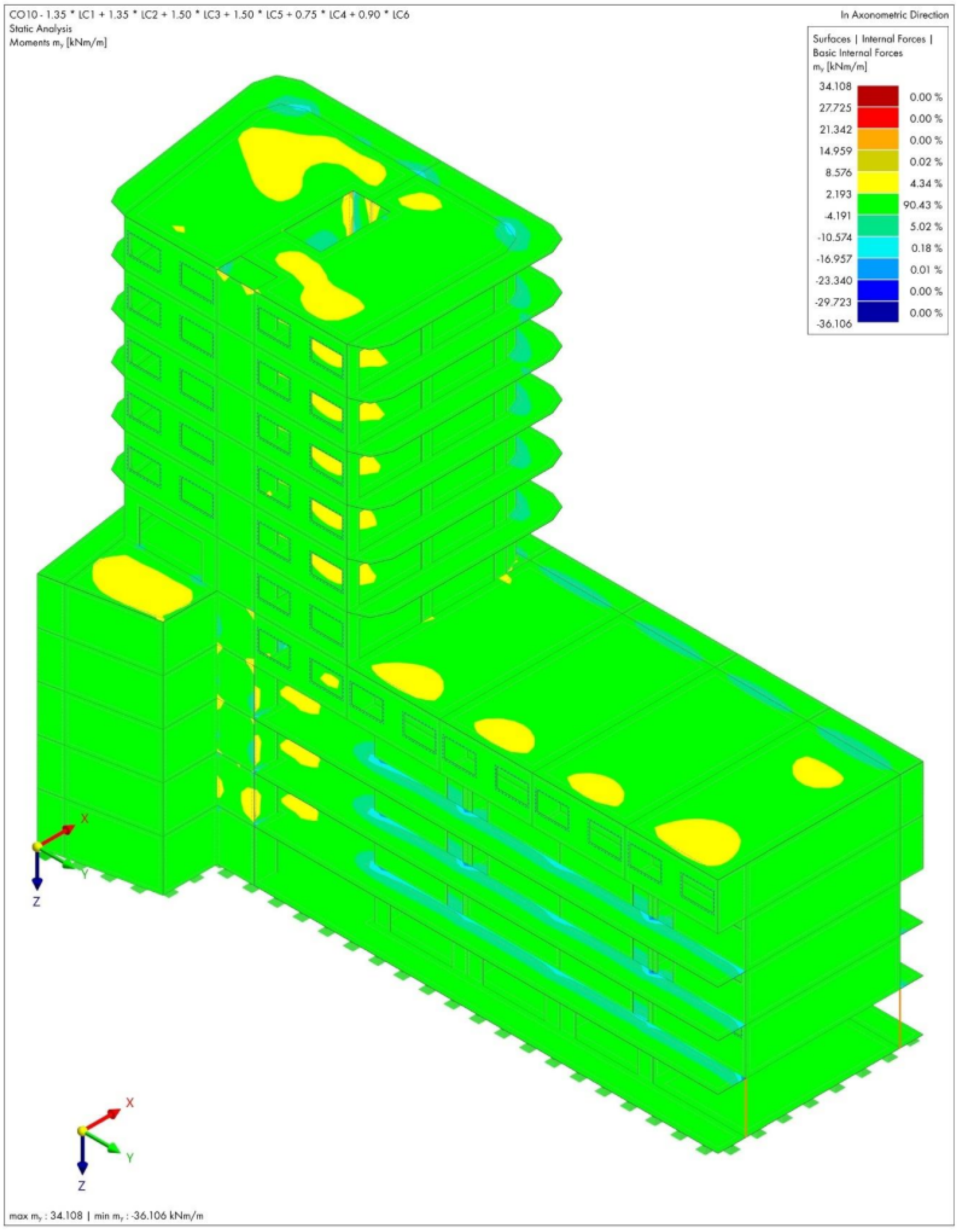
CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 1.50 * LC5 + 0.75 * LC4 + 0.90 * LC6
Static Analysis
Moments m_x [kNm/m]

In Axonometric Direction

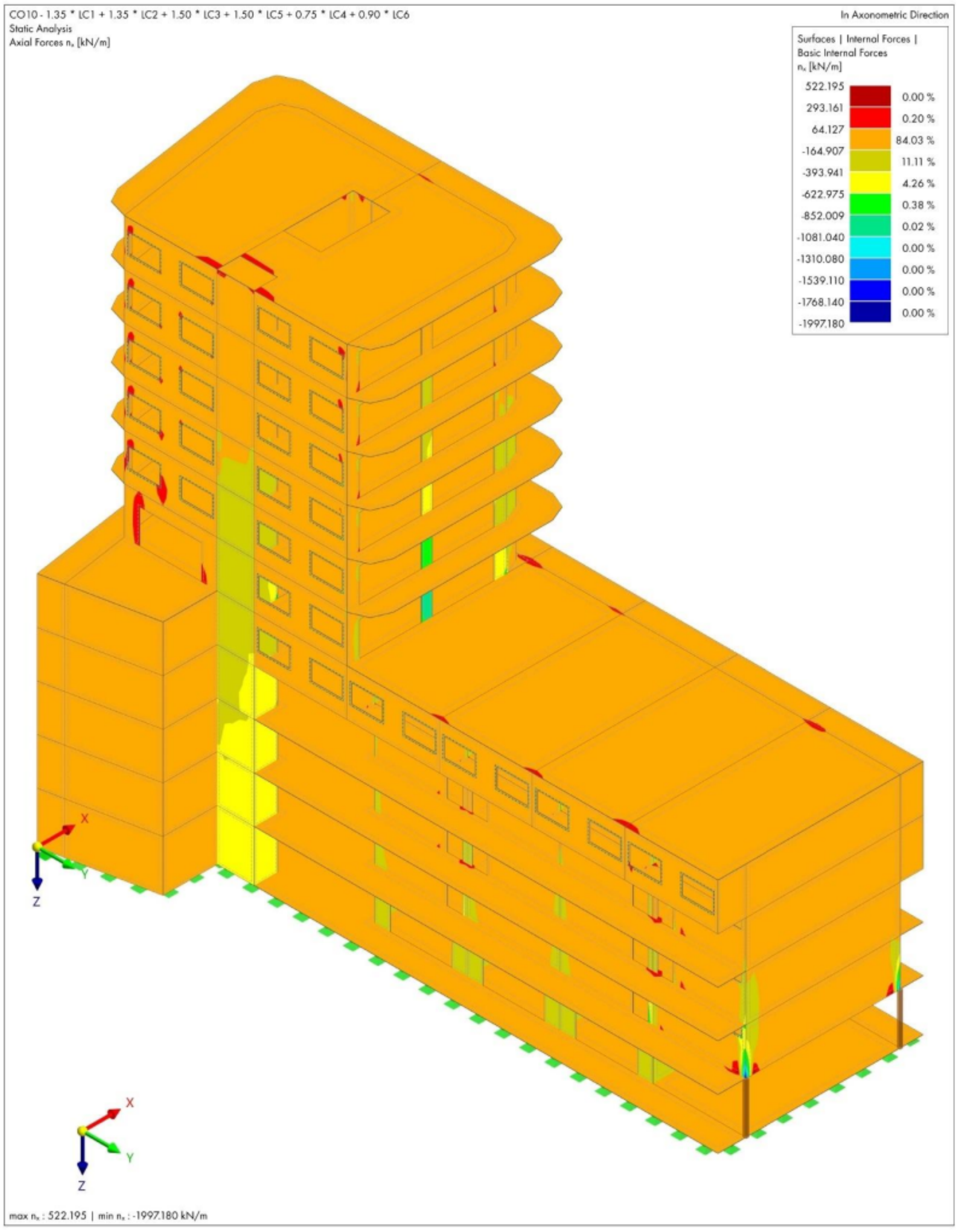


max m_x : 47.798 | min m_x : -41.181 kNm/m

7.2 **CO10: BASIC INTERNAL FORCES M_y, IN AXONOMETRIC DIRECTION** **Static Analysis**



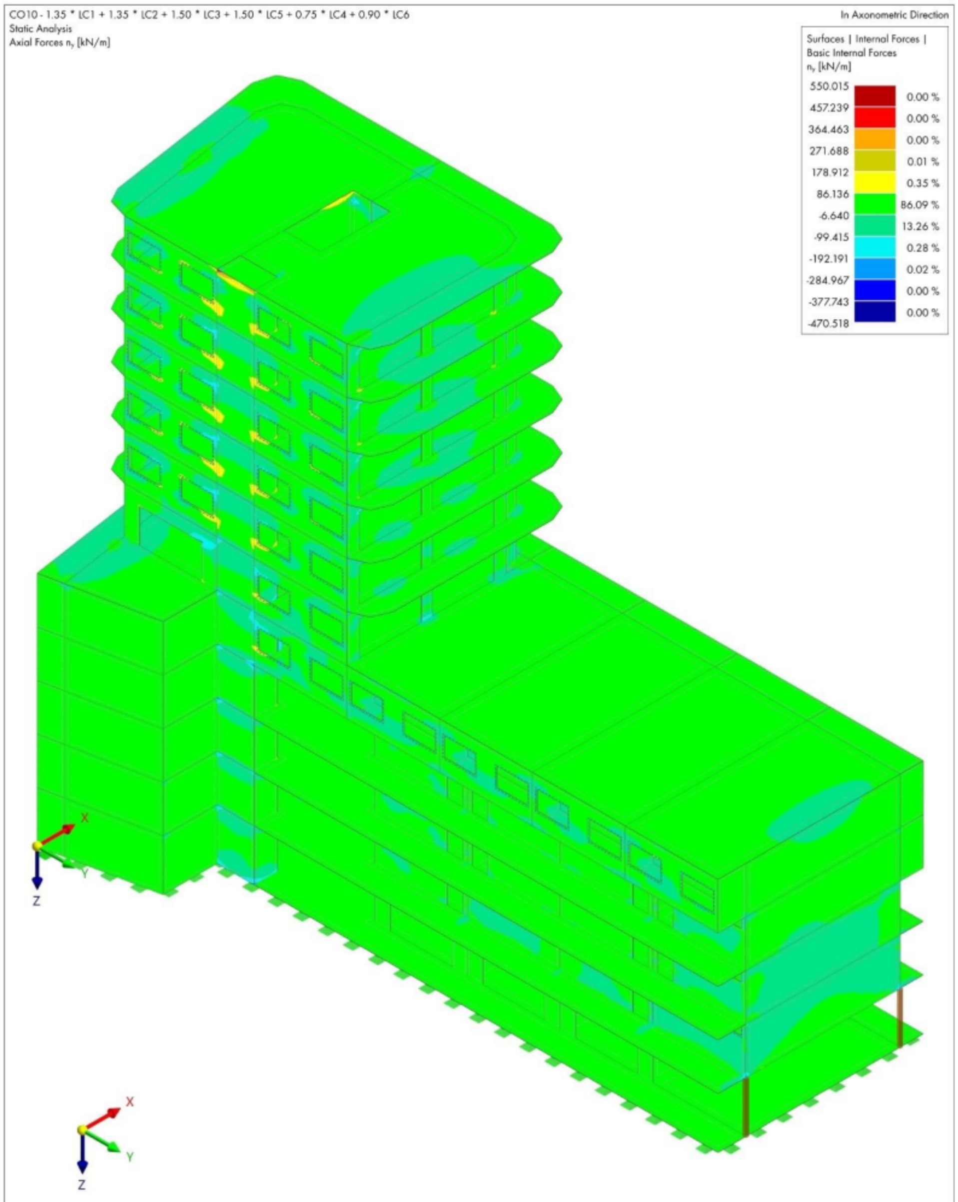
7.3 **CO10: BASIC INTERNAL FORCES N_x, IN AXONOMETRIC DIRECTION** **Static Analysis**



7.4 **CO10: BASIC INTERNAL FORCES N_y, IN AXONOMETRIC DIRECTION** **Static Analysis**

CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 1.50 * LC5 + 0.75 * LC4 + 0.90 * LC6
Static Analysis
Axial Forces n_y [kN/m]

In Axonometric Direction

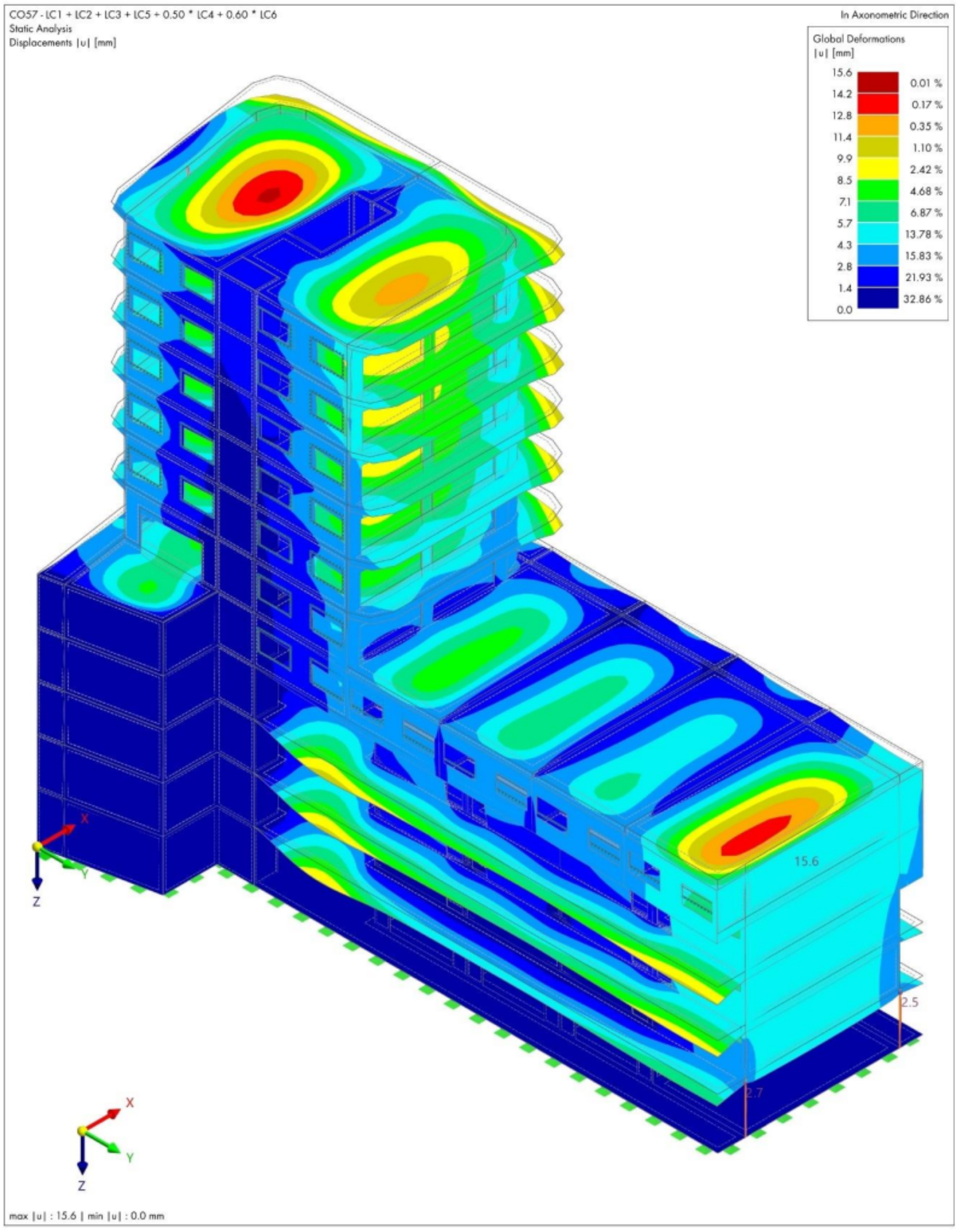


max n_y : 550.015 | min n_y : -470.518 kN/m

7.5 **CO57: GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Static Analysis**

CO57 - LC1 + LC2 + LC3 + LC5 + 0.50 * LC4 + 0.60 * LC6
Static Analysis
Displacements |u| [mm]

In Axonometric Direction



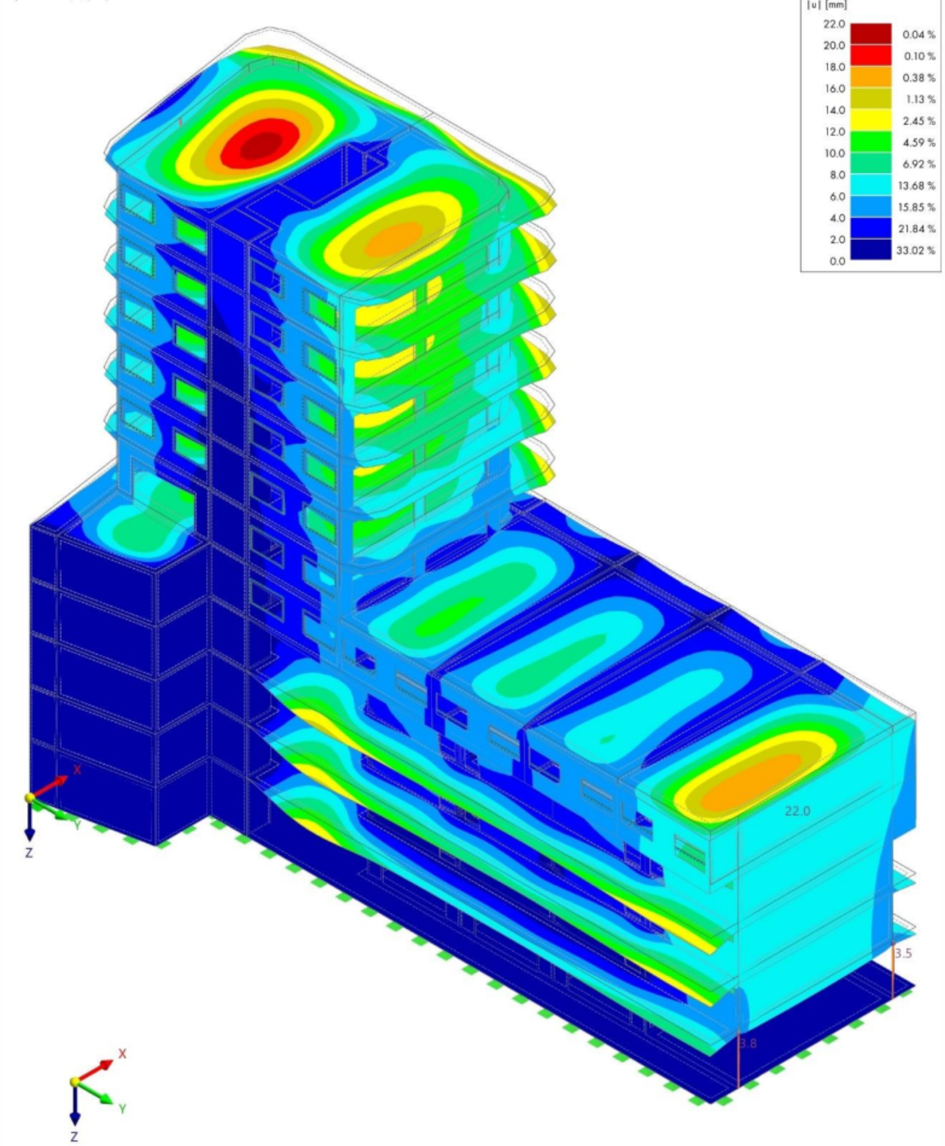
max |u| : 15.6 | min |u| : 0.0 mm

Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024 Page 25/38 Sheet 1
		MODEL

7.6 **CO104: GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Static Analysis**

CO104 - 1.60 * LC1 + 1.60 * LC2 + 1.18 * LC3 + 1.18 * LC5 + 0.50 * LC4 + 0.60 * LC6
Static Analysis
Displacements |u| [mm]

In Axonometric Direction



max |u| : 22.0 | min |u| : 0.0 mm

Marija Gulam

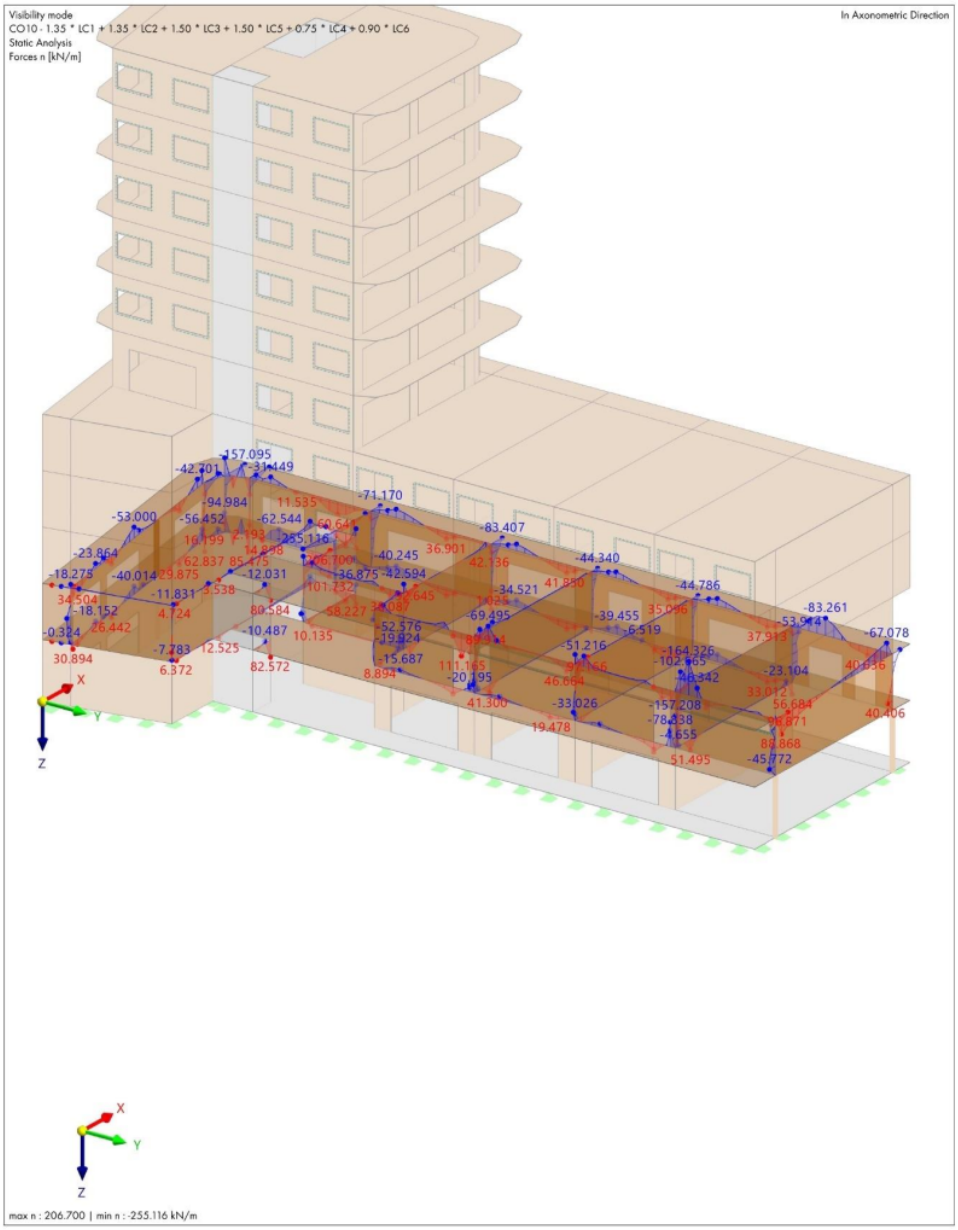
Model:
diplomski_zgradaA1

Date 21.8.2024 Page 26/38
Sheet 1

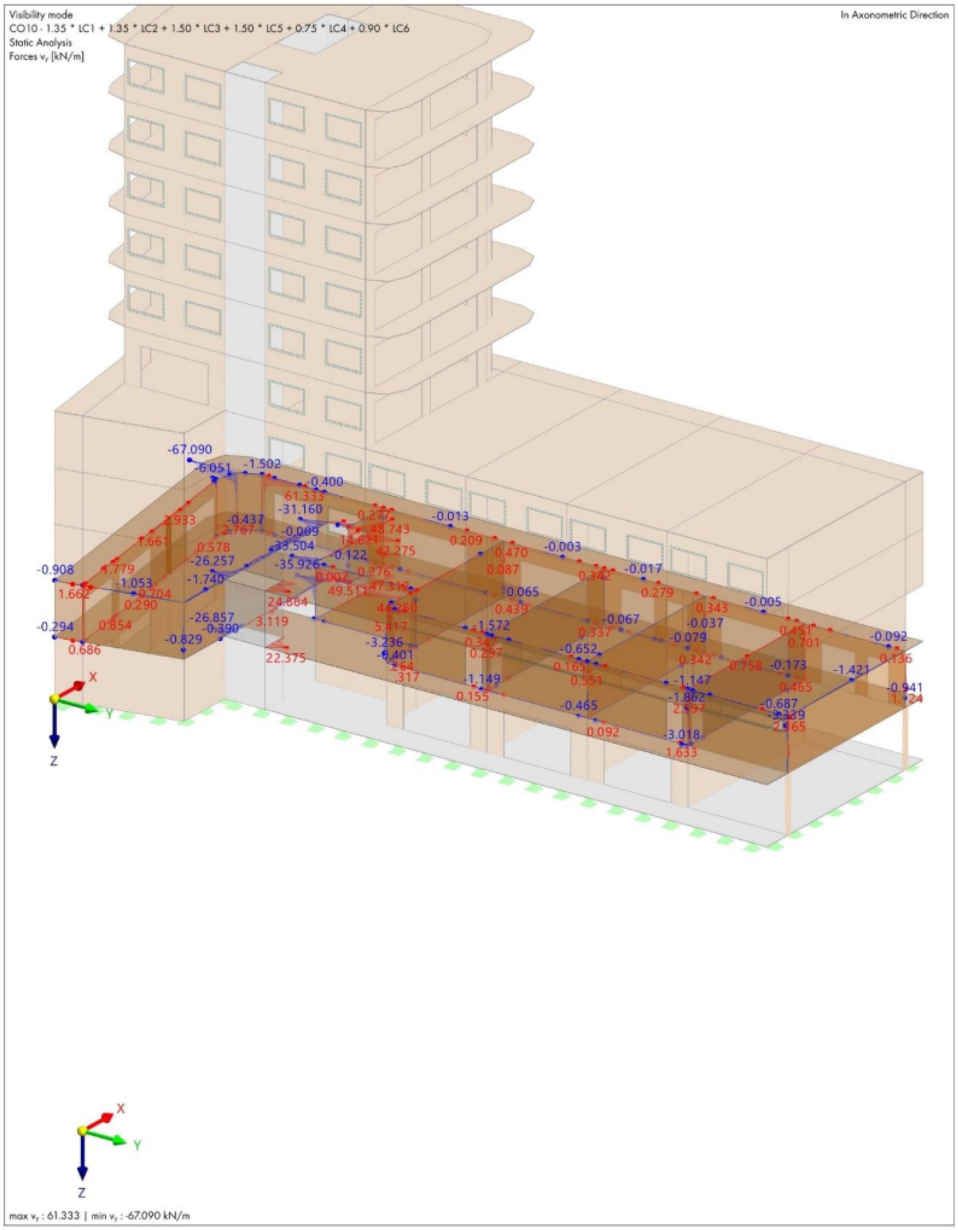
MODEL

7.7 CO10: FORCES N, IN AXONOMETRIC DIRECTION

Static Analysis



7.8 **CO10: FORCES V_y, IN AXONOMETRIC DIRECTION** **Static Analysis**



Marija Gulam

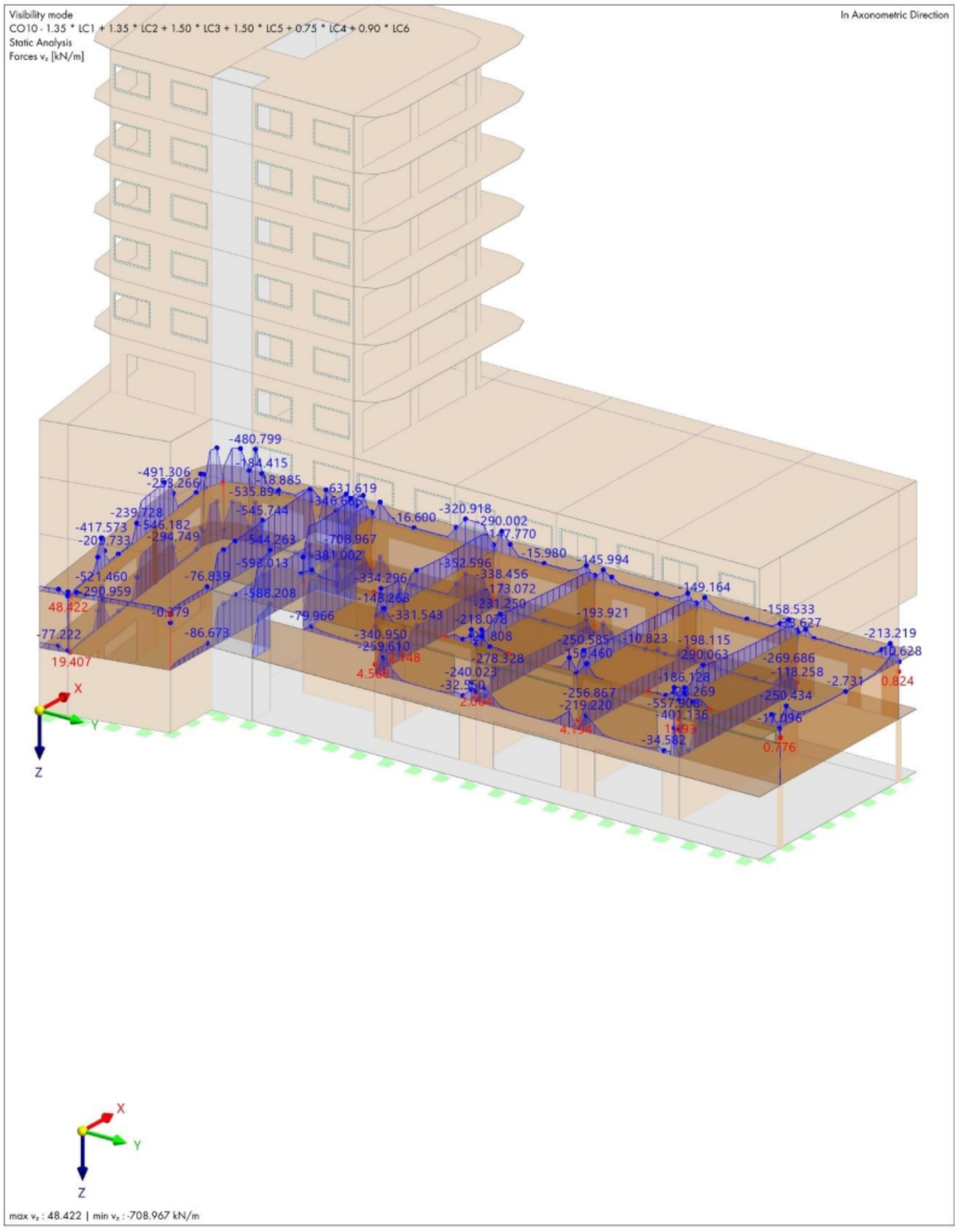
Dlubal

Model:
diplomski_zgradaA1

Date 21.8.2024 Page 28/38
Sheet 1

MODEL

7.9 **CO10: FORCES Vz, IN AXONOMETRIC DIRECTION** **Static Analysis**



8 Modal Analysis Results

8.1 NATURAL FREQUENCIES

Modal Analysis

Mode No.	Eigenvalue λ [1/s²]	Angular Frequency ω [rad/s]	Natural Frequency f [Hz]	Natural Period T [s]
1	103.124	10.155	1.616	0.619
2	321.642	17.934	2.854	0.350
3	409.372	20.233	3.220	0.311
4	729.392	27.007	4.298	0.233
5	952.937	30.870	4.913	0.204
6	3575.427	59.795	9.517	0.105
7	3802.785	61.667	9.815	0.102
8	4072.037	63.813	10.156	0.098
9	4648.098	68.177	10.851	0.092
10		68.274	10.866	0.092
11	5454.337	73.853	11.754	0.085
12	6210.160	78.805	12.542	0.080
13	6475.025	80.468	12.807	0.078
14	8982.998	94.779	15.084	0.066
15	9656.753	98.269	15.640	0.064
16	9772.166	98.854	15.733	0.064
17	9828.970	99.141	15.779	0.063
18	10015.143	100.076	15.928	0.063
19	10097.476	100.486	15.993	0.063
20	10136.179	100.679	16.023	0.062
21	10267.466	101.329	16.127	0.062
22	10292.320	101.451	16.146	0.062
23	10340.744	101.689	16.184	0.062
24	10379.716	101.881	16.215	0.062
25	10435.674	102.155	16.258	0.062
26	10867.221	104.246	16.591	0.060
27	11256.549		16.886	0.059
28	11577.141	107.597	17.125	0.058
29	11756.188	108.426	17.257	0.058
30	11807.545	108.663	17.294	0.058

8.2 EFFECTIVE MODAL MASSES

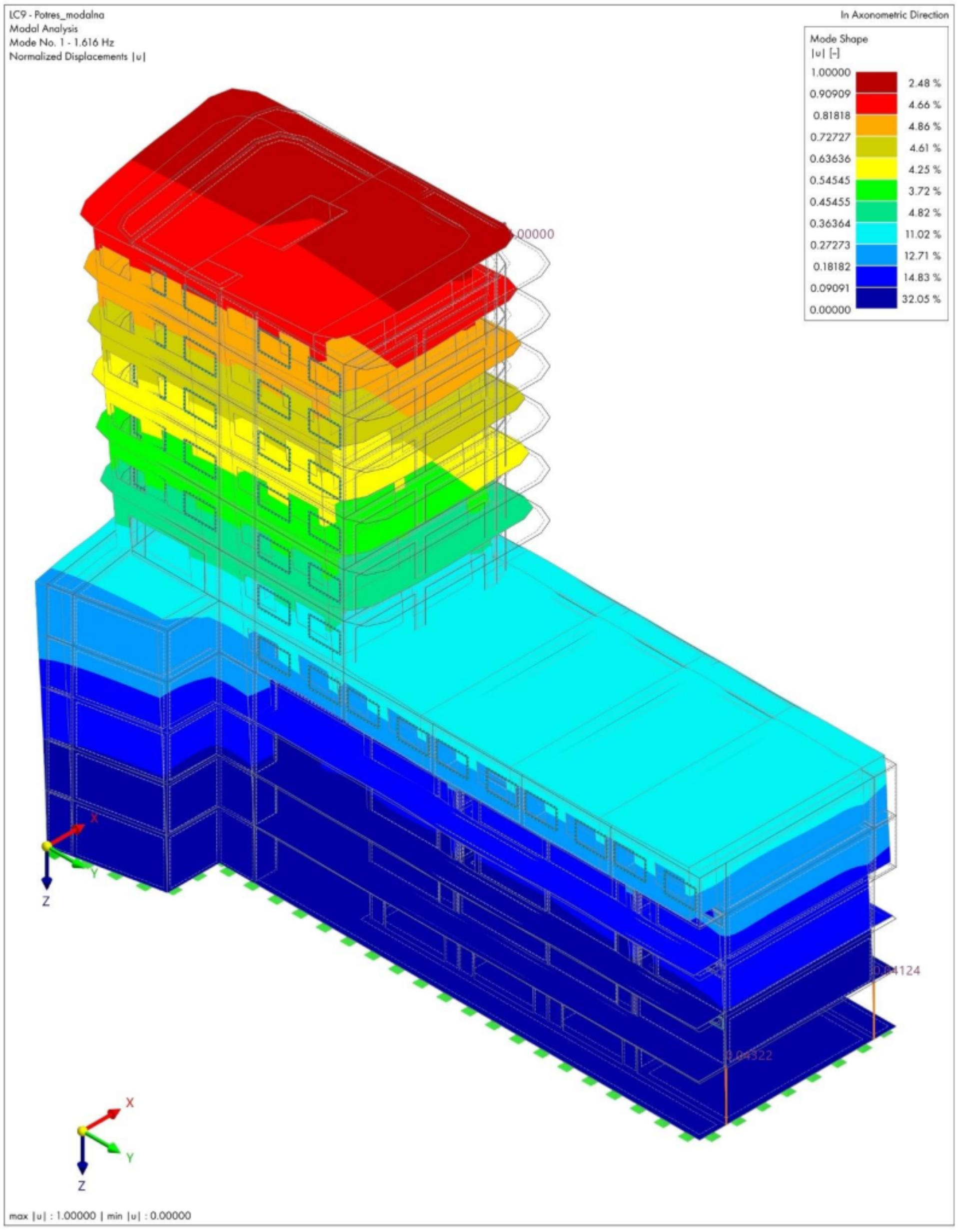
Modal Analysis

Mode No.	Modal Mass M_i [kg]	Transl. Eff. Modal Mass [kg] m_{eX}	m_{eY}	m_{eZ}	Rotat. Eff. Modal Mass [kgm²] $m_{e\varphi X}$	$m_{e\varphi Y}$	$m_{e\varphi Z}$	Transl. Eff. Modal Mass Factor [–] f_{meX}	f_{meY}	f_{meZ}	Rotat. Eff. Modal Mass Factor [–] $f_{m\varphi X}$	$f_{m\varphi Y}$	$f_{m\varphi Z}$
	LC9 - Potres_modalna												
1	316378.9	1336.1	1005270.0	0.0	52761200.00	51276.40	274059.00	0.001	0.604	0.000	0.387	0.000	0.001
2	82587.3	418950.0	8762.7	0.0	111940.00	17078900.00	14488000.00	0.252	0.005	0.000	0.001	0.125	0.065
3	120905.4	365356.0	609.8	0.0	64.35	47168200.00	98728900.00	0.219	0.000	0.000	0.000	0.346	0.441
4	143194.8	383435.0	7860.8	0.0	764782.00	3538420.00	72057400.00	0.230	0.005	0.000	0.006	0.026	0.322
5	375549.1	11697.9	397696.0	0.0	41454100.00	303596.00	518269.00	0.007	0.239	0.000	0.304	0.002	0.002
6	103675.1	46436.8	6618.2	0.0	989067.00	2248110.00	4860260.00	0.028	0.004	0.000	0.007	0.016	0.022
7	125540.5	186207.0	26947.5	0.0	3534620.00	18894700.00	7661600.00	0.112	0.016	0.000	0.026	0.138	0.034
8	23364.8	11328.8	85640.5	0.0	13455300.00	1821250.00	849909.00	0.007	0.051	0.000	0.099	0.013	0.004
9	278.5	398.8	2370.2	0.0	387370.00	34549.10	60415.90	0.000	0.001	0.000	0.003	0.000	0.000
10	283.0	319.3	3381.8	0.0	558707.00	30730.50	57596.90	0.000	0.002	0.000	0.004	0.000	0.000
11	17276.9	49974.1	166.7	0.0	27668.50	12915000.00	11606500.00	0.030	0.000	0.000	0.000	0.095	0.052
12	90525.9	613.9	25517.4	0.0	4587500.00	15879.80	1049730.00	0.000	0.015	0.000	0.034	0.000	0.005
13	55405.2	973.0	8881.5	0.0	1889720.00	75071.60	554114.00	0.001	0.005	0.000	0.014	0.001	0.002
14	16015.8	3211.0	245.3	0.0	13499.60	1111180.00	267165.00	0.002	0.000		0.000	0.008	0.001
15	579.8	8676.9	1332.5	0.0	214291.00	1562450.00	4.73	0.005	0.001	0.000	0.002	0.011	0.000
16	167.6	1595.9	1763.1	0.0	295745.00	274288.00	3849.17	0.001	0.001	0.000	0.002	0.002	0.000
17	176.6	165.8	3705.6	0.0	607508.00	18299.50	134208.00	0.000	0.002	0.000	0.004	0.000	0.001
18	447.1	294.5	21014.8	0.0	3486390.00	81232.10	3990.17	0.000	0.013	0.000	0.026	0.001	0.000
19	166.8	473.8	1303.6	0.0	219574.00	75511.50	1697.26	0.000	0.001	0.000	0.002	0.001	0.000
20	247.7	60.3	191.2	0.0	32800.30	9081.35	4442.17	0.000	0.000	0.000		0.000	0.000
21	169.9	32.1	139.5	0.0	26240.20	5188.96	3194.29	0.000	0.000	0.000	0.000	0.000	0.000
22	254.3	240.9	342.9	0.0	55028.60	32097.60	237.36	0.000	0.000	0.000	0.000	0.000	0.000
23	186.4	0.3	354.7	0.0	54342.90	690.66	1193.73	0.000	0.000	0.000	0.000	0.000	0.000
24	285.3	0.1	1219.0	0.0	209384.00	1061.15	17.38	0.000	0.001	0.000	0.002	0.000	0.000
25	221.7	199.5	1.7	0.0	462.87	32697.10	2374.39	0.000	0.000	0.000	0.000	0.000	0.000
26	206.6	6635.4	135.3	0.0	27974.20	1307530.00	22723.80	0.004	0.000	0.000	0.000	0.010	0.000
27	430.7	22164.0	760.4	0.0	143790.00	3470840.00	407931.00	0.013	0.000	0.000	0.001	0.025	0.002
28	297.2	14567.7	24.5	0.0	3728.58	2042270.00	1473200.00	0.009	0.000	0.000	0.000	0.015	0.007
29	195.4	1839.4	68.1	0.0	12834.50	210893.00	448136.00	0.001	0.000	0.000	0.000	0.002	0.002
30	157.6	3831.4	6.3	0.0	1594.97	531292.00	309477.00	0.002	0.000	0.000	0.000	0.004	0.001
Σ	1475172.0	1541020.0	1612340.0	0.0	1.26e+08	1.15e+08	2.16e+08	0.925	0.968	0.000	0.923	0.842	0.963
Σ_M		1665500.0	1665500.0	0.0	1.37e+08	1.37e+08	2.24e+08						
%		92.53 %	96.81 %		92.25 %	84.20 %	96.33 %						

8.3 **EFFECTIVE MODAL MASSES - EQUIVALENT MASS PER UNIT LENGTH** **Modal Analysis**

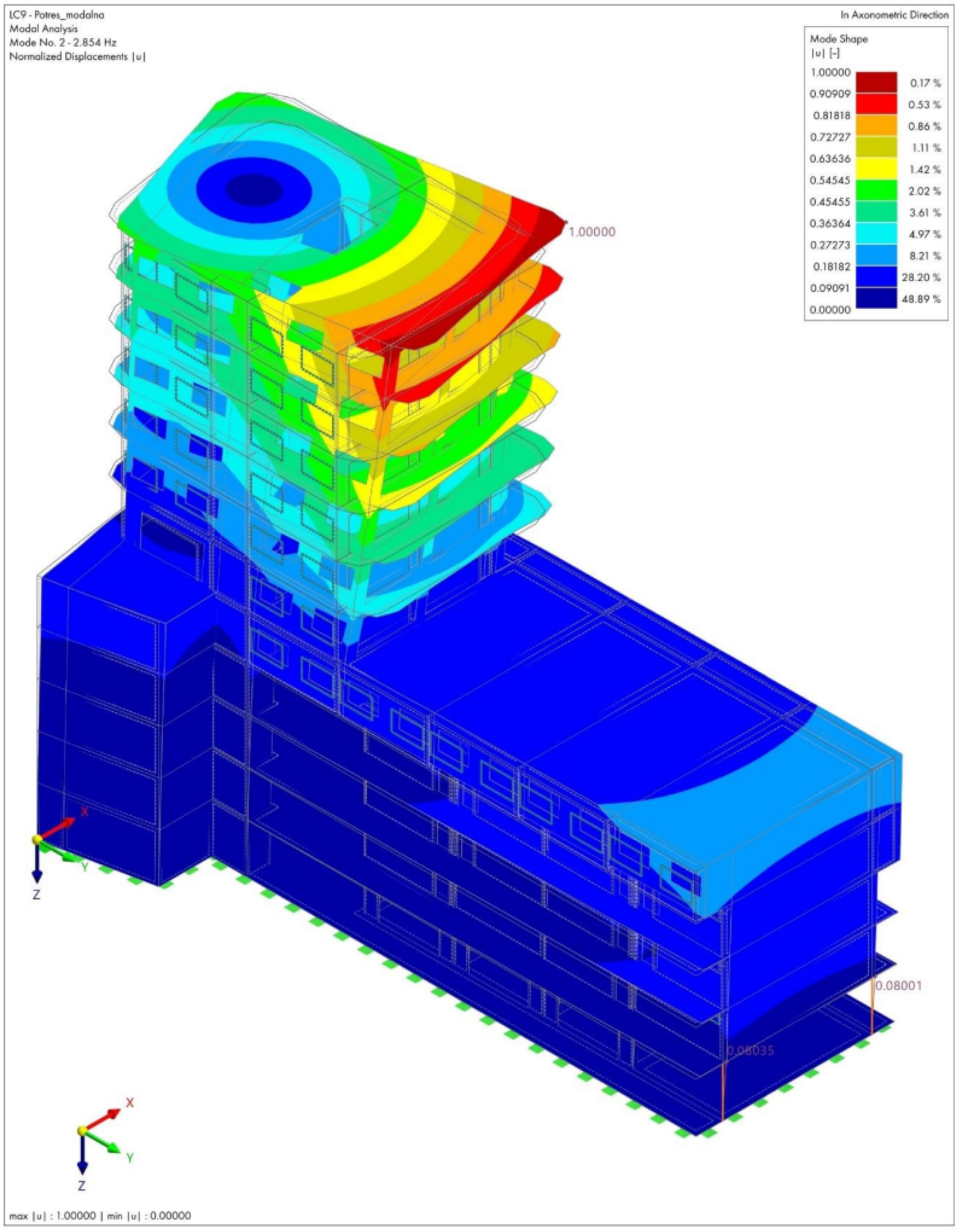
Mode No.	Modal Mass M_i [kg]
	AE LC9 - Potres_modalna
1	316378.9
2	82587.3
3	120905.4
4	143194.8
5	375549.1
6	103675.1
7	125540.5
8	23364.8
9	278.5
10	283.0
11	17276.9
12	90525.9
13	55405.2
14	16015.8
15	579.8
16	167.6
17	176.6
18	447.1
19	166.8
20	247.7
21	169.9
22	254.3
23	186.4
24	285.3
25	221.7
26	206.6
27	430.7
28	297.2
29	195.4
30	157.6
Σ	1475172.0
Σ_M	
%	

8.4 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**



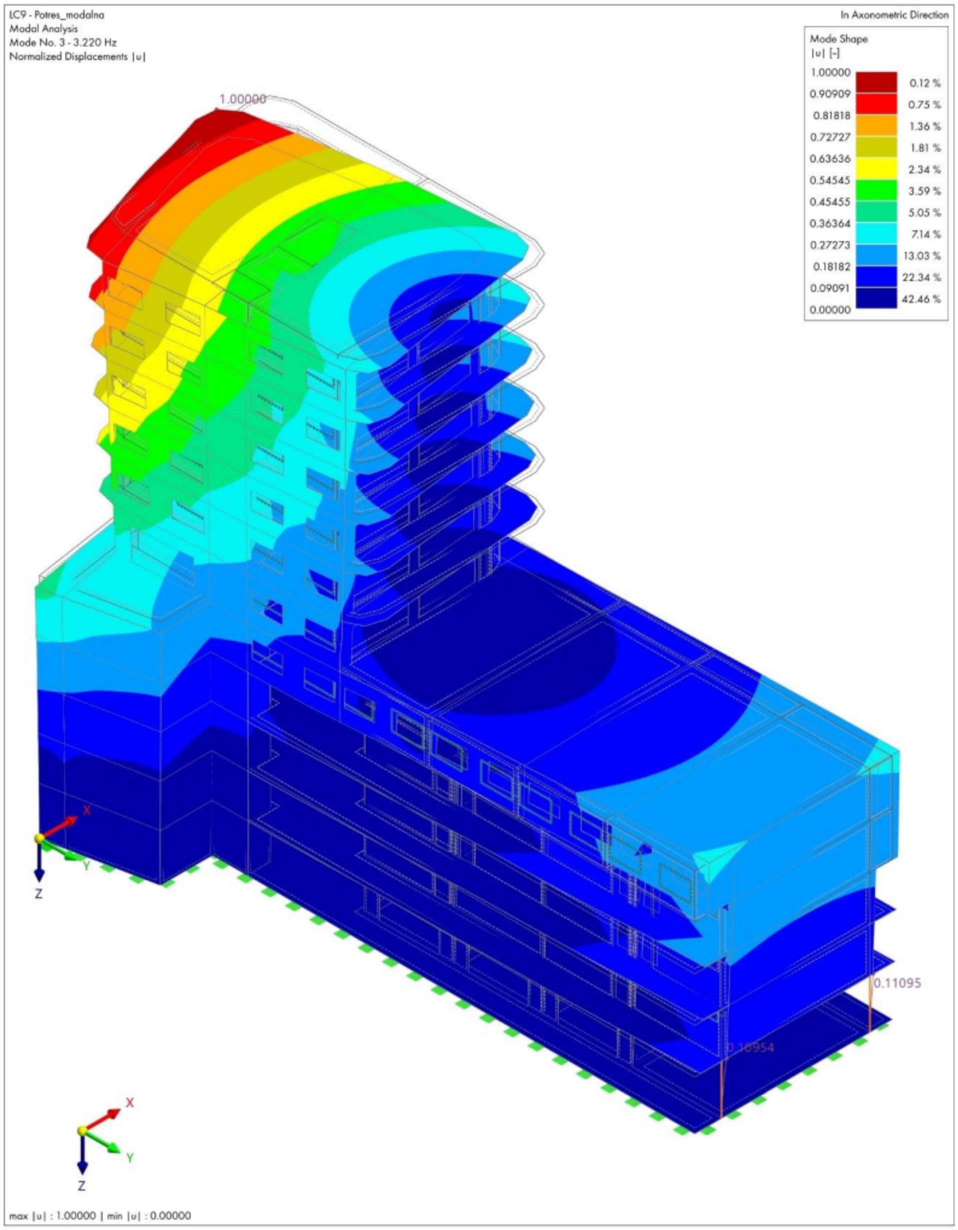
Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024 Page 32/38 Sheet 1
		MODEL

8.5 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**

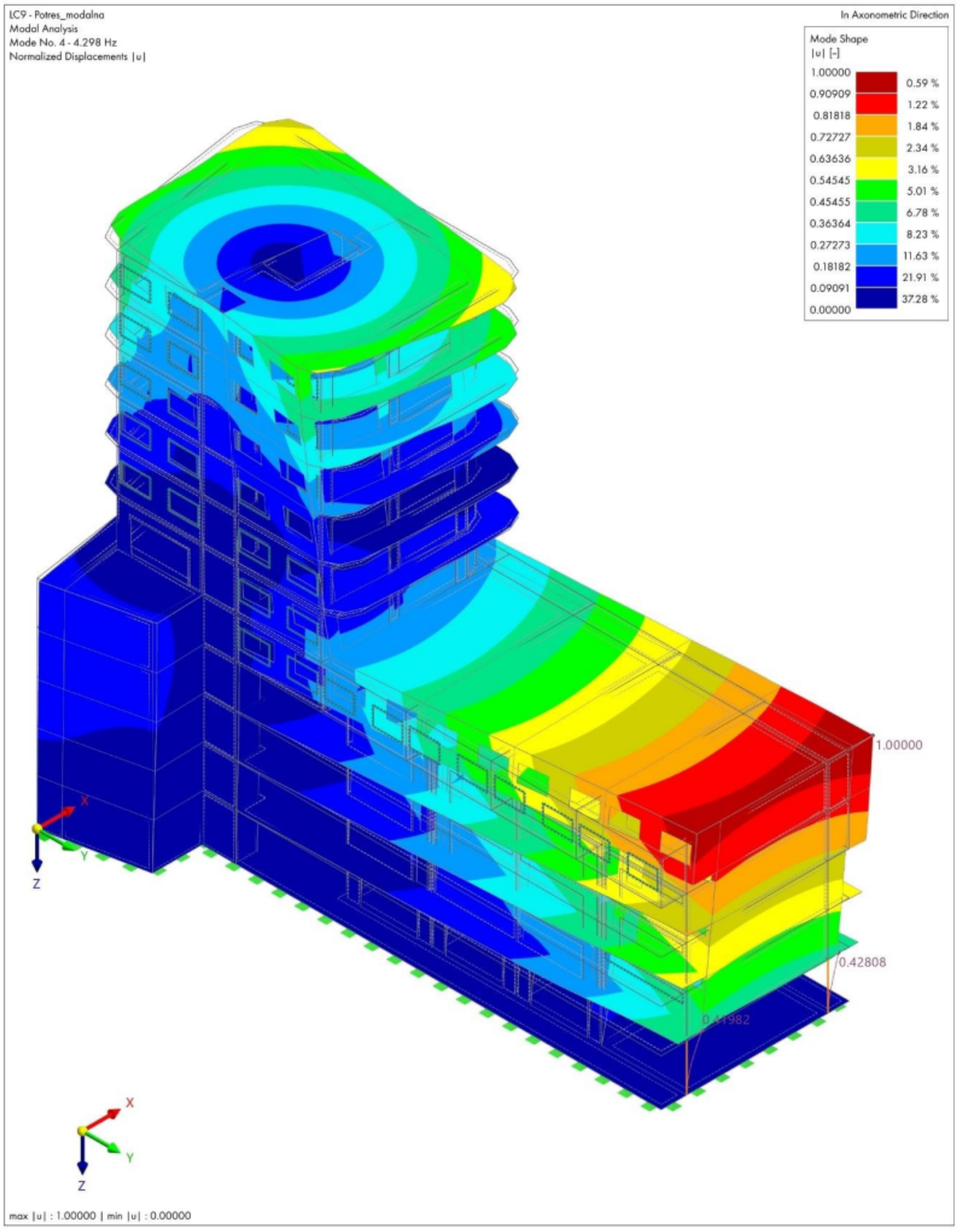


Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024 Page 33/38 Sheet 1
		MODEL

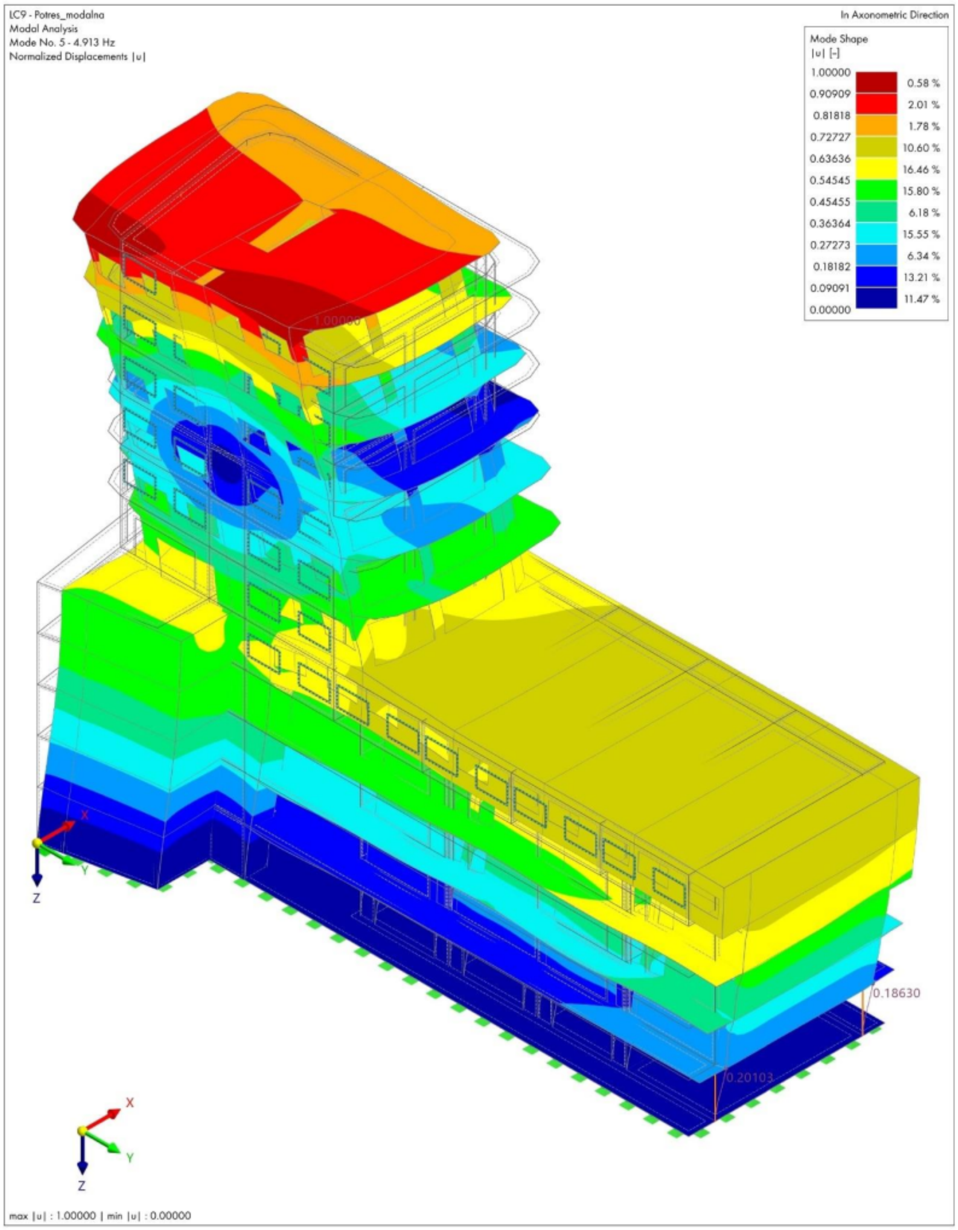
8.6 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**



8.7 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**

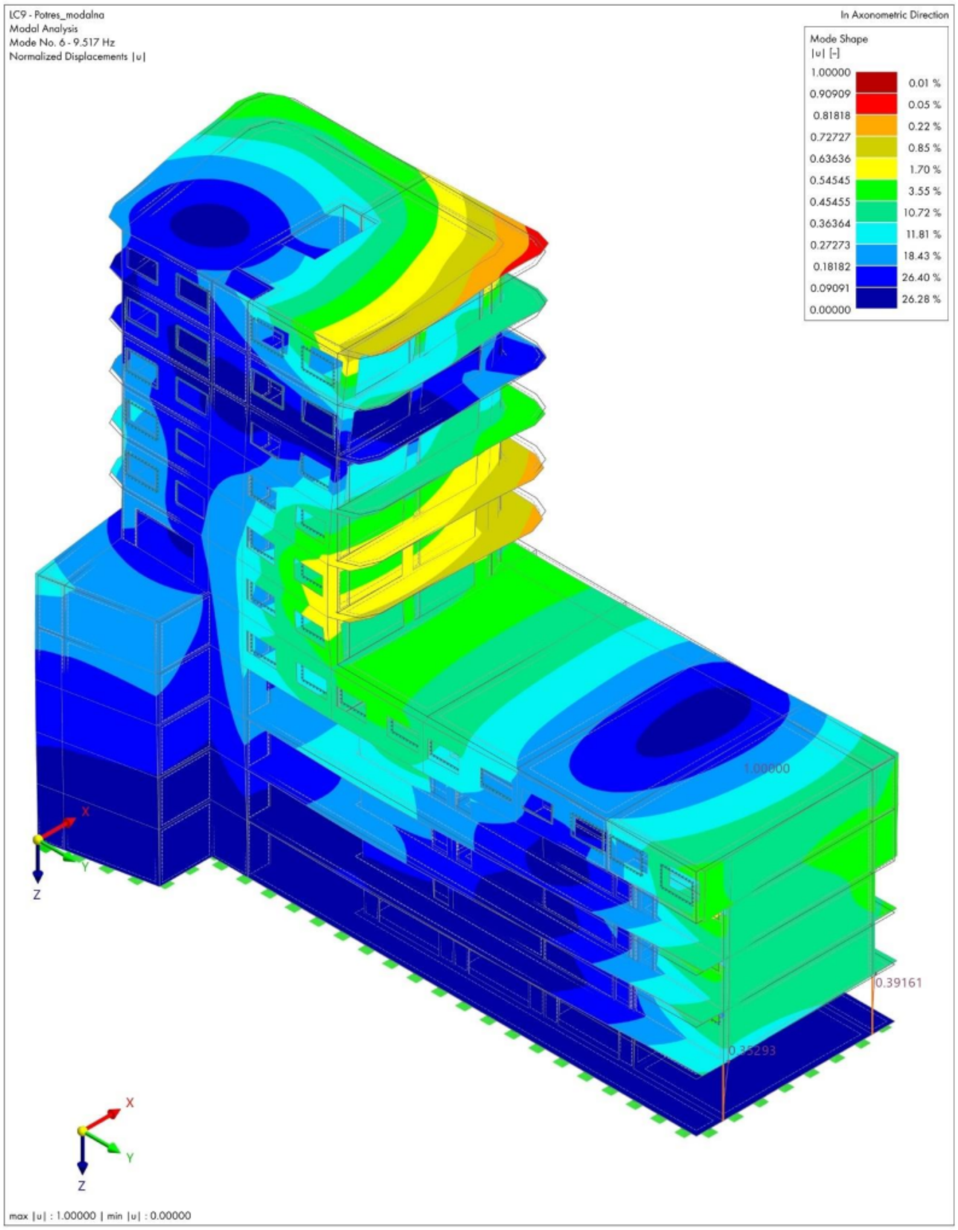


8.8 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**



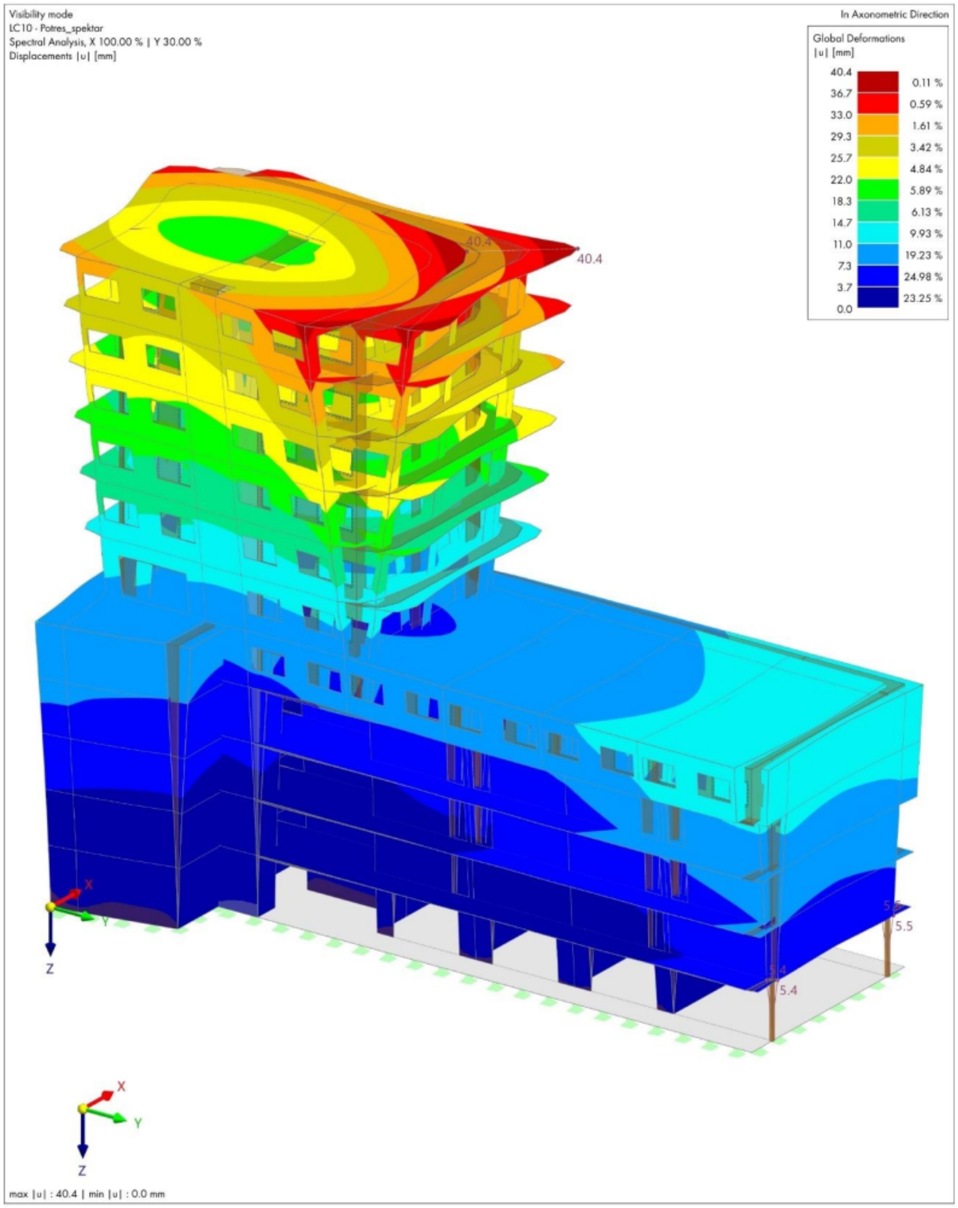
Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024 Page 36/38 Sheet 1 MODEL

8.9 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**



Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024 Page 37/38 Sheet 1
		MODEL

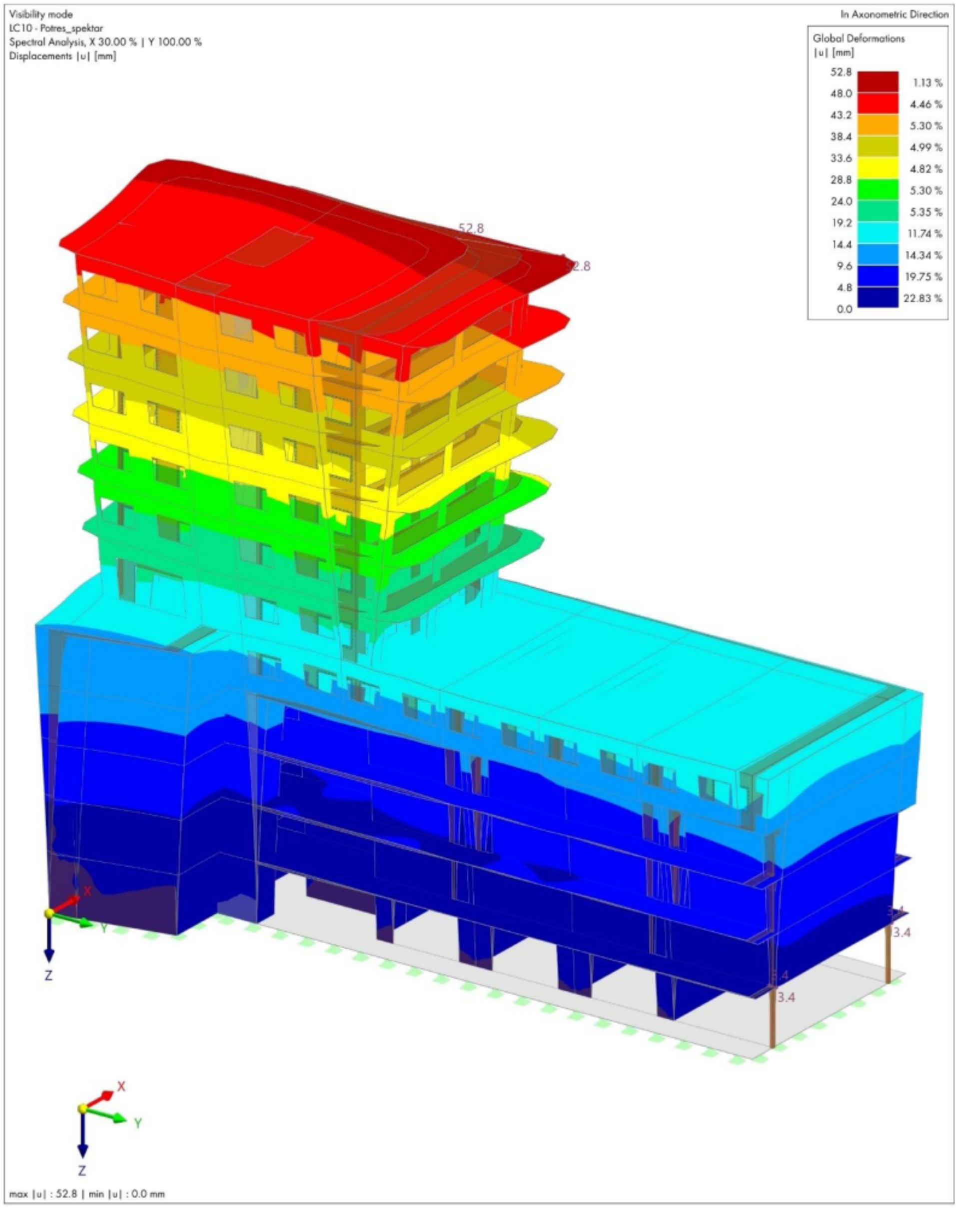
G **LC10: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Spectral Analysis**



www.dlubal.com RFEM 6.07.0002 - General 3D structures solved using FEM

Marija Gulam	Model: diplomski_zgradaA1	Date 21.8.2024	Page 38/38	Sheet 1
		MODEL		

H **LC10: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Spectral Analysis**



2.4.2 Proračun zgrade B (P+5)

Marija Gulam

Dlubal

Model:
diplomski_zgradaB

Date	21.8.2024	Page	1/33
		Sheet	1

MODEL

CONTENTS

1	Basic Objects	2
1.1	Materials	2
1.2	Thicknesses	2
1.2.1	Thicknesses - Layer Info	2
1.2.2	Thicknesses - Layers	2
1.2.3	Thicknesses - Options for CLT	2
1.3	Model, In Axonometric Direction	3
1.4	Model, In Axonometric Direction	4
2	Types for Surfaces	5
2.1	Surface Supports	5
3	Types for Special Objects	5
3.1		5
3.1.1		5
3.1.2	Coupled Diagrams	5
4	Load Cases & Combinations	5
4.1	Load Cases	5
4.2	Static Analysis Settings	6
4.3	Modal Analysis Settings	7
4.3.1	Modal Analysis Settings - Neglect Masses	7
4.4	Spectral Analysis Settings	8
4.5	Combination Wizards	8
4.5.1	Combination Wizards - Initial State Items	8
A	LC2: Loading, In Axonometric Direction	10
B	LC3: Loading, In Axonometric Direction	11
C	LC5: Loading, In Axonometric Direction	12
D	LC4: Loading, In Axonometric Direction	13
E	LC6: Loading, In Axonometric Direction	14
5	Dynamic Loads	15
5.1	Response Spectra	15
5.1.1	Response Spectra - Parameters	15
5.1.2	Response Spectra | Diagram	15
6	Static Analysis Results	15
6.1	CO10: Basic Internal Forces m_x, In Axonometric Axonometric Direction	16
6.2	CO10: Basic Internal Forces m_y, In Axonometric Axonometric Direction	17
6.3	CO10: Basic Internal Forces n_x, In Axonometric Direction	18
6.4	CO10: Basic Internal Forces n_y, In Axonometric Direction	19
6.5	CO57: Global Deformations |u|, In Axonometric Direction	20
6.6	CO104: Global Deformations |u|, In Axonometric Direction	21
6.7	CO10: Forces n, In Axonometric Direction	22
6.8	CO10: Forces v_y, In Axonometric Direction	23
6.9	CO10: Forces v_z, In Axonometric Direction	24
7	Modal Analysis Results	25
7.1	Natural Frequencies	25
7.2	Effective Modal Masses	25
7.3	Effective Modal Masses - Equivalent Mass per Unit Length	26
7.4	LC9: Mode Shape |u|, In Axonometric Direction	27
7.5	LC9: Mode Shape |u|, In Axonometric Direction	28
7.6	LC9: Mode Shape |u|, In Axonometric Direction	29
7.7	LC9: Mode Shape |u|, In Axonometric Direction	30
7.8	LC9: Mode Shape |u|, In Axonometric Direction	31
F	LC10: Envelope Values - Max and Min Values, Global Deformations |u|, In Axonometric Direction	32
G	LC10: Envelope Values - Max and Min Values, Global Deformations |u|, In Axonometric Direction	33

1 Basic Objects

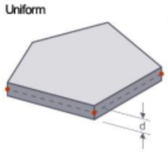
1.1 MATERIALS

Legend
Concrete Settings
Stiffness modification

Material No.	Material Name	Material Type	Analysis Model	Options
1	C24 BBS XL | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	
2	C24 BBS XL | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	
3	GL32h | Isotropic | Linear Elastic	Timber	Isotropic | Linear Elastic	
4	C35/45 | Isotropic | Linear Elastic	Concrete	Isotropic | Linear Elastic	

1.2 THICKNESSES

Uniform



Thick. No.	Type	Assigned to Surface No.	Material	Symbol	Thickness Value	Unit	Nodes	Direction
1	Layers | d : 220.0 mm | Layers: 7							
	Layers	54,79-81,88-91,93,95,237-239,246-249,251,255,261,344-346,428-432,437-439,446-449,451,453,483-487,489-494						
2	Layers | d : 140.0 mm | Layers: 5							
	Layers	1-6,8,11-19,55-58,82-86,96,130-138,240-244,252,253,256,259,260,306-314,433-436,440-444,454,456-463,470-476,502-506,513-518						
3	Uniform | d : 200.0 mm | 4 - C35/45							
	Uniform	92,250,347,450,455,464-469,477-482,495-501,507-512,519-524	4	d	200.0	mm		

1.2.1 THICKNESSES - LAYER INFO

Thick. No.	Total Thickness d [mm]	Total Weight g [N/m²]	Direction of Main Thickness	Comment
1	220.0	990.0	0.00	
2	140.0	630.0	0.00	

1.2.2 THICKNESSES - LAYERS

Thick. No.	Layer No.	Object	Material	Thickness t [mm]	Rotation β [deg]	Number of Int. Points	Spec. W. g_i [N/m³]	Weight g [N/m²]
1	1	Directly	1	40.0	0.00	9	4500.0	180.0
	2	Directly	2	40.0	90.00	9	4500.0	180.0
	3	Directly	1	20.0	0.00	9	4500.0	90.0
	4	Directly	2	20.0	90.00	9	4500.0	90.0
	5	Directly	1	20.0	0.00	9	4500.0	90.0
	6	Directly	2	40.0	90.00	9	4500.0	180.0
	7	Directly	1	40.0	0.00	9	4500.0	180.0
2	1	Directly	1	40.0	0.00	9	4500.0	180.0
	2	Directly	2	20.0	90.00	9	4500.0	90.0
	3	Directly	1	20.0	0.00	9	4500.0	90.0
	4	Directly	2	20.0	90.00	9	4500.0	90.0
	5	Directly	1	40.0	0.00	9	4500.0	180.0

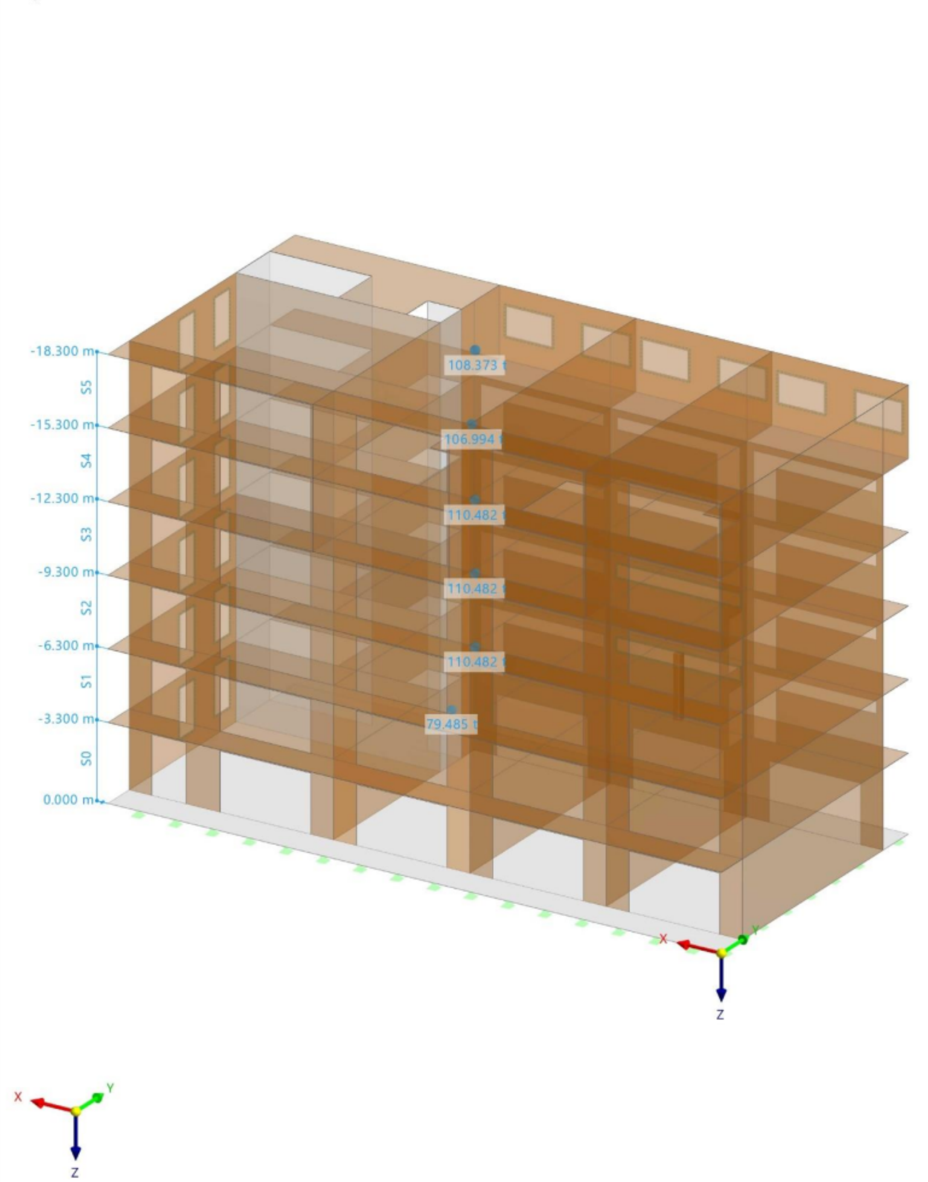
1.2.3 THICKNESSES - OPTIONS FOR CLT

Thick. No.	Options for CLT Name	Symbol	Value	Unit
1	Design for failure of net section and failure in glued contact surface is enabled.		☐	
2	Design for failure of net section and failure in glued contact surface is enabled.		☐	

1.3 **MODEL, IN AXONOMETRIC DIRECTION**

Visibility mode

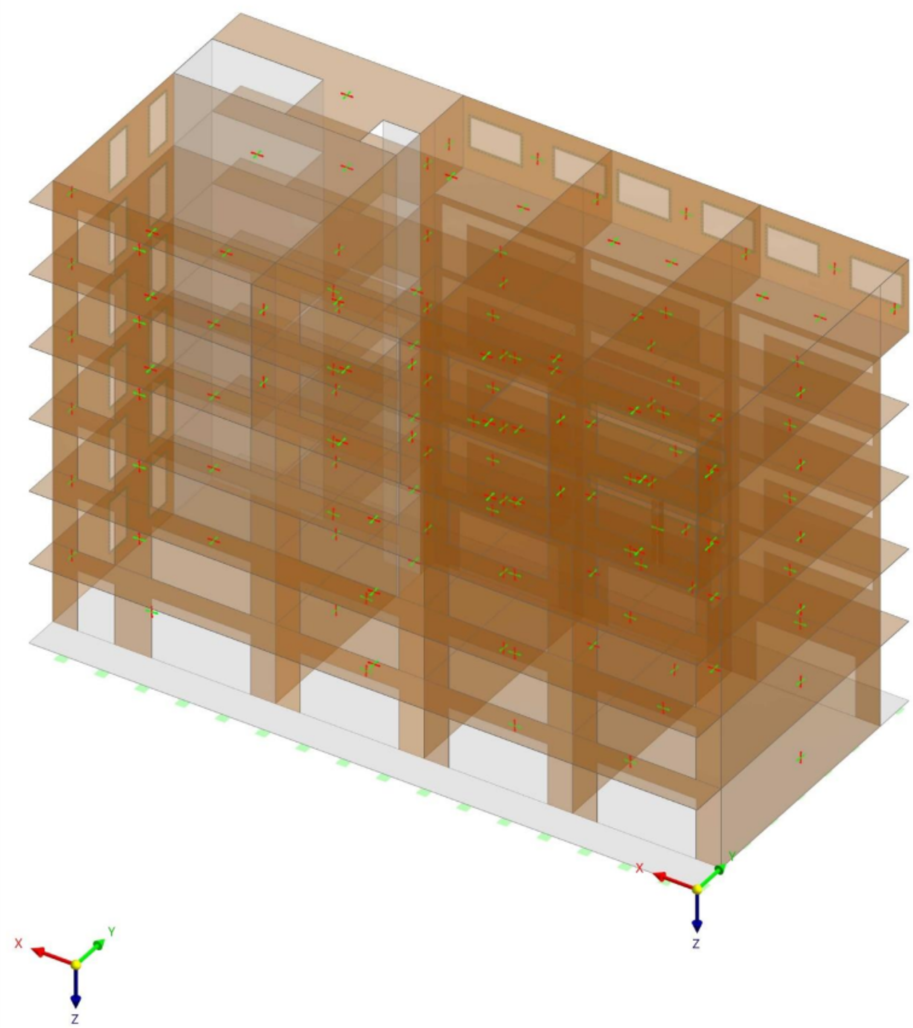
In Axonometric Direction



1.4 **MODEL, IN AXONOMETRIC DIRECTION**

Visibility mode

In Axonometric Direction



2 Types for Surfaces

2.1 SURFACE SUPPORTS

Support No.	Surfaces No.	Translational Spring $C_{u,x}$ [kN/m³]	$C_{u,y}$ [kN/m³]	$C_{u,z}$ [kN/m³]	Shear Spring $C_{v,xz}$ [kN/m]	$C_{v,yz}$ [kN/m]
1	☑☑☑ ☑☑ | Rigid					
	92,250,347,450,455,495	☒	☒	☒	☒	☒

3 Types for Special Objects

3.1 LINE RELEASE TYPES

Release No.	Local Axis System Type	No.	In Plane	Translational Spring [kN/m²] $C_{u,x}$	$C_{u,y}$	$C_{u,z}$	Spring Constant $C_{\varphi,x}$ [kNm·rad⁻¹·m⁻¹]	Rot. Angle β [deg]
1	☐☐☐ ☑ | Line Releases: 50-63)							
	Original line			☐	☐	☐	☒	0.00

3.1.1 LINE RELEASE TYPES - ACCEPTANCE CRITERIA FOR DIAGRAMS

Release No.	Acceptance Criteria for Diagrams Description	Symbol	Value	Unit
1	☐☐☐ ☑ | Line Releases: 50-63)			

3.1.2 LINE RELEASE TYPES - ACCEPTANCE CRITERIA FOR COUPLED DIAGRAMS

Release No.	Acceptance Criteria for Coupled Diagrams Description	Symbol	Value	Unit
1	☐☐☐ ☑ | Line Releases: 50-63)			

4 Load Cases & Combinations

4.1 LOAD CASES

Legend
Accidental torsion

LC No.	Settings	Value	Unit	To Solve	Options
1	G Self-weight				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			
	Action category	G Permanent			
	Self-weight - Factor in direction X	0.000	--		
	Self-weight - Factor in direction Y	0.000	--		
	Self-weight - Factor in direction Z	1.000	--		
	Load duration	Permanent			
	Self-weight mode for geotechnical analysis	Normal			
2	G Dodatno stalno				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			
	Action category	G Permanent			
	Load duration	Permanent			
	Self-weight mode for geotechnical analysis	Normal			
3	QI A Uporabno				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			
	Action category	QI A Imposed loads - category A: domestic, residential areas			
	Load duration	Medium-term			
	Factor Phi	Independently occupied floors			
	Self-weight mode for geotechnical analysis	Normal			
	Imposed load is considered as fatigue	☐			
4	Qs Snijeg				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			

4.1 **LOAD CASES**

LC No.	Settings	Value	Unit	To Solve	Options
	Action category	Qs Snow/Ice loads - H <= 1000 m			
	Load duration	Short-term			
	Self-weight mode for geotechnical analysis	Normal			
5	QI A Uporabno krov				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			
	Action category	QI A Imposed loads - category A: domestic, residential areas			
	Load duration	Medium-term			
	Factor Phi	Roofs			
	Self-weight mode for geotechnical analysis	Normal			
	Imposed load is considered as fatigue	☐			
6	Qw Vjetar pritiskajuci				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			
	Action category	Qw Wind			
	Load duration	Short-term			
	Self-weight mode for geotechnical analysis	Normal			
7	Qw Vjetar odizuci				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			
	Action category	Qw Wind			
	Load duration	Short-term			
	Self-weight mode for geotechnical analysis	Normal			
9	AE Potres				
	Analysis type	Modal Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Modal analysis settings	MOS1 - #30 | Lanczos			
	Import masses from	SEIM CO168			
	Action category	AE Seismic actions			
	Self-weight mode for geotechnical analysis	Normal			
10	AE				
	Analysis type	Response Spectrum Analysis		☒	
	Associated standard	EN 1990 | Base + Timber | CEN | 2010-04			
	Spectral analysis settings	SPS1 - SRSS | Scaled Sum 30.00 %			
	Import modal analysis from	AE LC9			
	Action category	AE Seismic actions			
	Load duration	Instantaneous			
	Self-weight mode for geotechnical analysis	Normal			

4.2 **STATIC ANALYSIS SETTINGS**

Settings No.	Description	Symbol	Value	Unit
1	Geometrically linear | Newton-Raphson			
	Analysis type		Geometrically linear	
	Iterative method for nonlinear analysis		Newton-Raphson	
	Maximum number of iterations		100	
	Number of load increments		1	
	Modify standard precision and tolerance settings		☐	
	Ignore all nonlinearities		☐	
	Modify loading by multiplier factor		☐	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
	Stability check based on deformation rate		☐	
2	Second-order (P-Δ) | Picard | 100 | 1			
	Analysis type		Second-order (P-Δ)	
	Iterative method for nonlinear analysis		Picard	
	Maximum number of iterations		100	
	Number of load increments		1	
	Modify standard precision and tolerance settings		☐	
	Ignore all nonlinearities		☐	

4.2 STATIC ANALYSIS SETTINGS

Settings No.	Description	Symbol	Value	Unit
	Modify loading by multiplier factor		☐	
	Consider favorable effect due to tension in members		☒	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Refer internal forces to deformed structure		☒	
	Refer internal forces to deformed structure for axial forces		☒	
	Refer internal forces to deformed structure for shear forces		☒	
	Refer internal forces to deformed structure for moments		☒	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
	Stability check based on deformation rate		☐	
3	Large deformations | Newton-Raphson | 100 | 1			
	Analysis type		Large deformations	
	Iterative method for nonlinear analysis		Newton-Raphson	
	Maximum number of iterations		100	
	Number of load increments		1	
	Modify standard precision and tolerance settings		☐	
	Ignore all nonlinearities		☐	
	Modify loading by multiplier factor		☐	
	Consider favorable effect due to tension in members		☒	
	Try to calculate unstable structure		☐	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
	Stability check based on deformation rate		☐	

4.3 MODAL ANALYSIS SETTINGS

Settings No.	Description	Symbol	Value	Unit
1	#30 | Lanczos			
	Number of modes method		User-Defined	
	Number of modes		30	
	Solution method		Lanczos	
	Mass matrix type		Consistent	
	Acting masses in X-direction enabled	u_X	☒	
	Acting masses in Y-direction enabled	u_Y	☒	
	Acting masses in Z-direction enabled	u_Z	☐	
	Acting masses about X-axis enabled	φ_X	☐	
	Acting masses about Y-axis enabled	φ_Y	☐	
	Acting masses about Z-axis enabled	φ_Z	☐	
	Mass conversion type		Z-components of loads	
	Neglect masses		User-Defined	
2	#10 | Lanczos			
	Number of modes method		User-Defined	
	Number of modes		10	
	Solution method		Lanczos	
	Mass matrix type		Consistent	
	Acting masses in X-direction enabled	u_X	☒	
	Acting masses in Y-direction enabled	u_Y	☒	
	Acting masses in Z-direction enabled	u_Z	☐	
	Acting masses about X-axis enabled	φ_X	☐	
	Acting masses about Y-axis enabled	φ_Y	☐	
	Acting masses about Z-axis enabled	φ_Z	☐	
	Mass conversion type		Z-components of loads	
	Neglect masses		In all fixed nodal and line supports	

4.3.1 MODAL ANALYSIS SETTINGS - NEGLECT MASSES

MA	Object		Components in Direction			Components About Axis			
No.	Type	List	u_X	u_Y	u_Z	φ_X	φ_Y	φ_Z	Comment
1	Surface	92,250,347,450,455,495	☒	☒	☒	☒	☒	☒	

4.4 **SPECTRAL ANALYSIS SETTINGS**

Settings No.	Description	Symbol	Value	Unit
1	SRSS | Scaled Sum 30.00 %			
	Combination rule for periodic responses		SRSS	
	Use equivalent linear combination		☐	
	Signed results using dominant mode		☐	
	Save results of all selected modes		☒	
	Combination rule for directional components		Scaled Sum	
	Combination rule for directional components		30.00	%
	Consider independent directions in envelope results		☐	

4.5 **COMBINATION WIZARDS**

Wizard No.	Settings	Value
1	Load combinations | SA2 - Second-order (P-Δ) | Picard | 100 | 1	
	Assigned to	DS 1-6
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1
	Consider imperfection case	☒
	Consider initial state	☐
	Structure modification enabled	☐
	Generate same combinations without imperfection case	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐
	Assigned to	DS 1-6
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1
	Consider imperfection case	☒
	Consider initial state	☐
	Structure modification enabled	☐
	Generate same combinations without imperfection case	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐
2	Load combinations | SA1 - Geometrically linear | Newton-Raphson	
	Assigned to	
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson
	Consider imperfection case	☐
	Consider initial state	☐
	Structure modification enabled	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐
	Assigned to	
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson
	Consider imperfection case	☐
	Consider initial state	☐
	Structure modification enabled	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐
3	Result combinations	
	Assigned to	DS 7
	Generate combinations	Result combinations (linear analysis)
	Consider imperfection case	☐
	Generate as permanent superposition	☒
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Assigned to	DS 7
	Generate combinations	Result combinations (linear analysis)
	Consider imperfection case	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐

4.5.1 **COMBINATION WIZARDS - INITIAL STATE ITEMS**

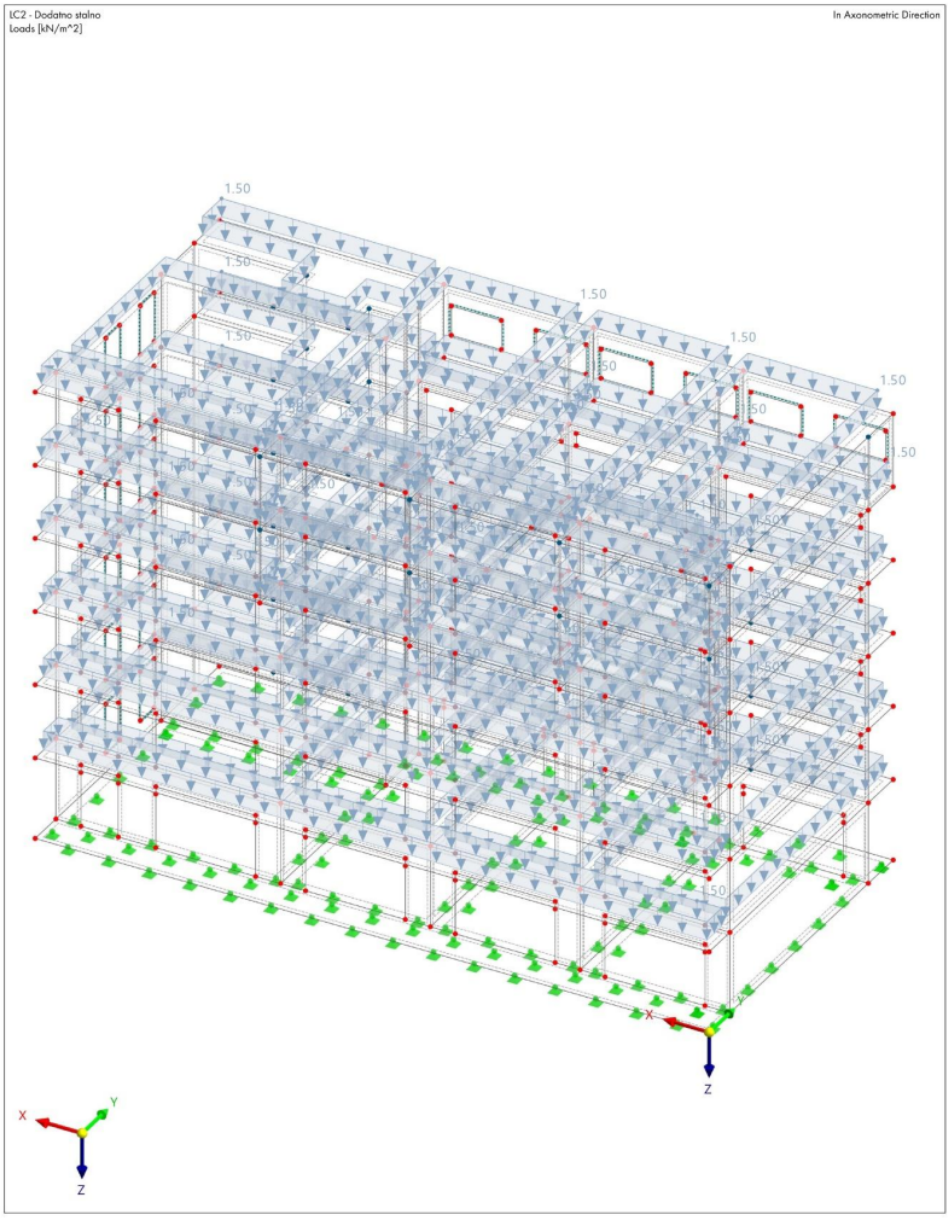
Wizard No.	Definition Type	Case Object
1	Load combinations | SA2 - Second-order (P-Δ) | Picard | 100 | 1	
2	Load combinations | SA1 - Geometrically linear | Newton-Raphson	

4.5.1 COMBINATION WIZARDS - INITIAL STATE ITEMS

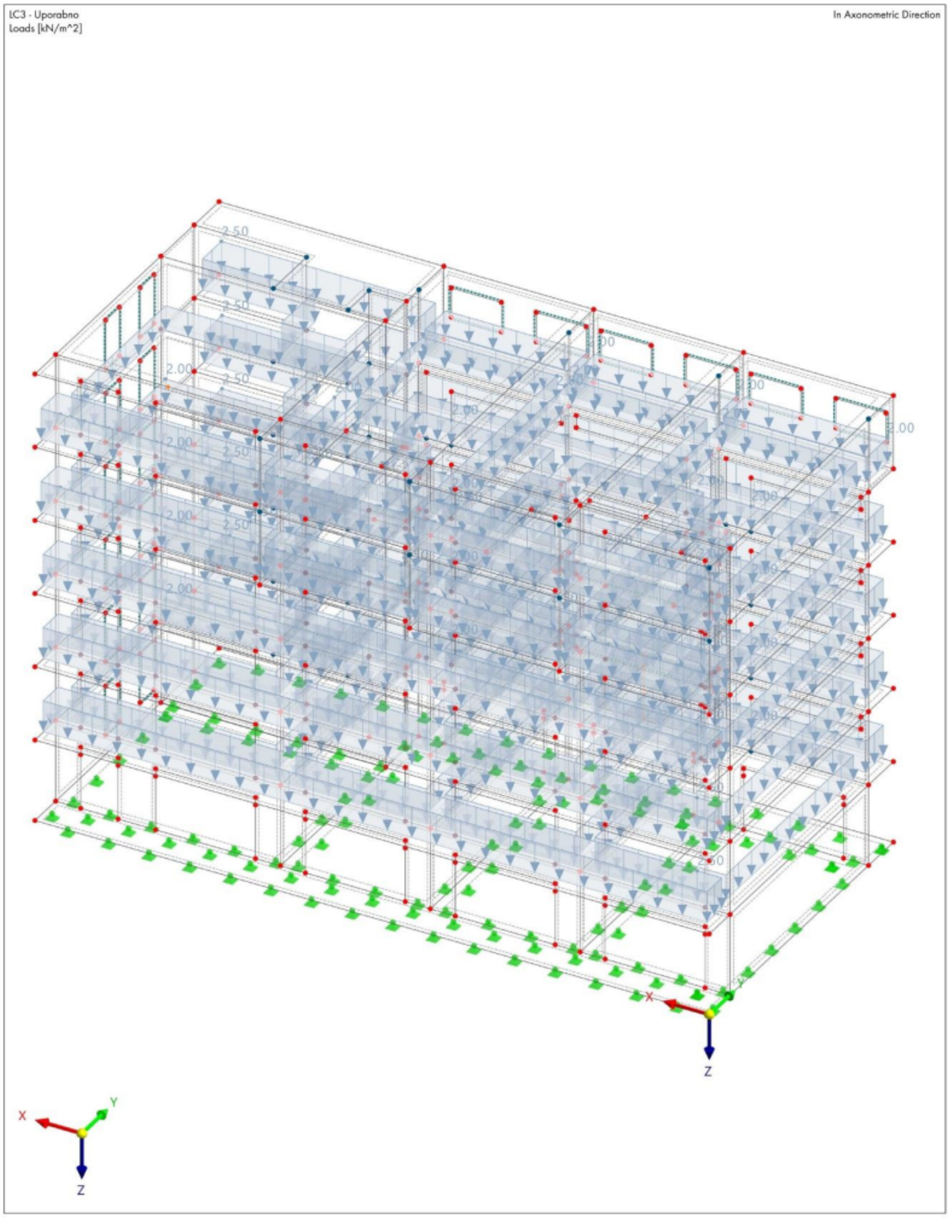
Wizard No.	Definition Type	Case Object
3	Result combinations	

Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 10/33 Sheet 1
		MODEL

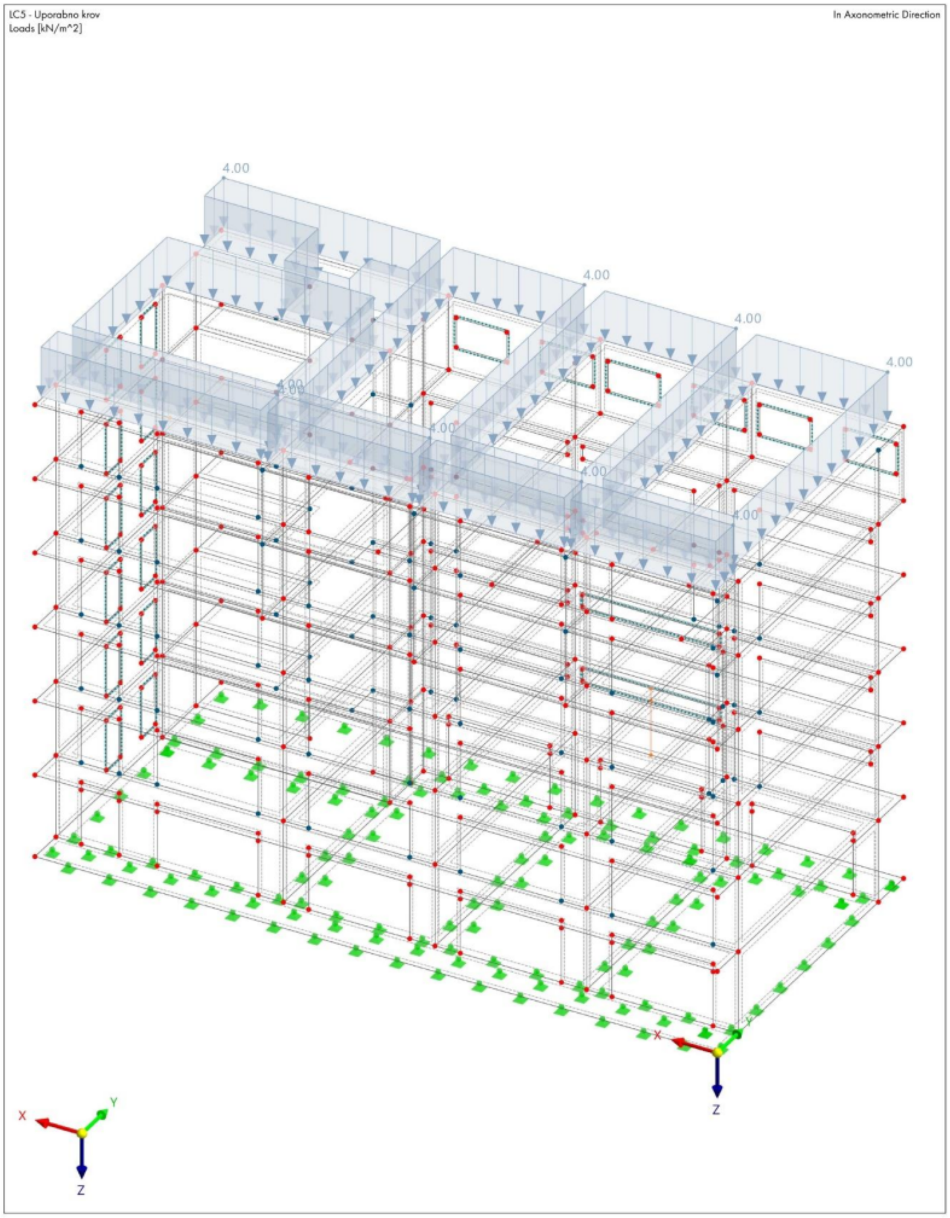
A **LC2: LOADING, IN AXONOMETRIC DIRECTION**



B **LC3: LOADING, IN AXONOMETRIC DIRECTION**

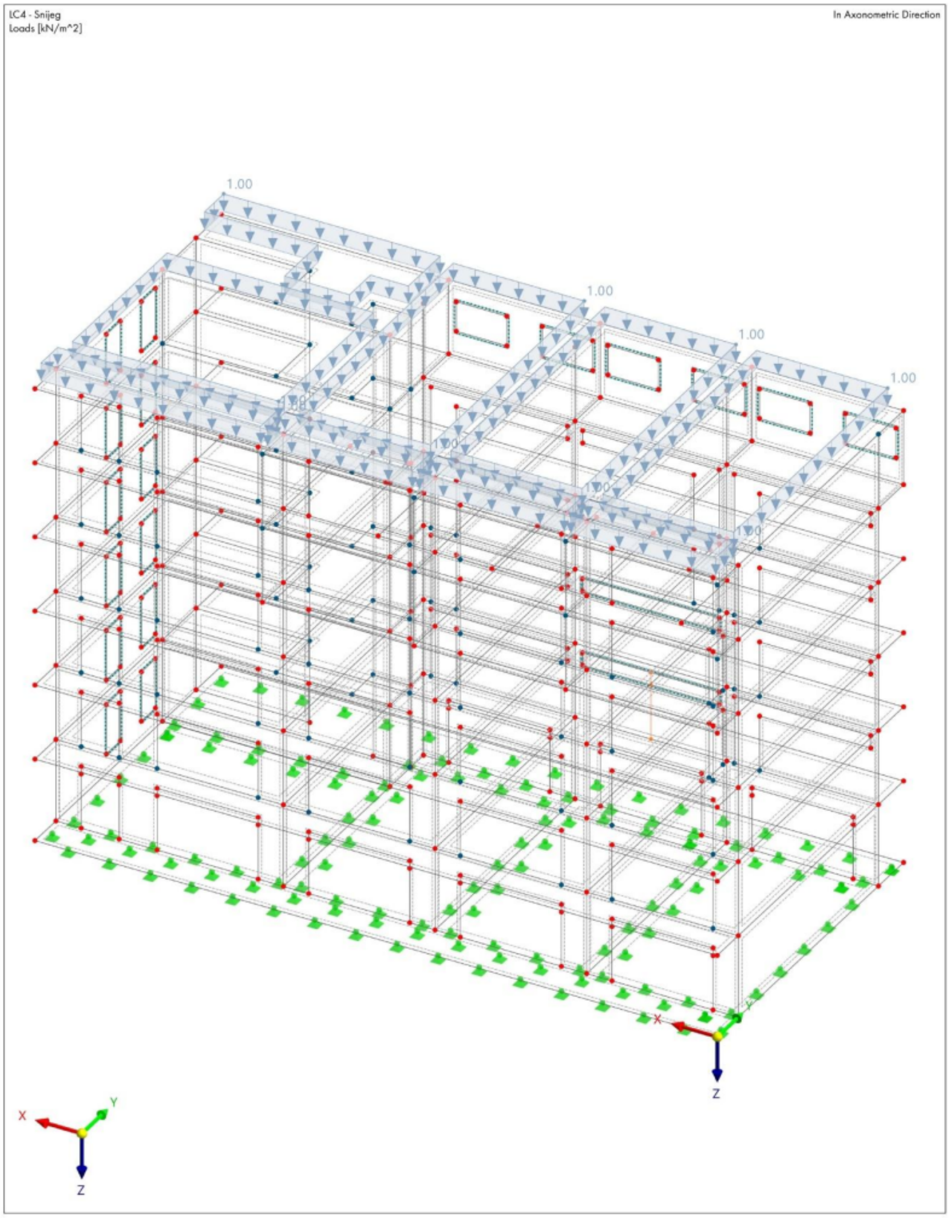


C **LC5: LOADING, IN AXONOMETRIC DIRECTION**



Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 13/33 Sheet 1
		MODEL

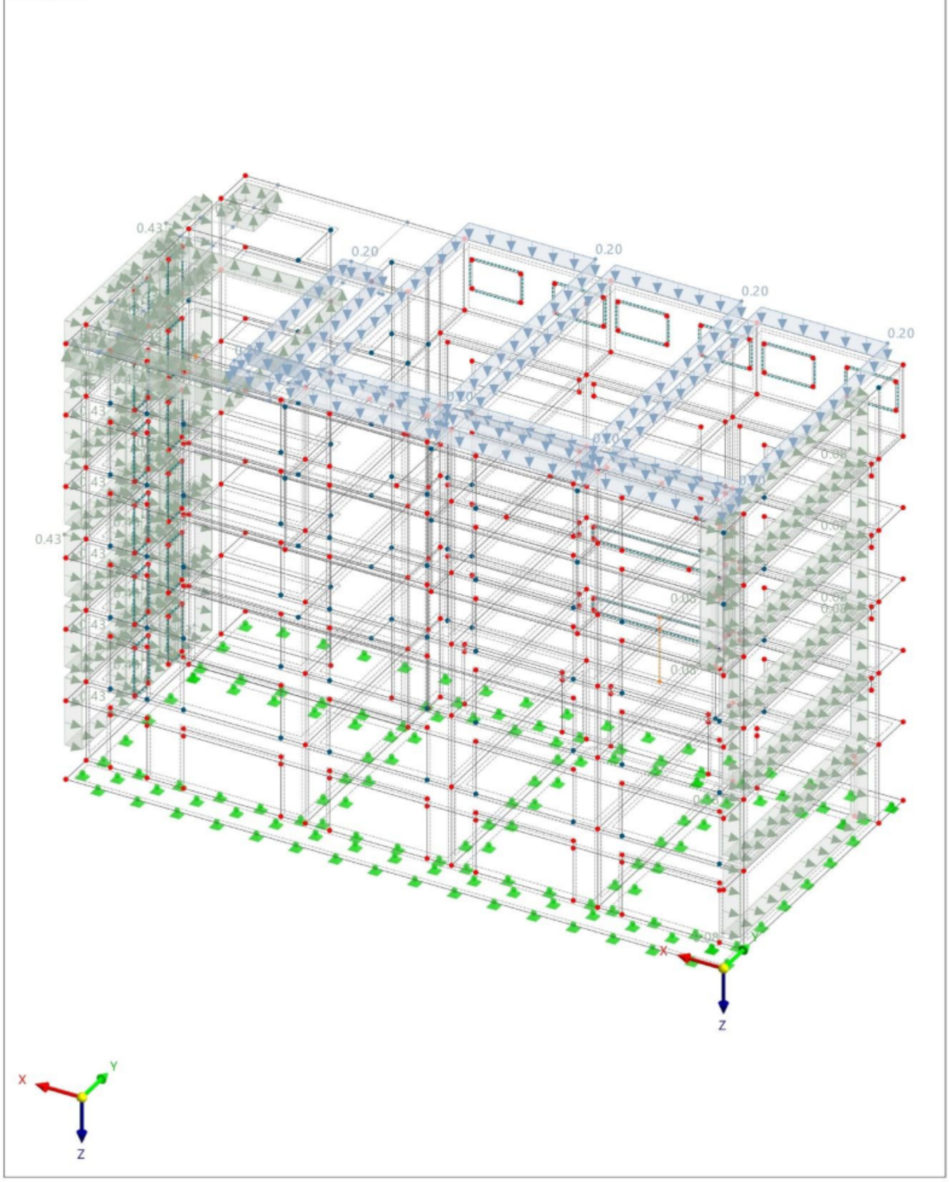
D **LC4: LOADING, IN AXONOMETRIC DIRECTION**



E **LC6: LOADING, IN AXONOMETRIC DIRECTION**

LC6 - Vjetar pritiskajuci
Loads [kN/m^2]

In Axonometric Direction



5 Dynamic Loads

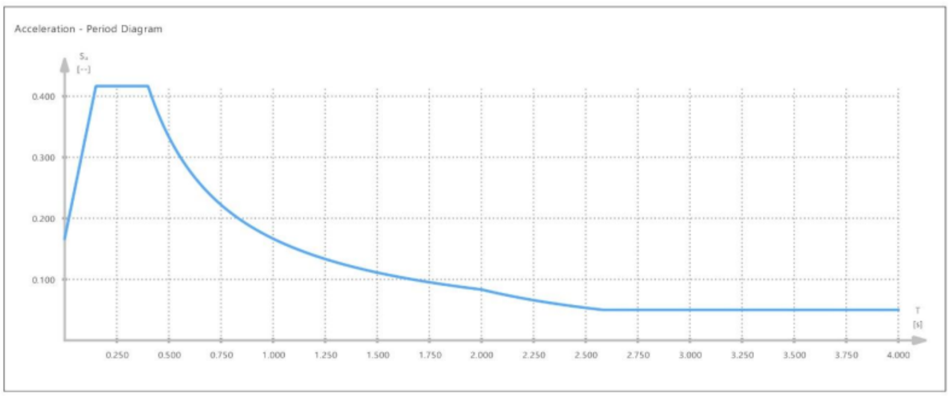
5.1 RESPONSE SPECTRA

RS No.	Definition Type	Comment
1	According to Standard - EN 1998-1 | HRN | 2011-06	

5.1.1 RESPONSE SPECTRA - PARAMETERS

RS No.	Parameter	Symbol	Value	Unit	Reference
1	According to Standard - EN 1998-1 | HRN | 2011-06				
	Type of spectrum				
	Spectrum shape		Design Spectrum		
	Spectrum direction		Horizontal		
	Ground type		A		
	Earthquake action				
	Reference peak ground acceleration	a_{gR}	25.00	%	
	Importance class		II		
		γ_I	1.000	–	4.2.5(5)P
	Design ground acceleration | Horizontal	a_g	0.250	–	
	Factors				
	Behavior factor	q	1.500	–	
	Limit value	β	0.200	–	3.2.2.2(4)P, NA 2.11
	Ground type parameters				
	Soil factor | Ground type A	S	1.000	–	3.2.2.2(2)P, Tab. 3.2
	Control period | Ground type A	T_B	0.150	s	3.2.2.2(2)P, Tab. 3.2
	Control period | Ground type A	T_C	0.400	s	3.2.2.2(2)P, Tab. 3.2
	Control period | Ground type A	T_D	2.000	s	3.2.2.2(2)P, Tab. 3.2
	Maximum period	T_{max}	4.000	s	

5.1.2 RESPONSE SPECTRA | DIAGRAM

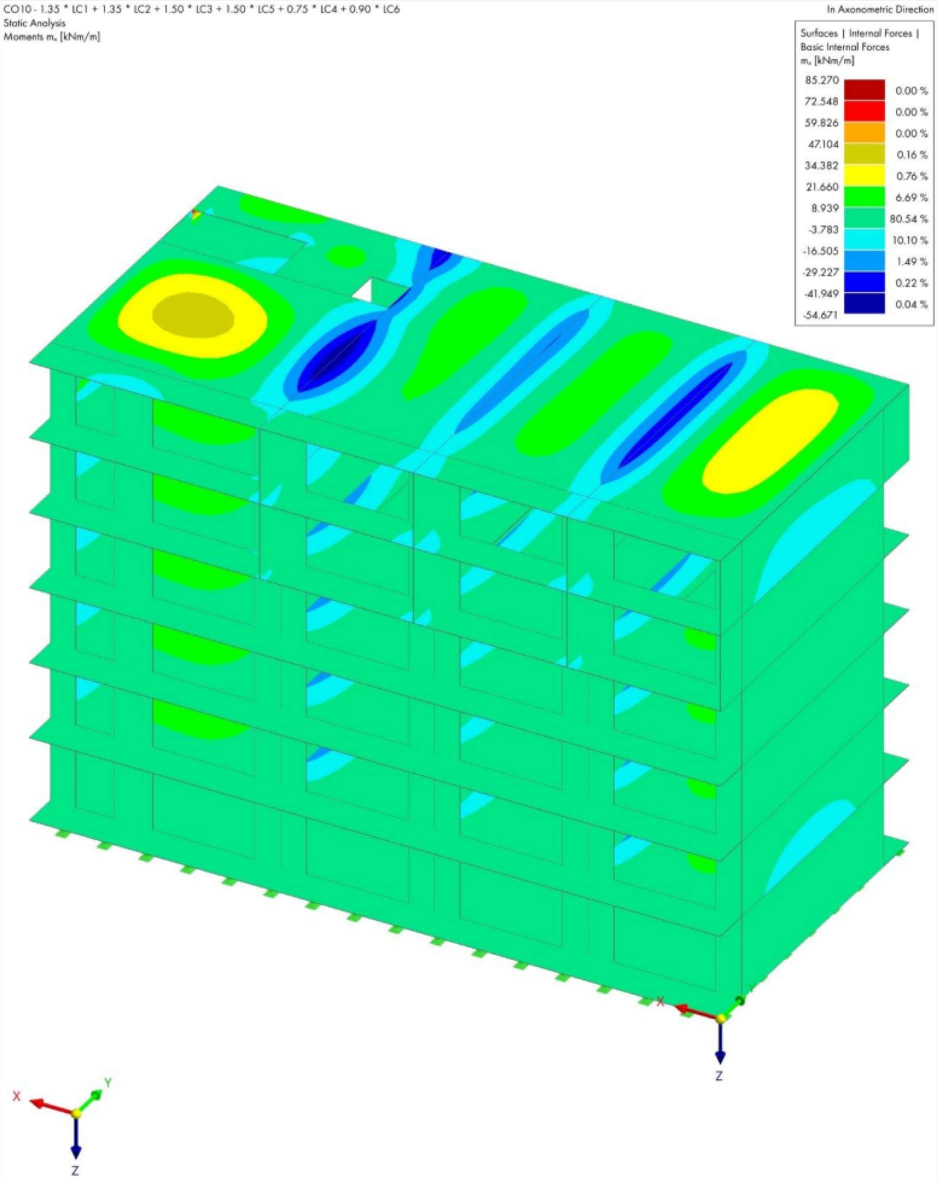


6 Static Analysis Results

Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024	Page 16/33	Sheet 1
		MODEL		

6.1 **CO10: BASIC INTERNAL FORCES M_x, IN AXONOMETRIC DIRECTION** **Static Analysis**

CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 1.50 * LC5 + 0.75 * LC4 + 0.90 * LC6
Static Analysis
Moments m_x [kNm/m]

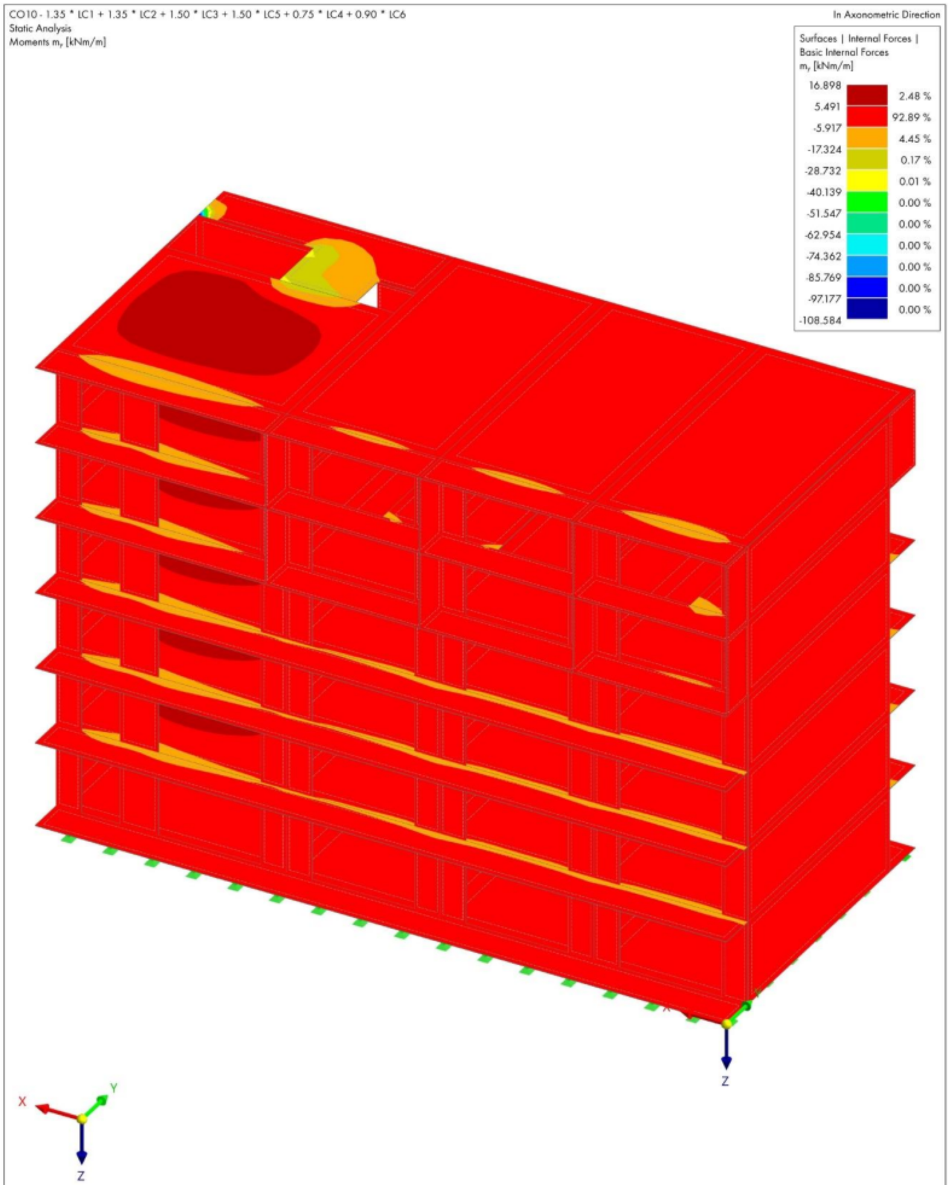


max m_x : 85.270 | min m_x : -54.671 kNm/m

Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 17/33 Sheet 1
		MODEL

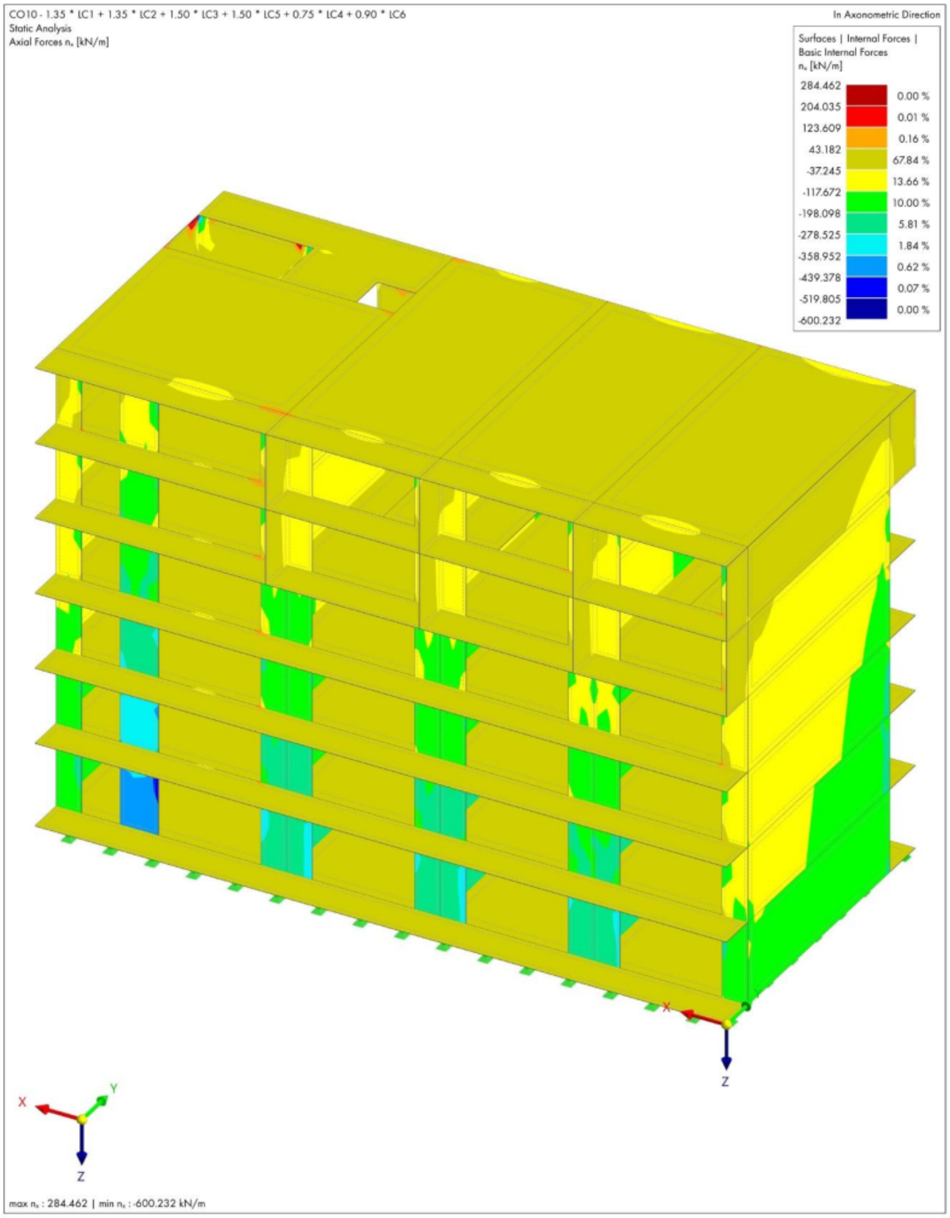
6.2 **CO10: BASIC INTERNAL FORCES M_y, IN AXONOMETRIC DIRECTION** — **Static Analysis**

CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 1.50 * LC5 + 0.75 * LC4 + 0.90 * LC6
Static Analysis
Moments m_y [kNm/m]



max m_y : 16.898 | min m_y : -108.584 kNm/m

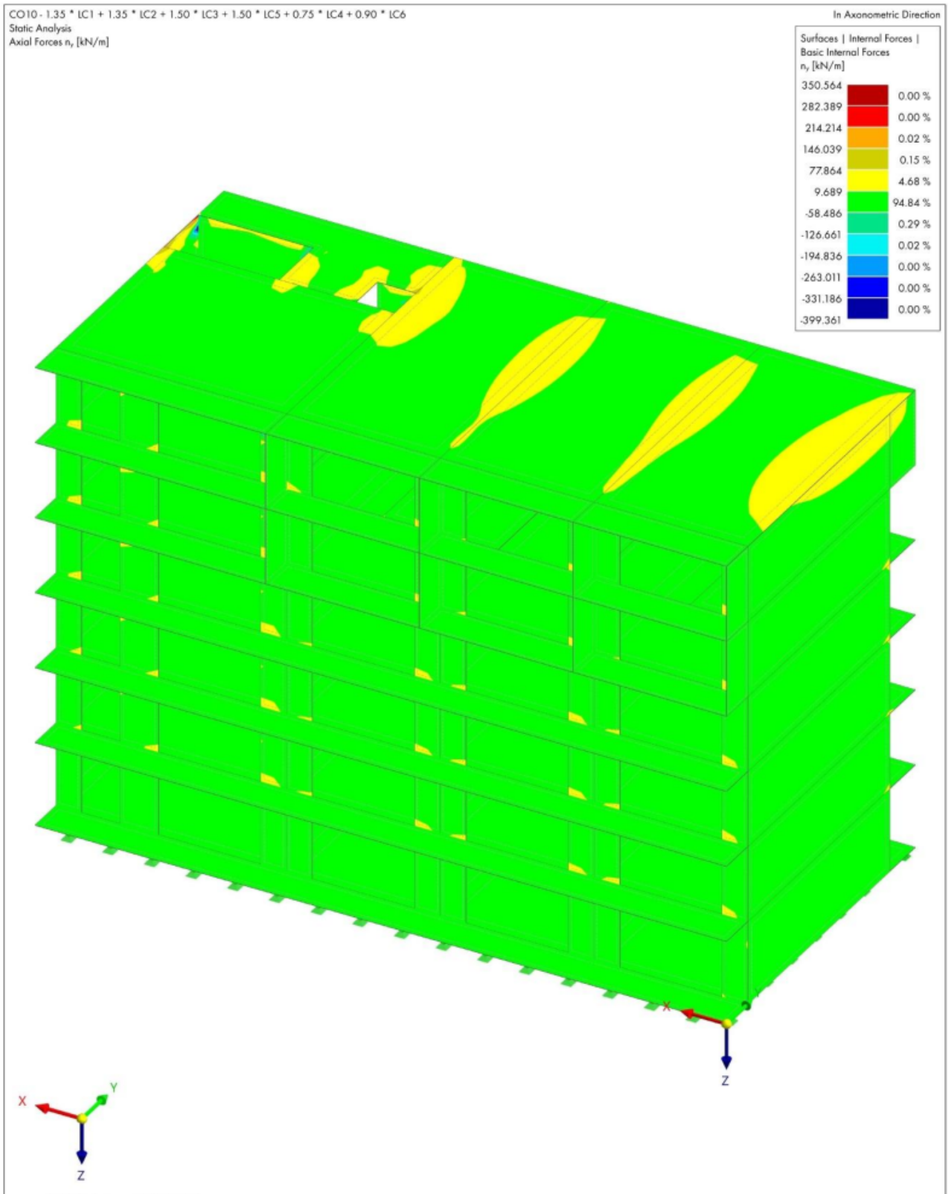
6.3 **CO10: BASIC INTERNAL FORCES N_x, IN AXONOMETRIC DIRECTION** **Static Analysis**



6.4 CO10: BASIC INTERNAL FORCES N_y, IN AXONOMETRIC DIRECTION

Static Analysis

CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 1.50 * LC5 + 0.75 * LC4 + 0.90 * LC6
Static Analysis
Axial Forces n_y [kN/m]



max n_y : 350.564 | min n_y : -399.361 kN/m

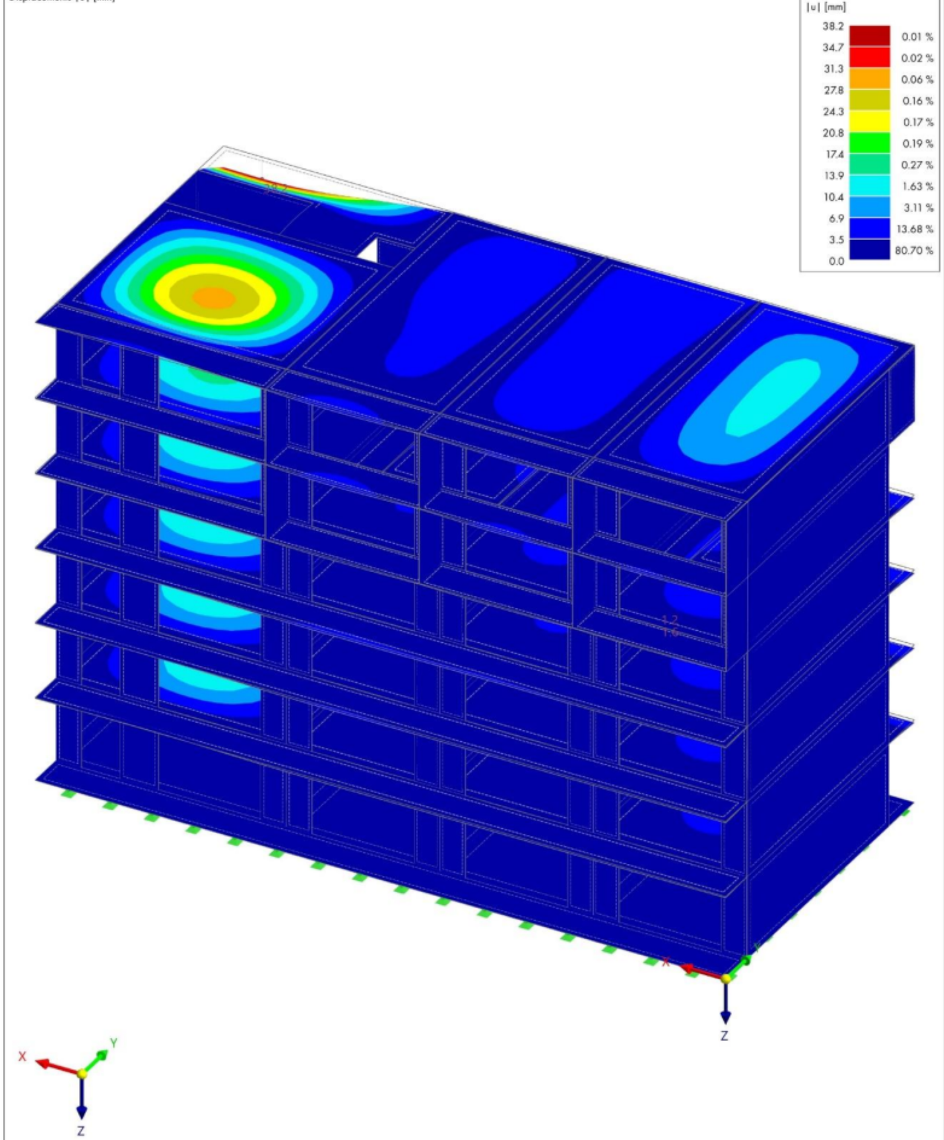
Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 20/33 Sheet 1
		MODEL

6.5 CO57: GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION

Static Analysis

CO57 - LC1 + LC2 + LC3 + LC5 + 0.50 * LC4 + 0.60 * LC6
Static Analysis
Displacements |u| [mm]

In Axonometric Direction

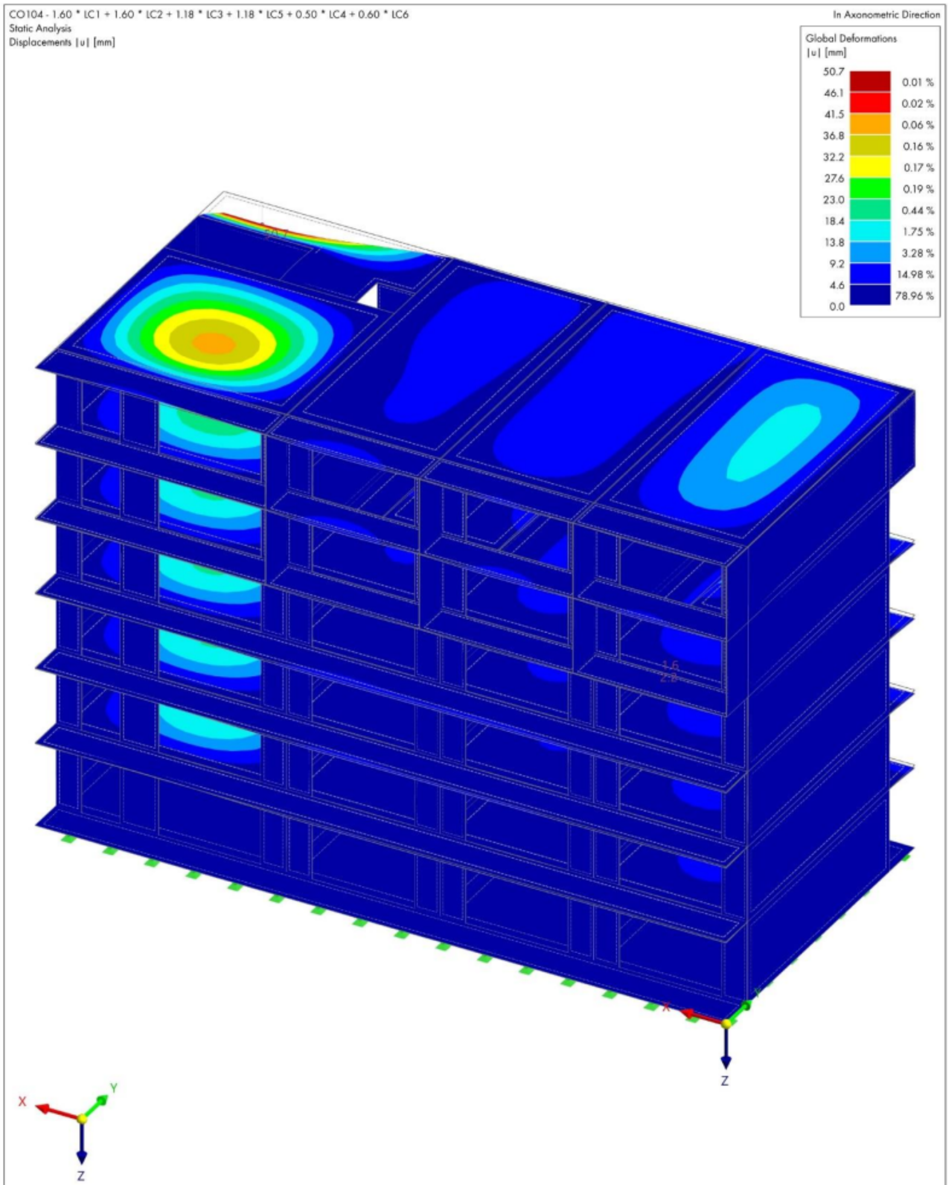


max |u| : 38.2 | min |u| : 0.0 mm

6.6 **CO104: GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Static Analysis**

CO104 - 1.60 * LC1 + 1.60 * LC2 + 1.18 * LC3 + 1.18 * LC5 + 0.50 * LC4 + 0.60 * LC6
Static Analysis
Displacements |u| [mm]

In Axonometric Direction



max |u| : 50.7 | min |u| : 0.0 mm

Marija Gulam

Model: diplomski_zgradaB

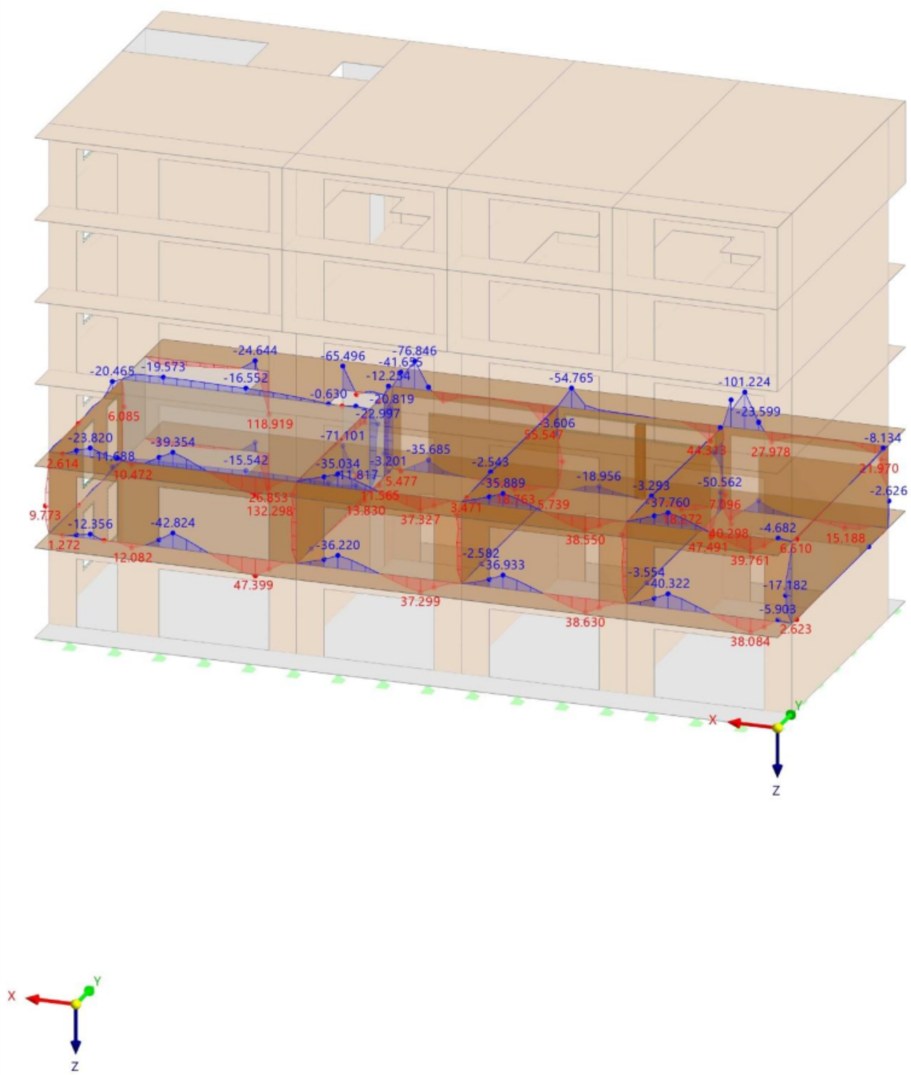
Date 21.8.2024 | Page 22/33 | Sheet 1

MODEL

6.7 CO10: FORCES N, IN AXONOMETRIC DIRECTION — Static Analysis

Visibility mode
CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 1.50 * LC5 + 0.75 * LC4 + 0.90 * LC6
Static Analysis
Forces n [kN/m]

In Axonometric Direction



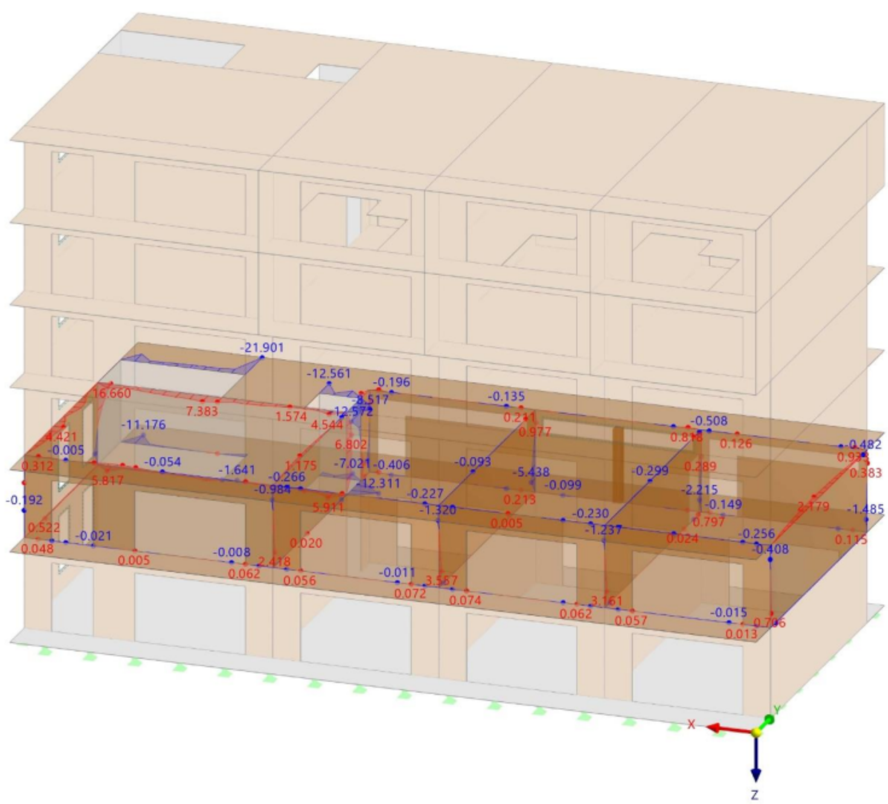
max n : 132.298 | min n : -101.224 kN/m

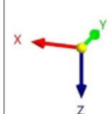
Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024	Page 23/33
			Sheet 1
		MODEL	

6.8 **CO10: FORCES V_y, IN AXONOMETRIC DIRECTION** — **Static Analysis**

Visibility mode
CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 1.50 * LC5 + 0.75 * LC4 + 0.90 * LC6
Static Analysis
Forces v_y [kN/m]

In Axonometric Direction





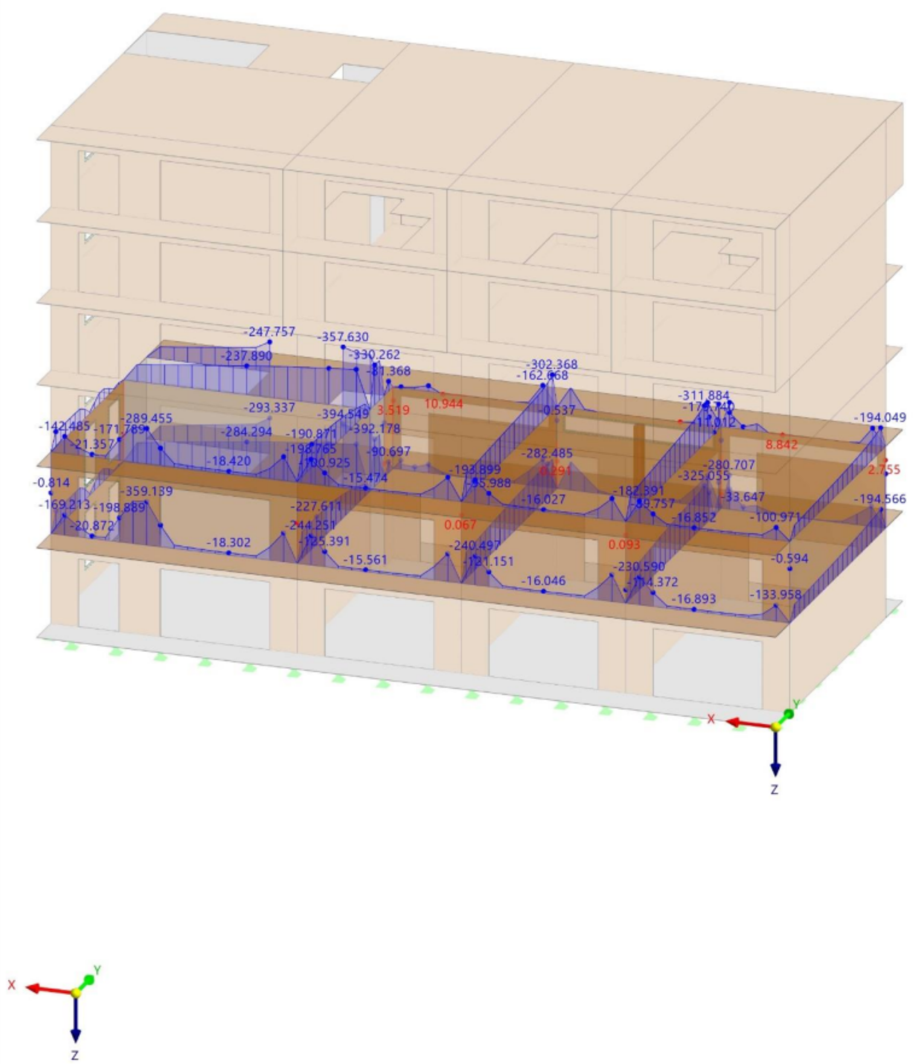
max v_y : 16.660 | min v_y : -21.901 kN/m

Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 24/33 Sheet 1
		MODEL

6.9 **CO10: FORCES V_z, IN AXONOMETRIC DIRECTION** **Static Analysis**

Visibility mode
CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 1.50 * LC5 + 0.75 * LC4 + 0.90 * LC6
Static Analysis
Forces v_z [kN/m]

In Axonometric Direction



max v_z : 10.944 | min v_z : -394.549 kN/m

7 Modal Analysis Results

7.1 NATURAL FREQUENCIES

Modal Analysis

Mode No.	Eigenvalue λ [1/s²]	Angular Frequency ω [rad/s]	Natural Frequency f [Hz]	Natural Period T [s]
1	568.440	23.842	3.795	0.264
2	856.992	29.274	4.659	0.215
3	1399.371	37.408	5.954	0.168
4	5169.051	71.896	11.443	0.087
5	6226.656	78.909	12.559	0.080
6	8885.000	94.260	15.002	0.067
7	9167.025	95.745	15.238	0.066
8	9763.791	98.812	15.726	0.064
9	9832.110	99.157	15.781	0.063
10		99.829	15.888	0.063
11	10107.339	100.535	16.001	0.062
12	10263.613	101.309	16.124	0.062
13	10331.877	101.646	16.177	0.062
14	10356.832	101.769	16.197	0.062
15	10387.465	101.919	16.221	0.062
16	10399.076	101.976	16.230	0.062
17	10445.550	102.203	16.266	0.061
18	11336.086	106.471	16.945	0.059
19	11534.755	107.400	17.093	0.059
20	11616.367	107.779	17.154	0.058
21	11717.925	108.249	17.228	0.058
22	15355.050	123.915	19.722	0.051
23	16992.123	130.354	20.746	0.048
24	17656.838	132.879	21.148	0.047
25	18240.354	135.057	21.495	0.047
26	18924.761	137.567	21.895	0.046
27	19216.383		22.063	0.045
28	19318.066	138.989	22.121	0.045
29	19357.853	139.133	22.144	0.045
30	19531.217	139.754	22.243	0.045

7.2 EFFECTIVE MODAL MASSES

Modal Analysis

Mode No.	Modal Mass M_i [kg]	Transl. Eff. Modal Mass [kg] m_{eX}	m_{eY}	m_{eZ}	Rotat. Eff. Modal Mass [kgm²] $m_{eφX}$	$m_{eφY}$	$m_{eφZ}$	Transl. Eff. Modal Mass Factor [--] f_{meX}	f_{meY}	f_{meZ}	Rotat. Eff. Modal Mass Factor [--] $f_{meφX}$	$f_{meφY}$	$f_{meφZ}$
	AE LC9 - Potres												
1	161851.0	13180.7	572597.0	0.0	4921980.00	114755.00	7450500.00	0.015	0.666	0.000	0.201	0.005	0.107
2	101741.2	73688.4	85463.8	0.0	787526.00	614152.00	39465500.00	0.086	0.099	0.000	0.032	0.025	0.569
3	194373.2	534602.0	222.5	0.0	370.74	5937580.00	6463210.00	0.622	0.000	0.000	0.000	0.242	0.093
4	33728.3	24197.9	71226.8	0.0	7581220.00	1616450.00	2103810.00	0.028	0.083	0.000	0.309	0.066	0.030
5	68761.6	48429.8	52671.7	0.0	4571370.00	3733120.00	2021060.00	0.056	0.061	0.000	0.186	0.152	0.029
6	386.1	400.3	5.6	0.0	790.38	5966.56	1105.47	0.000	0.000	0.000	0.000	0.000	0.000
7	955.5	36860.9	1866.4	0.0	85217.00	2373580.00	3835670.00	0.043	0.002	0.000	0.003	0.097	0.055
8	185.6	168.2	396.4	0.0	33360.20	18066.90	36168.10	0.000	0.000	0.000	0.001	0.001	0.001
9	196.6	15.5	133.2	0.0	12961.10	287.08	55758.40	0.000	0.000	0.000	0.001	0.000	0.001
10	134.1	220.0	44.9	0.0	4875.01	25660.80	133.86	0.000	0.000	0.000	0.000	0.001	0.000
11	735.2	9096.7	1061.0	0.0	20612.50	520169.00	1060200.00	0.011	0.001	0.000	0.001	0.021	0.015
12	206.6	225.7	481.0	0.0	22257.90	14608.80	23361.40	0.000	0.001	0.000	0.001	0.001	0.000
13	314.0	1700.1	283.8	0.0	30456.20	94145.90	447485.00	0.002	0.000	0.000	0.001	0.004	0.006
14	118.7	36.4	13.5	0.0	1095.40	2094.65	28695.60	0.000	0.000		0.000	0.000	0.000
15	158.2	739.9	48.5	0.0	878.73	46328.40	138368.00	0.001	0.000	0.000	0.000	0.002	0.002
16	117.4	0.0	62.3	0.0	5332.81	1.44	4.13	0.000	0.000	0.000	0.000	0.000	0.000
17	258.7	171.4	159.0	0.0	19937.20	9313.53	26681.10	0.000	0.000	0.000	0.001	0.000	0.000
18	1350.1	2695.6	108.3	0.0	42544.30	149558.00	66039.50	0.003	0.000	0.000	0.002	0.006	0.001
19	257.6	18270.7	275.1	0.0	14764.80	1435140.00	8119.08	0.021	0.000	0.000	0.001	0.058	0.000
20	197.0	2739.9	169.2	0.0	18469.80	207230.00	296.06	0.003	0.000	0.000		0.008	0.000
21	446.4	11119.3	1.3	0.0	4352.77	1022390.00	84078.00	0.013	0.000	0.000	0.000	0.042	0.001
22	6451.8	2.6	28959.4	0.0	2197730.00	4032.29	57853.70	0.000	0.034	0.000	0.090	0.000	0.001
23	4933.1	6334.5	655.8	0.0	59415.80	265057.00	70210.00	0.007	0.001	0.000	0.002	0.011	0.001
24	4969.1	2840.4	287.0	0.0	31344.20	619495.00	105069.00	0.003	0.000	0.000	0.001	0.025	0.002
25	603.0	2486.5	230.1	0.0	23595.70	207015.00	1013010.00	0.003	0.000	0.000	0.001	0.008	0.015
26	575.8	13.0	321.2	0.0	17388.30	735.08	84073.90	0.000	0.000	0.000	0.001	0.000	0.001
27	115.7	5.1	14.2	0.0	1317.41	264.65	267.36	0.000	0.000	0.000	0.000	0.000	0.000
28	88.6	0.4	4.9	0.0	738.09	95.19	590.72	0.000	0.000	0.000	0.000	0.000	0.000
29	95.6	5.0	25.7	0.0	4206.81	158.82	175.61	0.000	0.000	0.000	0.000	0.000	0.000
30	301.1	0.3	73.1	0.0	6860.14	22.49	5256.71	0.000	0.000	0.000	0.000	0.000	0.000
Σ	584606.8	790248.0	817863.0	0.0	20523000.00	19037500.00	64652800.00	0.919	0.952	0.000	0.836	0.776	0.932
$Σ_M$		859518.0	859518.0	0.0	24545400.00	24545400.00	69361600.00						
%		91.94 %	95.15 %		83.61 %	77.56 %	93.21 %						

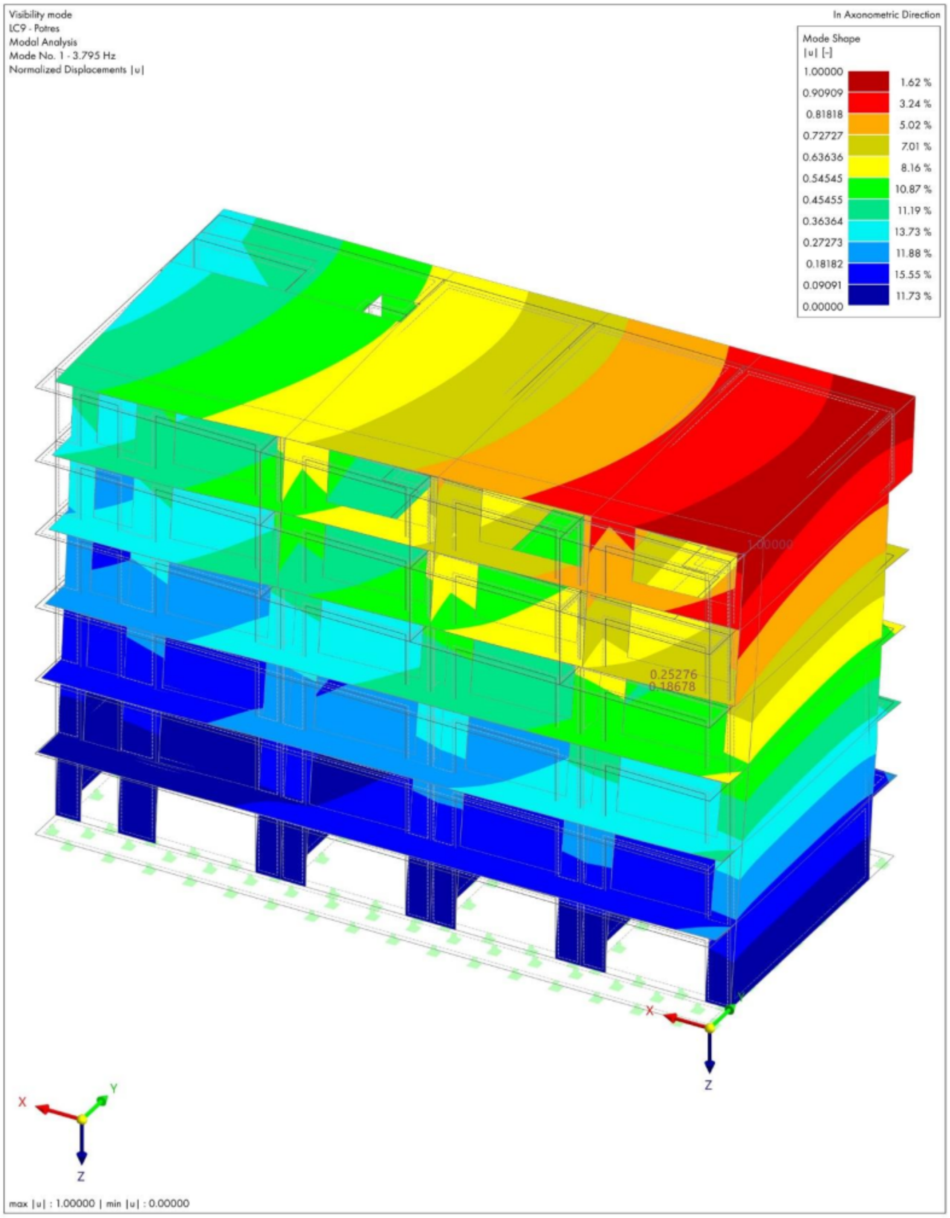
7.3 EFFECTIVE MODAL MASSES - EQUIVALENT MASS PER UNIT LENGTH

Modal Analysis

Mode No.	Modal Mass M_i [kg]
	AE LC9 - Potres
1	161851.0
2	101741.2
3	194373.2
4	33728.3
5	68761.6
6	386.1
7	955.5
8	185.6
9	196.6
10	134.1
11	735.2
12	206.6
13	314.0
14	118.7
15	158.2
16	117.4
17	258.7
18	1350.1
19	257.6
20	197.0
21	446.4
22	6451.8
23	4933.1
24	4969.1
25	603.0
26	575.8
27	115.7
28	88.6
29	95.6
30	301.1
Σ	584606.8
Σ_M	
%	

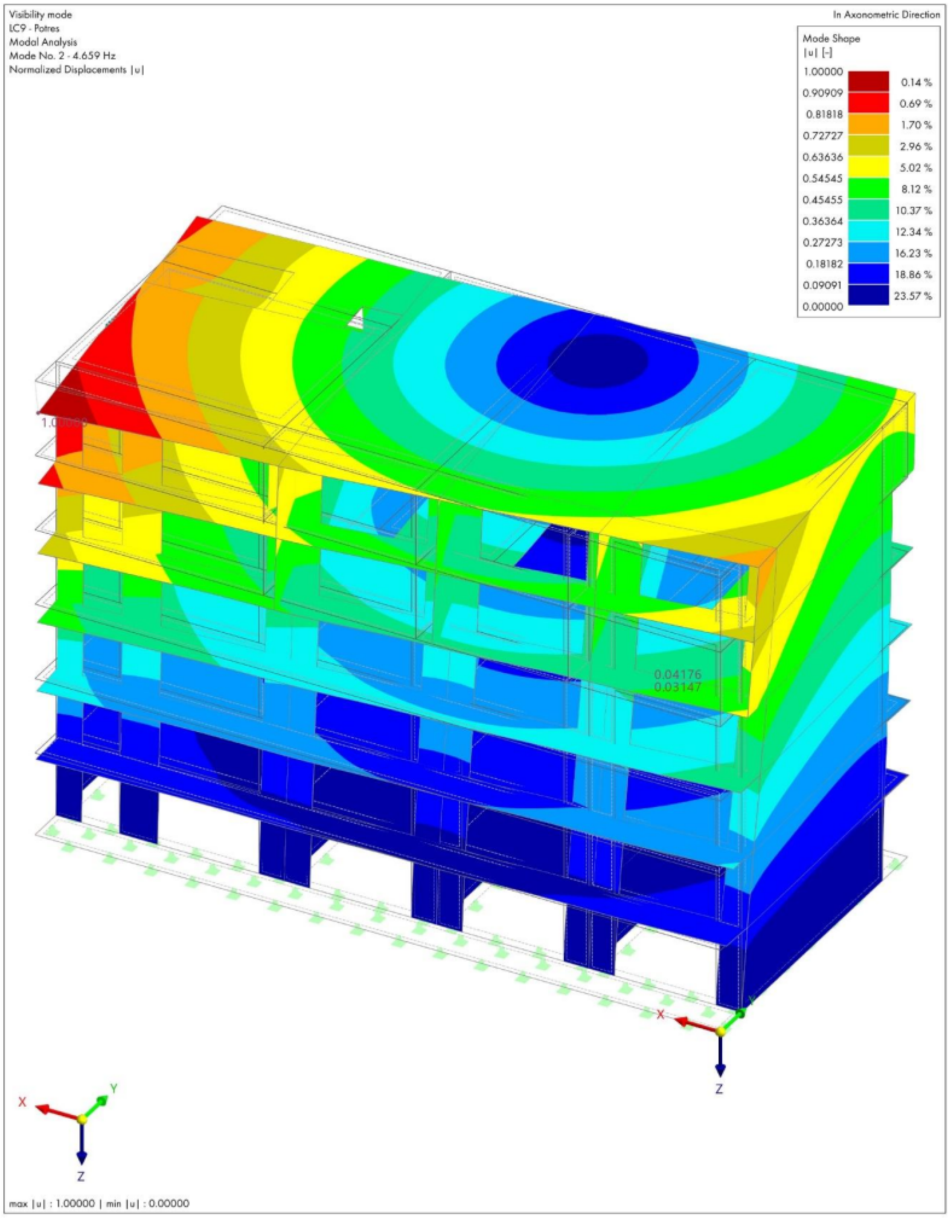
Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 27/33 Sheet 1
		MODEL

7.4 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**

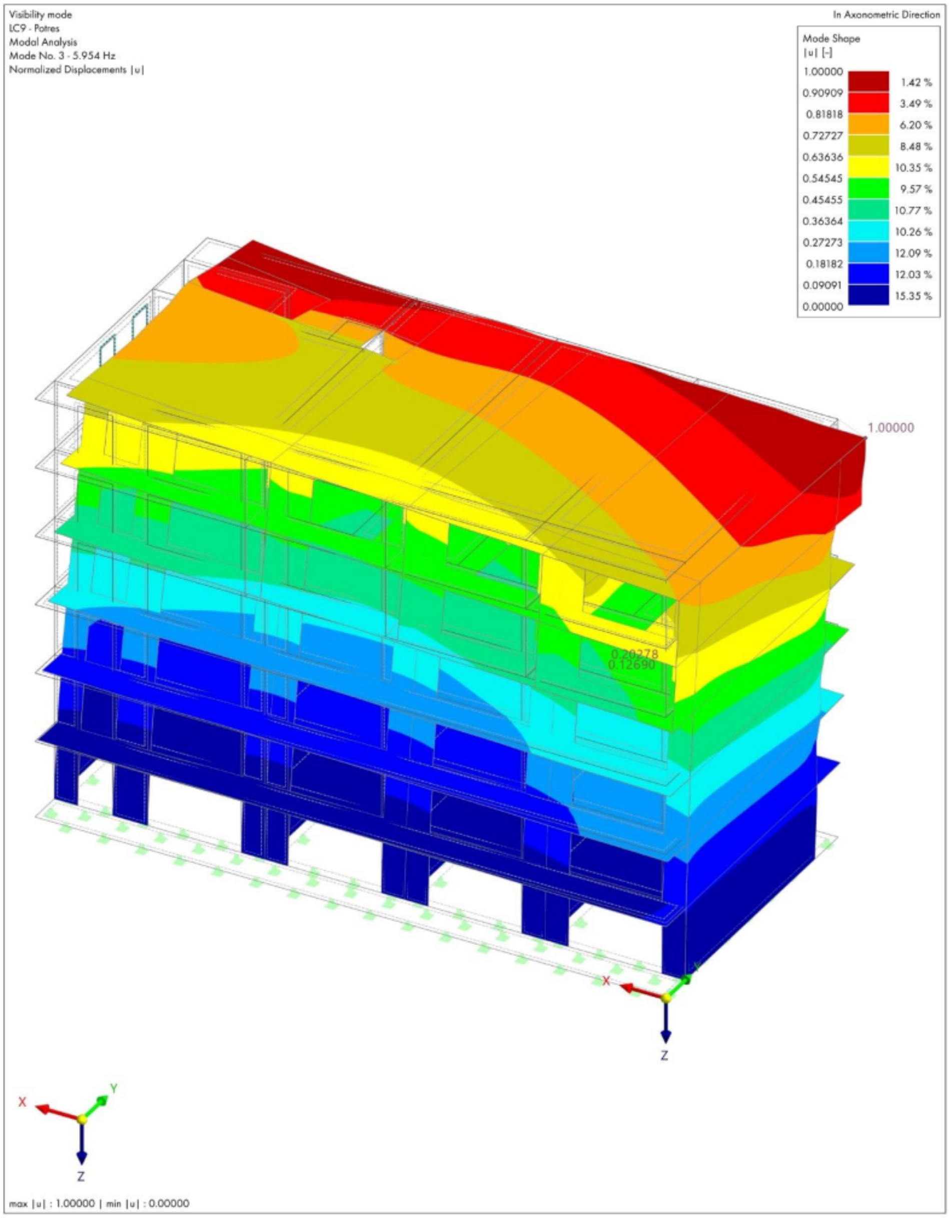


Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 28/33 Sheet 1
		MODEL

7.5 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**

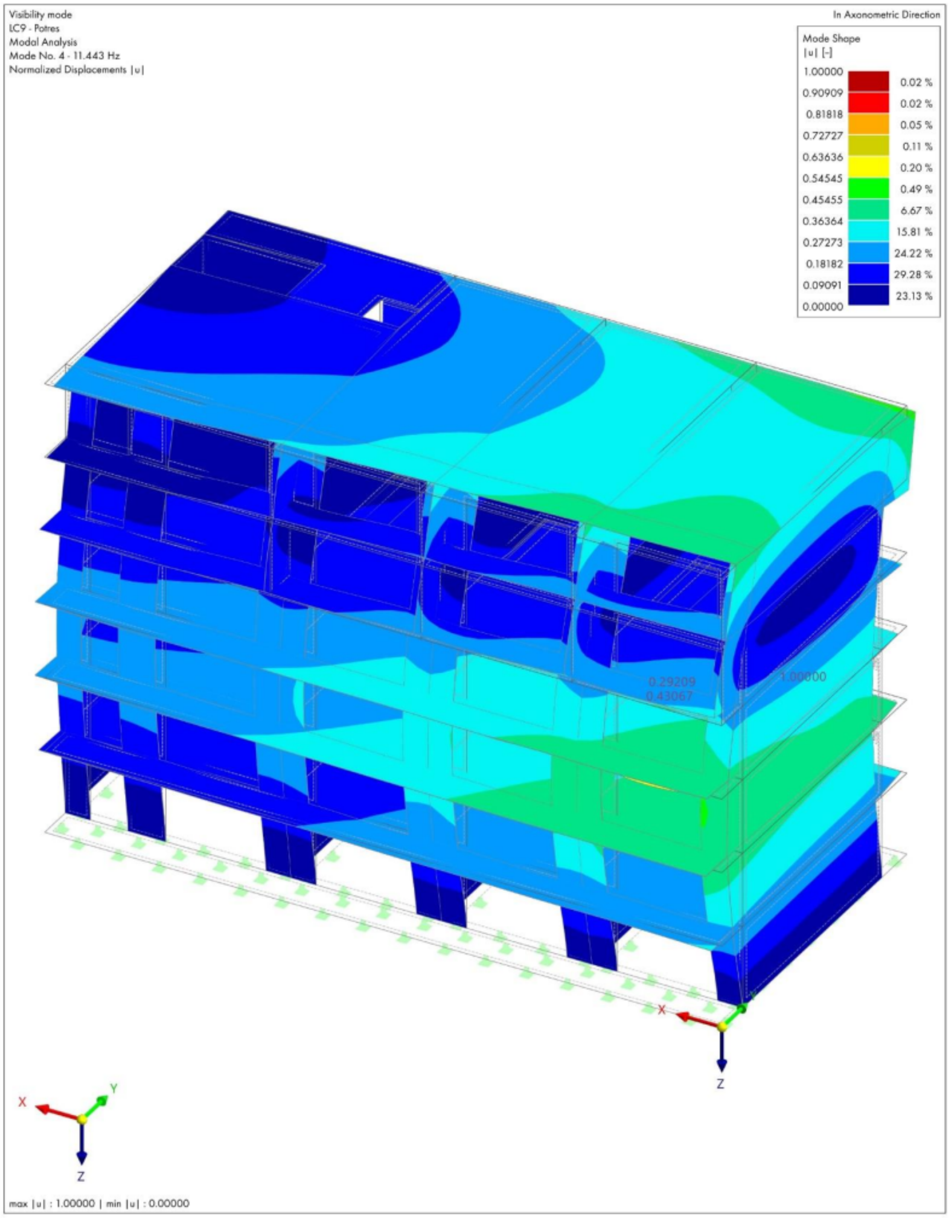


7.6 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** — **Modal Analysis**



Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 30/33 Sheet 1
		MODEL

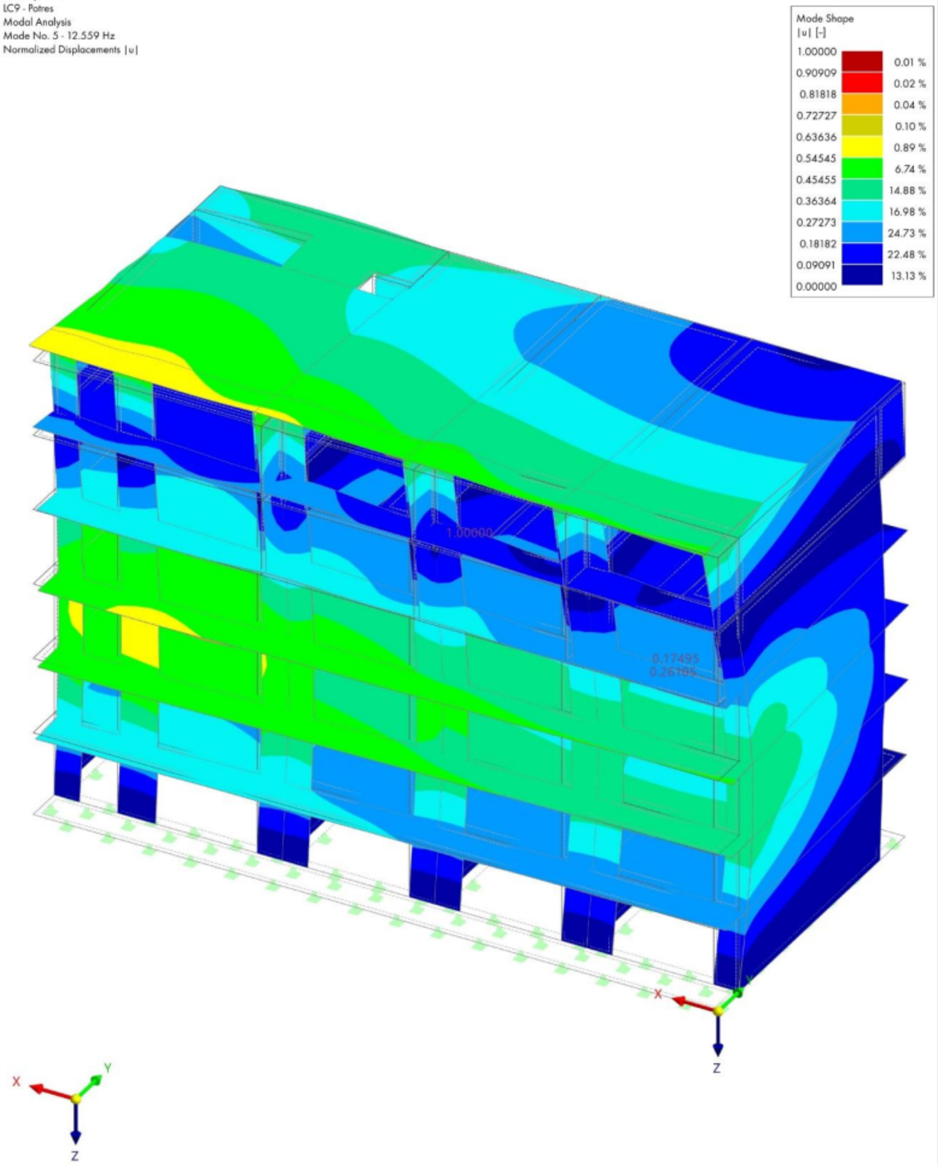
7.7 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**



7.8 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**

Visibility mode
LC9 - Potres
Modal Analysis
Mode No. 5 - 12.559 Hz
Normalized Displacements |u|

In Axonometric Direction

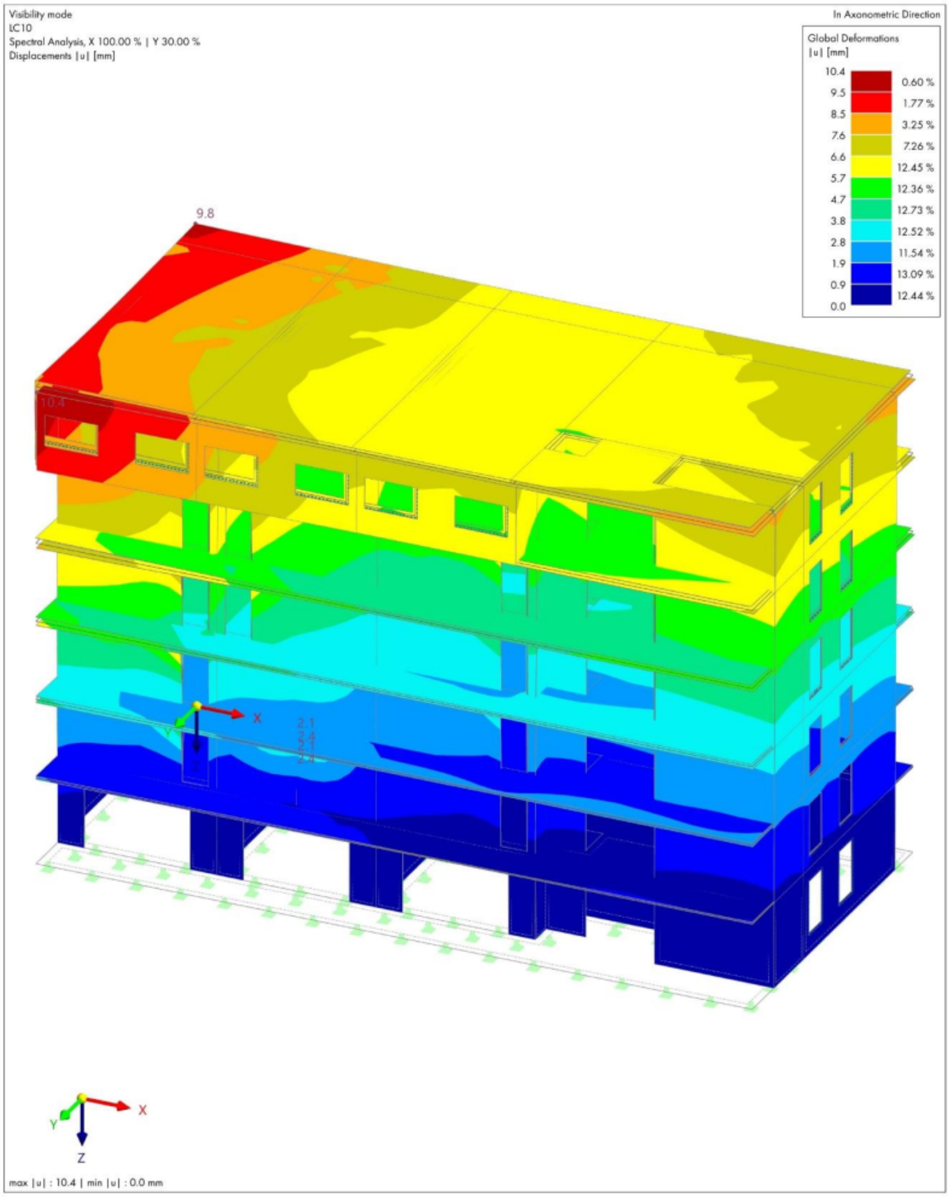


max |u| : 1.00000 | min |u| : 0.00000

Marija Gulam

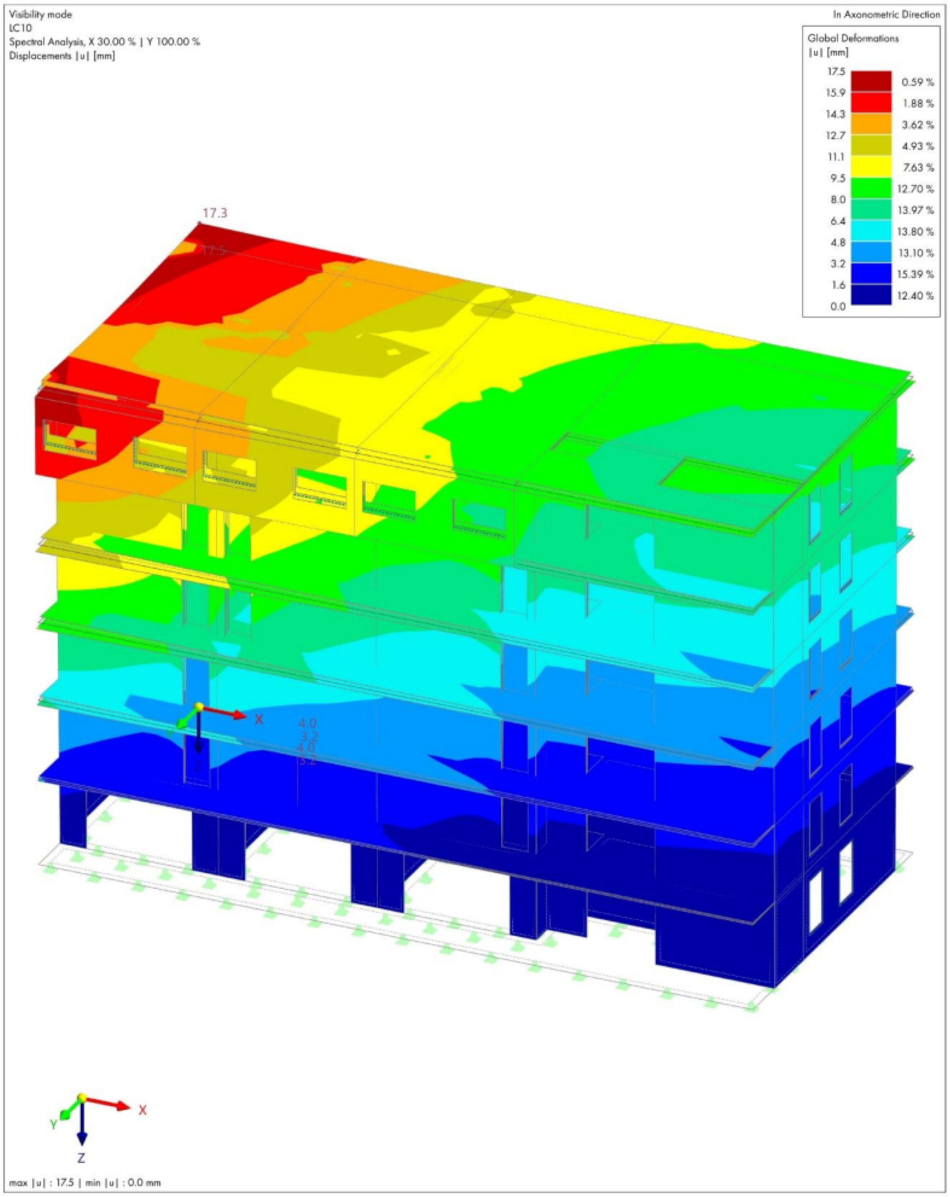
Model: diplomski_zgradaB	Date 21.8.2024	Page 32/33
		Sheet 1
	MODEL	

F **LC10: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Spectral Analysis**



Marija Gulam	Model: diplomski_zgradaB	Date 21.8.2024 Page 33/33 Sheet 1
		MODEL

G **LC10: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Spectral Analysis**



2.5 Dimenzioniranje nosivih dijelova konstrukcije

Dimenzioniranje nosivih dijelova konstrukcije napravljeno je u software-ima *Dlubal RFEM* i *Calculatis*, a provedeno je za karakteristične elemente mjerodavne za cijelu konstrukciju.

Odrađeno je dimenzioniranje na granična stanja nosivosti i uporabljivosti te su odrađene provjere za požar i vibracije.

Kontinuirane ploče u zgradi A su na 5 raspona, dok su u zgradi B na 3 raspona, dobivene su jednake debljine za obe zgrade te je prikazano dimenzioniranje krovne ploče zgrade A i međukatne konstrukcije zgrade B.

Ploče na velikim rasponima bile su izazovne za dimenzioniranje te je isprobano više mogućih varijanti. Jedno od isprobanih rješenja bilo je sustav ploče s gredicama, ali zbog prevelike visine presjeka nije zadovoljilo minimalnu svijetlu visinu etaže. Kao optimalno rješenje odabrana je CLT ploča s čeličnom gredom, na taj način je dobivena kontinuirana ploča preko 2 raspona.

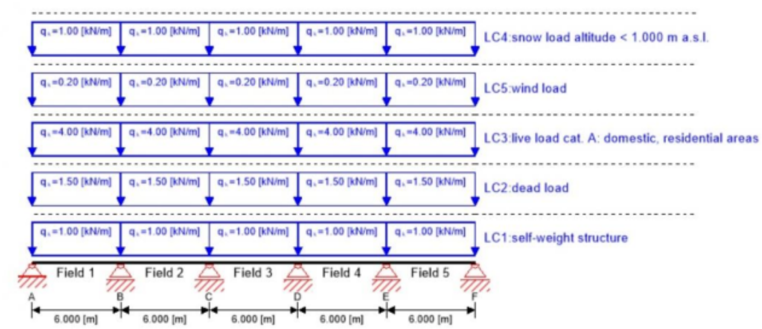
Kao mjerodavni zid odabran je zid s najvećim otvorom u prizemlju konstrukcije.

2.5.1 Krovna ploča

2.5.1.1 Kontinuirano oslonjena ploča

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

System

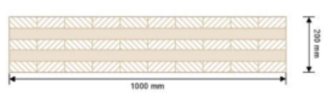


Global utilization ratio 85%

ULS	42%	ULS Fire	21%	SLS	85%	Vibration	73%	Support	-1%

Product data

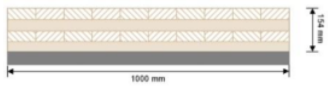
Section: CLT 200 L5s



Layer	Thickness	Orientation	Material
1	40.0 mm	0°	C24 spruce ETA (2022)
2	40.0 mm	90°	C24 spruce ETA (2022)
3	40.0 mm	0°	C24 spruce ETA (2022)
4	40.0 mm	90°	C24 spruce ETA (2022)
5	40.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**200.0 mm**		

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Section Fire: CLT 200 L5s



Layer	Thickness	Orientation	Material
1	40.0 mm	0°	C24 spruce ETA (2022)
2	40.0 mm	90°	C24 spruce ETA (2022)
3	40.0 mm	0°	C24 spruce ETA (2022)
4	34.0 mm	90°	C24 spruce ETA (2022)
t_{CLT}	**154.0 mm**		
Time	**60 min**		

Fire resistance class: R 60

Fire protection layering:
no additional fire protection

k_0	d_0	$d_{char,0,h}$	$d_{ef,h}$	$d_{char,0,v}$	$d_{ef,v}$
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
1	7	39.0	46.0	0.0	0.0

Material values

Material	$f_{m,k}$	$f_{t,0,k}$	$f_{t,90,k}$	$f_{c,0,k}$	$f_{c,90,k}$	$f_{v,k}$	$f_{r,k\,min}$	$E_{0,mean}$	G_{mean}	$G_{r,mean}$
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
C24 spruce ETA (2022)	24.00	14.00	0.12	21.00	2.50	4.00	1.25	12,000.00	690.00	50.00

Load

Load case groups

	Load case category	Type	Duration	Kmod	γ_{inf}	γ_{sup}	Ψ_0	Ψ_1	Ψ_2
LC1	self-weight structure	G	permanent	0.6	1	1.35	1	1	1
LC2	dead load	G	permanent	0.6	1	1.35	1	1	1
LC3	live load cat. A: domestic, residential areas	Q	medium term	0.8	0	1.5	0.7	0.5	0.3
LC4	snow load altitude < 1.000 m a.s.l.	Q	short term	0.9	0	1.5	0.5	0.2	0
LC5	wind load	Q	short term	0.9	0	1.5	0.6	0.2	0

LC1:self-weight structure

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

continuous load	
Field	Load at start
	[kN/m]
1	1.00
2	1.00
3	1.00
4	1.00
5	1.00

LC2:dead load

continuous load	
Field	Load at start
	[kN/m]
1	1.50
2	1.50
3	1.50
4	1.50
5	1.50

LC3:live load cat. A: domestic, residential areas

continuous load	
Field	Load at start
	[kN/m]
1	4.00
2	4.00
3	4.00
4	4.00
5	4.00

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

LC4:snow load altitude < 1.000 m a.s.l.

continuous load	
Field	Load at start [kN/m]
1	1.00
2	1.00
3	1.00
4	1.00
5	1.00

LC5:wind load

continuous load	
Field	Load at start [kN/m]
1	0.20
2	0.20
3	0.20
4	0.20
5	0.20

ULS Combinations

	Combination rule
LCO1	1.35/1.00 * LC1 + 1.35/1.00 * LC2
LCO2	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3
LCO3	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3 + 1.50/0.00 * 0.50 * LC4
LCO4	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3 + 1.50/0.00 * 0.50 * LC4 + 1.50/0.00 * 0.60 * LC5
LCO5	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC4
LCO6	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC4 + 1.50/0.00 * 0.70 * LC3

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

ULS Combinations

	Combination rule
LCO7	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC4 + 1.50/0.00 * 0.70 * LC3 + 1.50/0.00 * 0.60 * LC5
LCO8	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC5
LCO9	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC5 + 1.50/0.00 * 0.70 * LC3
LCO10	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC5 + 1.50/0.00 * 0.70 * LC3 + 1.50/0.00 * 0.50 * LC4

ULS Combinations Fire

	Combination rule
LCO11	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO12	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3
LCO13	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4
LCO14	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.00 * LC5
LCO15	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC4
LCO16	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.30 * LC3
LCO17	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC5
LCO18	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC5
LCO19	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC5 + 1.00/0.00 * 0.30 * LC3
LCO20	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC5 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4

SLS Characteristic Combination

	Combination rule
LCO21	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO22	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC3 + 1.00/0.00 * 0.50 * LC4 + 1.00/0.00 * 0.60 * LC5
LCO23	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC4 + 1.00/0.00 * 0.70 * LC3 + 1.00/0.00 * 0.60 * LC5
LCO24	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC5 + 1.00/0.00 * 0.70 * LC3 + 1.00/0.00 * 0.50 * LC4

SLS Quasi-permanent Combination

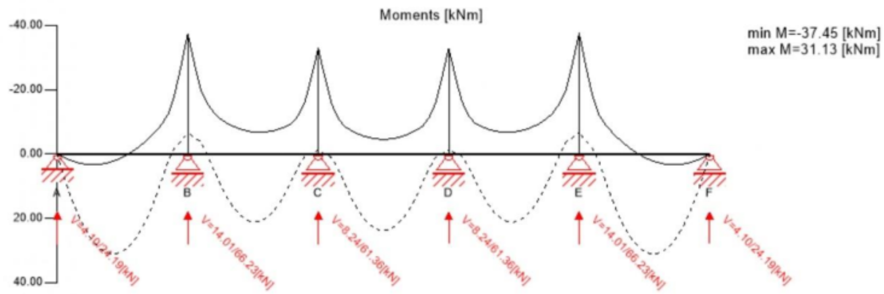
	Combination rule
LCO25	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO26	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.00 * LC5
LCO27	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC5

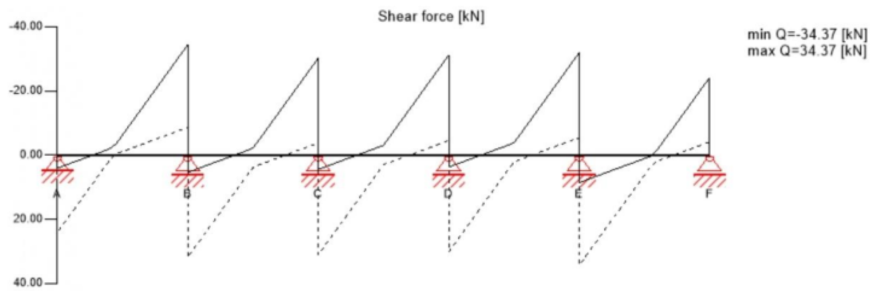
Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

SLS Quasi-permanent Combination

	Combination rule
LCO28	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC5 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4

Ultimate limit state (ULS) - design results





ULS Flexural design

Field	Dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]		
1	6.0	24.00	1.25	0.80	1.10	16.90	-37.45	7.09	42%	LCO2
2	0.0	24.00	1.25	0.80	1.10	16.90	-37.45	7.09	42%	LCO2
3	0.0	24.00	1.25	0.80	1.10	16.90	-32.89	6.23	37%	LCO2
4	6.0	24.00	1.25	0.80	1.10	16.90	-37.45	7.09	42%	LCO2
5	0.0	24.00	1.25	0.80	1.10	16.90	-37.45	7.09	42%	LCO2

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

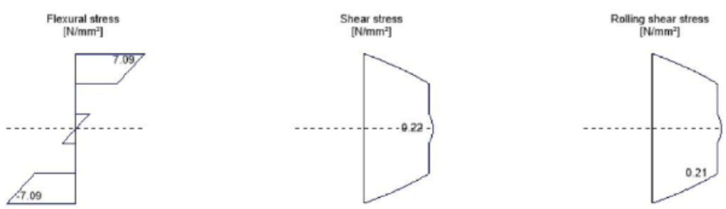
ULS Shear analysis

Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	6.0	4.00	1.25	0.80	2.56	-34.37	0.22	9%	LCO2
2	0.0	4.00	1.25	0.80	2.56	31.87	0.21	8%	LCO2
3	6.0	4.00	1.25	0.80	2.56	-31.14	0.20	8%	LCO2
4	6.0	4.00	1.25	0.80	2.56	-31.87	0.21	8%	LCO2
5	0.0	4.00	1.25	0.80	2.56	34.37	0.22	9%	LCO2

ULS Rolling shear

Field	Dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	6.0	1.05	1.25	0.80	0.67	-34.37	0.21	31%	LCO2
2	0.0	1.05	1.25	0.80	0.67	31.87	0.19	29%	LCO2
3	6.0	1.05	1.25	0.80	0.67	-31.14	0.19	28%	LCO2
4	6.0	1.05	1.25	0.80	0.67	-31.87	0.19	29%	LCO2
5	0.0	1.05	1.25	0.80	0.67	34.37	0.21	31%	LCO2

Stress diagram



storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

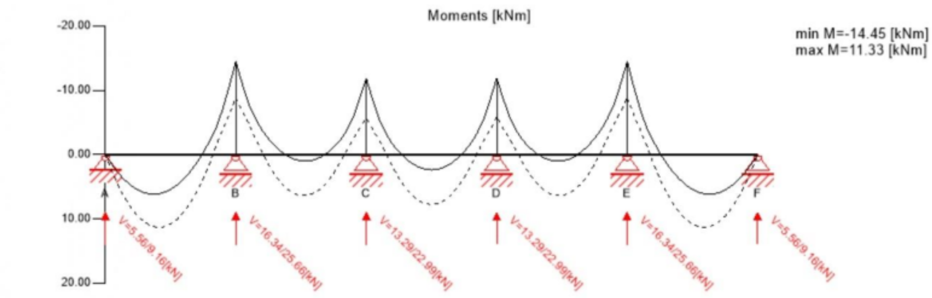
Flexural stress analysis							
$M_{y,d}$ =	-37.45	kNm		$f_{m,k}$ =	24.00	N/mm²	
$M_{z,d}$ =	0.00	kNm		$f_{m,k,z}$ =	24.00	N/mm²	
$N_{t,d}$ =	0.00	kN		γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{sys,y}$ =	1.10	-	
				$k_{h,m,y}$ =	1.00	-	
				$k_{h,m,z}$ =	1.00	-	
				k_l =	1.00	-	
$\sigma_{t,d}$ =	0.00	N/mm²		$f_{t,0,d}$ =	8.96	N/mm²	
$\sigma_{m,y,d}$ =	7.09	N/mm²		$f_{m,y,d}$ =	16.90	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							42%

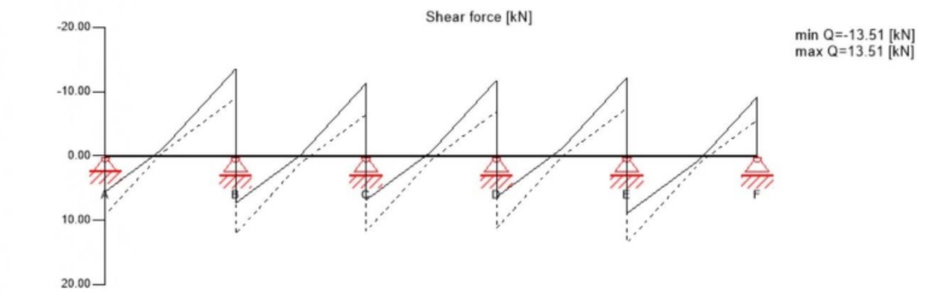
Shear stress analysis							
V_d =	-34.37	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{h,v}$ =	0.00	-	
$\tau_{v,d}$ =	0.22	N/mm²	<	$f_{v,d}$ =	2.56	N/mm²	✓
Utilization ratio							9%

Rolling shear analysis							
V_d =	-34.37	kN		$f_{r,k}$ =	1.05	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
$\tau_{r,d}$ =	0.21	N/mm²	<	$f_{r,d}$ =	0.67	N/mm²	✓
Utilization ratio							31%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Ultimate limit state (ULS) fire design - results





ULS Fire Flexural design

Field	Dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	k_{fi}	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]		
1	6.0	24.00	1.00	1.00	1.10	1.15	30.36	-14.45	6.25	21%	LCO12
2	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-14.45	6.25	21%	LCO12
3	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-11.86	5.13	17%	LCO12
4	6.0	24.00	1.00	1.00	1.10	1.15	30.36	-14.45	6.25	21%	LCO12
5	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-14.45	6.25	21%	LCO12

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

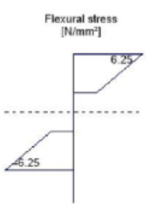
ULS Fire Shear analysis

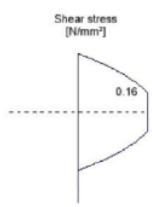
Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	k_{fi}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	6.0	4.00	1.00	1.00	1.15	4.60	-13.51	0.16	3%	LCO12
2	0.0	4.00	1.00	1.00	1.15	4.60	12.15	0.14	3%	LCO12
3	6.0	4.00	1.00	1.00	1.15	4.60	-11.73	0.14	3%	LCO12
4	6.0	4.00	1.00	1.00	1.15	4.60	-12.15	0.14	3%	LCO12
5	0.0	4.00	1.00	1.00	1.15	4.60	13.51	0.16	3%	LCO12

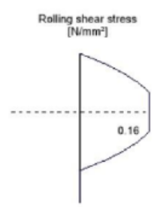
ULS Fire Rolling shear

Field	Dist.	$f_{r,k}$	γ_m	k_{mod}	k_{fi}	$f_{r,d}$	V_d	$\tau_{r,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	6.0	1.05	1.00	1.00	1.15	1.21	-13.51	0.16	13%	LCO12
2	0.0	1.05	1.00	1.00	1.15	1.21	12.15	0.14	12%	LCO12
3	6.0	1.05	1.00	1.00	1.15	1.21	-11.73	0.14	11%	LCO12
4	6.0	1.05	1.00	1.00	1.15	1.21	-12.15	0.14	12%	LCO12
5	0.0	1.05	1.00	1.00	1.15	1.21	13.51	0.16	13%	LCO12

Stress diagram







storaenso

Marija Gulam

University of Zagreb,
Faculty of Civil
Engineering

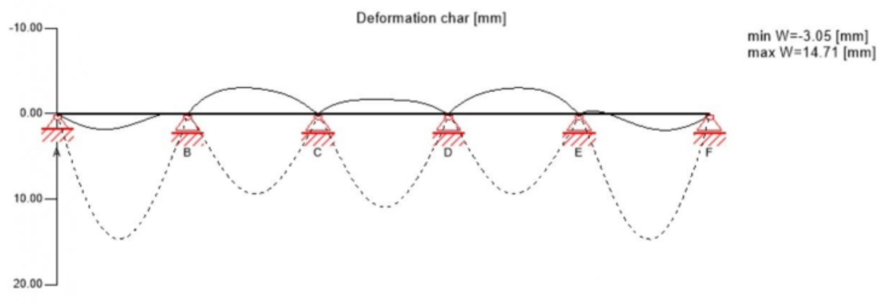
Flexural stress analysis Fire							
$M_{y,d}$ =	-14.45	kNm		$f_{m,k}$ =	24.00	N/mm²	
$M_{z,d}$ =	0.00	kNm		$f_{m,k,z}$ =	24.00	N/mm²	
$N_{t,d}$ =	0.00	kN		γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{sys,y}$ =	1.10	-	
				$k_{h,m,y}$ =	1.00	-	
				$k_{h,m,z}$ =	1.00	-	
				k_l =	1.00	-	
				k_{fi} =	1.15	-	
$\sigma_{t,d}$ =	0.00	N/mm²		$f_{t,0,d}$ =	16.10	N/mm²	
$\sigma_{m,y,d}$ =	6.25	N/mm²		$f_{m,y,d}$ =	30.36	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							21%

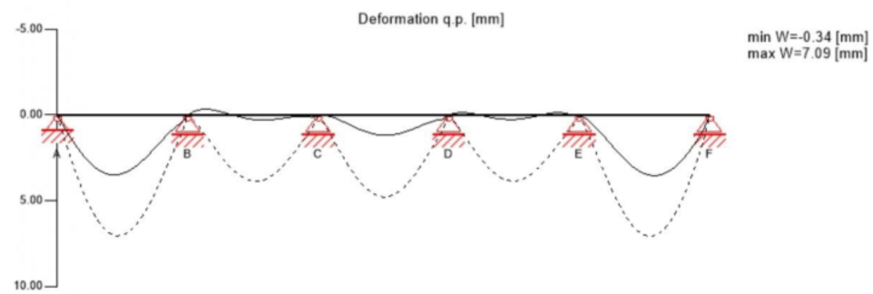
Shear stress analysis Fire							
V_d =	-13.51	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{h,v}$ =	0.00	-	
				k_{fi} =	1.15	-	
$\tau_{v,d}$ =	0.16	N/mm²	<	$f_{v,d}$ =	4.60	N/mm²	✓
Utilization ratio							3%

Rolling shear analysis Fire							
V_d =	-13.51	kN		$f_{r,k}$ =	1.05	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				k_{fi} =	1.15	-	
$\tau_{r,d}$ =	0.16	N/mm²	<	$f_{r,d}$ =	1.21	N/mm²	✓
Utilization ratio							13%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Service limit state design (SLS) - design results





w_{inst} = w[char]

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	20.0	14.6	73%
2	0.8	L/300	20.0	9.4	47%
3	0.8	L/300	20.0	10.9	55%
4	0.8	L/300	20.0	9.4	47%
5	0.8	L/300	20.0	14.7	74%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

w_{fin} = w[char] + w[q.p.]*kdef					
Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/250	24.0	20.3	84%
2	0.8	L/250	24.0	12.5	52%
3	0.8	L/250	24.0	14.8	61%
4	0.8	L/250	24.0	12.5	52%
5	0.8	L/250	24.0	20.4	85%

$w_{net,fin}$ = w[q.p.] + w[q.p.]*kdef					
Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	20.0	12.7	63%
2	0.8	L/300	20.0	7.0	35%
3	0.8	L/300	20.0	8.6	43%
4	0.8	L/300	20.0	7.0	35%
5	0.8	L/300	20.0	12.8	64%

Vibration analysis

General

Total mass	76.45	[t]
Tributary width	3.9	[m]
Stiffness Longitudinal direction	6336.0	[kNm²]
Stiffness Cross direction	1664.0	[kNm²]
Modal damping	4.0	[%]
α	0.1	[-]
Man weight	700.0	[N]
Modal mass	14874.9	[kg]

Analysis

Criterion	Calc.	Class I	Class II	Class I	Class II	Cl. I	Cl. II
Frequency criterion min	6.882 [Hz]	4.5 [Hz]	4.5 [Hz]	65 %	65 %	✓	✓
Frequency criterion	6.882 [Hz]	8.0 [Hz]	6.0 [Hz]	116 %	87 %		
Acceleration criterion	0.015 [m/s²]	0.05 [m/s²]	0.1 [m/s²]	30 %	15 %	✓	
Stiffness criterion	0.182 [mm]	0.25 [mm]	0.5 [mm]	73 %	36 %	✓	✓

storaenso

Marija Gulam

University of Zagreb, Faculty of Civil Engineering

Support reaction

Load case category	k_{mod}	A_V	B_V	C_V	D_V	E_V	F_V
				[kN]			
self-weight structure	0.6	2.38	6.76	5.86	5.86	6.76	2.38
		2.38	6.76	5.86	5.86	6.76	2.38
dead load	0.6	3.57	10.14	8.79	8.79	10.14	3.57
		3.57	10.14	8.79	8.79	10.14	3.57
live load cat. A: domestic, residential areas	0.8	10.76	28.95	27.72	27.72	28.95	10.76
		-1.24	-1.92	-4.28	-4.28	-1.92	-1.24
snow load altitude < 1.000 m a.s.l.	0.9	2.38	6.76	5.86	5.86	6.76	2.38
		0.00	0.00	0.00	0.00	0.00	0.00
wind load	0.9	0.48	1.35	1.17	1.17	1.35	0.48
		0.00	0.00	0.00	0.00	0.00	0.00

Reference documents for this analysis

English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
ETA-14/0349	European Technical Assessment ETA-14/0349
Expertise Rolling shear - no edge gluing, H.J. Blass	Expertise on Rolling shear for CLT
EN 1995-1-2	EN 1995-1-2 - Eurocode 5 — Design of timber structures — Part 1-2: General — Structural fire design
Technical expertise 122/2011/02: analysis of load bearing capacity and separation performance of CLT elements	Verification of the load bearing capacity and the insulation criterion of CLT structures with Stora Enso CLT
Technical expertise 2434/2012 - BB: failure time tf of gypsum fire boards (GKF) according to ON B 3410	Expertise on failure time tf of gypsum wall fire boards according to ON B3410 and gypsum wall boards type DF according to EN 520
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements

storaenso

Marija Gulam

University of Zagreb,
Faculty of Civil
Engineering

Reference documents for this analysis

English title	Description
Fire safety in timber buildings - technical guildeline for Europe	Fire safety in timber buildings - technical guideline for Europe; publishes by SP Technical Research Institute of Sweden
National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12	ÖNORM EN 1995-1-2 - National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12
Expertise Rolling shear, H.J. Blass	Expertise on rolling shear strength and rolling shear modulus of CLT panels
ÖNORM EN 1995-1-1_NA, chapter 7.3	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings; chapter 7.3

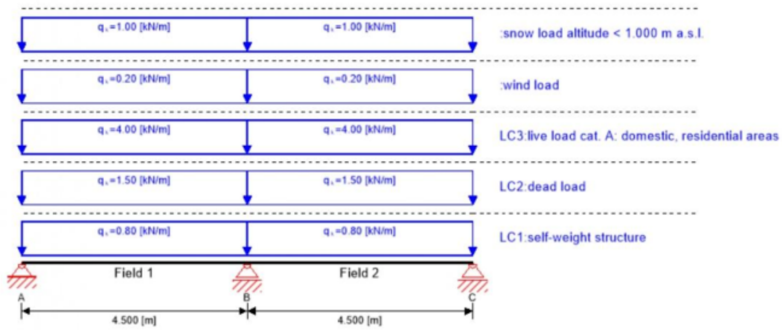
Disclaimer

2.5.1.2 Ploča velikog raspona

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

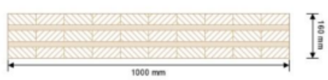
System



Global utilization ratio									86%
ULS	35%	ULS Fire	17%	SLS	55%	Vibration	86%	Support	-1%

Product data

Section: CLT 160 L5s

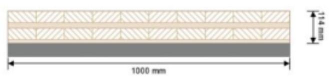


Layer	Thickness	Orientation	Material
1	40.0 mm	0°	C24 spruce ETA (2022)
2	20.0 mm	90°	C24 spruce ETA (2022)
3	40.0 mm	0°	C24 spruce ETA (2022)
4	20.0 mm	90°	C24 spruce ETA (2022)
5	40.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**160.0 mm**		

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Section Fire: CLT 160 L5s



Layer	Thickness	Orientation	Material
1	40.0 mm	0°	C24 spruce ETA (2022)
2	20.0 mm	90°	C24 spruce ETA (2022)
3	40.0 mm	0°	C24 spruce ETA (2022)
4	14.0 mm	90°	C24 spruce ETA (2022)
t_{CLT}	**114.0 mm**		
Time	**60 min**		

Fire resistance class: R 60

Fire protection layering:
no additional fire protection

k_0	d_0	$d_{char,0,h}$	$d_{ef,h}$	$d_{char,0,v}$	$d_{ef,v}$
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
1	7	39.0	46.0	0.0	0.0

Material values

Material	$f_{m,k}$	$f_{t,0,k}$	$f_{t,90,k}$	$f_{c,0,k}$	$f_{c,90,k}$	$f_{v,k}$	$f_{r,k\,min}$	$E_{0,mean}$	G_{mean}	$G_{r,mean}$
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
C24 spruce ETA (2022)	24.00	14.00	0.12	21.00	2.50	4.00	1.25	12,000.00	690.00	50.00

Load

Load case groups

	Load case category	Type	Duration	Kmod	γ_{inf}	γ_{sup}	Ψ_0	Ψ_1	Ψ_2
LC1	self-weight structure	G	permanent	0.6	1	1.35	1	1	1
LC2	dead load	G	permanent	0.6	1	1.35	1	1	1
LC3	live load cat. A: domestic, residential areas	Q	medium term	0.8	0	1.5	0.7	0.5	0.3
	snow load altitude < 1.000 m a.s.l.	Q	short term	0.9	0	1.5	0.5	0.2	0
	wind load	Q	short term	0.9	0	1.5	0.6	0.2	0

LC1:self-weight structure

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

continuous load

Field	Load at start [kN/m]
1	0.80
2	0.80

LC2:dead load

continuous load

Field	Load at start [kN/m]
1	1.50
2	1.50

LC3:live load cat. A: domestic, residential areas

continuous load

Field	Load at start [kN/m]
1	4.00
2	4.00

:snow load altitude < 1.000 m a.s.l.

continuous load

Field	Load at start [kN/m]
1	1.00
2	1.00

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

:wind load

continuous load	
Field	Load at start [kN/m]
1	0.20
2	0.20

ULS Combinations

	Combination rule
LCO1	1.35/1.00 * LC1 + 1.35/1.00 * LC2
LCO2	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3
LCO3	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3 + 1.50/0.00 * 0.50 *
LCO4	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3 + 1.50/0.00 * 0.50 * + 1.50/0.00 * 0.60 *
LCO5	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 *
LCO6	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * + 1.50/0.00 * 0.70 * LC3
LCO7	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * + 1.50/0.00 * 0.70 * LC3 + 1.50/0.00 * 0.60 *
LCO8	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 *
LCO9	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * + 1.50/0.00 * 0.70 * LC3
LCO10	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * + 1.50/0.00 * 0.70 * LC3 + 1.50/0.00 * 0.50 *

ULS Combinations Fire

	Combination rule
LCO11	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO12	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3
LCO13	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 *
LCO14	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.00 *
LCO15	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 *
LCO16	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.30 * LC3
LCO17	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 *

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

ULS Combinations Fire

	Combination rule
LCO18	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 *
LCO19	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.30 * LC3
LCO20	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 *

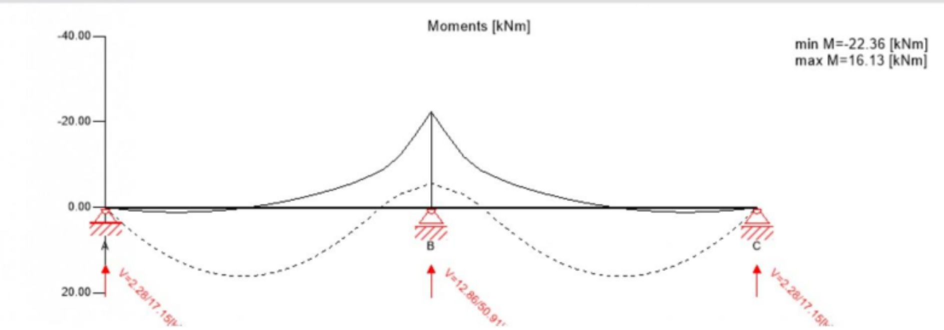
SLS Characteristic Combination

	Combination rule
LCO21	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO22	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC3 + 1.00/0.00 * 0.50 * + 1.00/0.00 * 0.60 *
LCO23	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * + 1.00/0.00 * 0.70 * LC3 + 1.00/0.00 * 0.60 *
LCO24	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * + 1.00/0.00 * 0.70 * LC3 + 1.00/0.00 * 0.50 *

SLS Quasi-permanent Combination

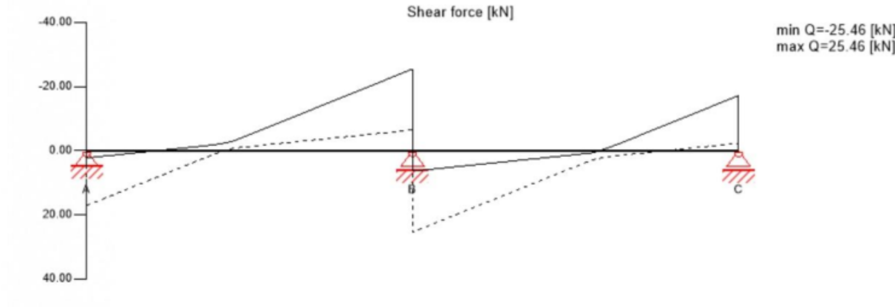
	Combination rule
LCO25	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO26	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.00 *
LCO27	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 *
LCO28	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 *

Ultimate limit state (ULS) - design results



Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Ultimate limit state (ULS) - design results



ULS Flexural design

Field	Dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]		
1	4.5	24.00	1.25	0.80	1.10	16.90	-22.36	-5.88	35%	LCO2
2	0.0	24.00	1.25	0.80	1.10	16.90	-22.36	-5.88	35%	LCO2

ULS Shear analysis

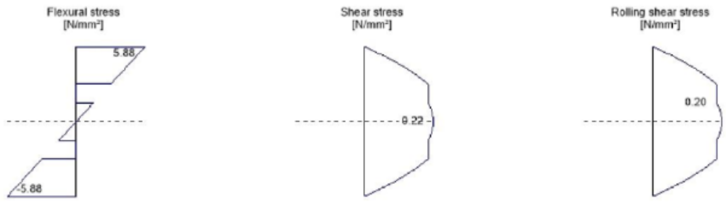
Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	4.5	4.00	1.25	0.80	2.56	-25.46	0.22	9%	LCO2
2	0.0	4.00	1.25	0.80	2.56	25.46	0.22	9%	LCO2

ULS Rolling shear

Field	Dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	4.5	1.25	1.25	0.80	0.80	-25.46	0.20	25%	LCO2
2	0.0	1.25	1.25	0.80	0.80	25.46	0.20	25%	LCO2

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Stress diagram



Flexural stress analysis

$M_{y,d}$ =	-22.36	kNm		$f_{m,k}$ =	24.00	N/mm²	
$M_{z,d}$ =	0.00	kNm		$f_{m,k,z}$ =	24.00	N/mm²	
$N_{t,d}$ =	0.00	kN		γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{sys,y}$ =	1.10	-	
				$k_{h,m,y}$ =	1.00	-	
				$k_{h,m,z}$ =	1.00	-	
				k_l =	1.00	-	
$\sigma_{t,d}$ =	0.00	N/mm²		$f_{t,0,d}$ =	8.96	N/mm²	
$\sigma_{m,y,d}$ =	-5.88	N/mm²		$f_{m,y,d}$ =	16.90	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							35%

Shear stress analysis

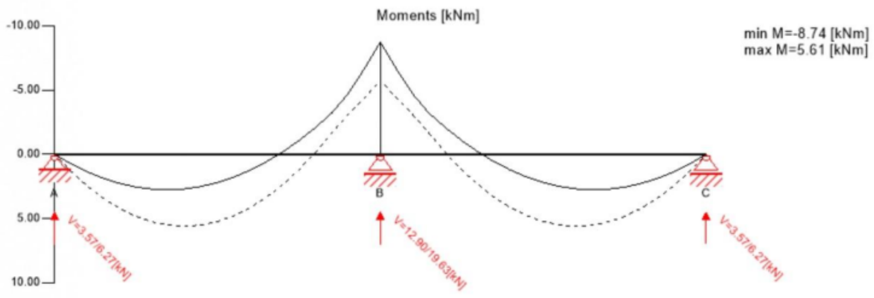
V_d =	25.46	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{h,v}$ =	0.00	-	
$\tau_{v,d}$ =	0.22	N/mm²	<	$f_{v,d}$ =	2.56	N/mm²	✓
Utilization ratio							9%

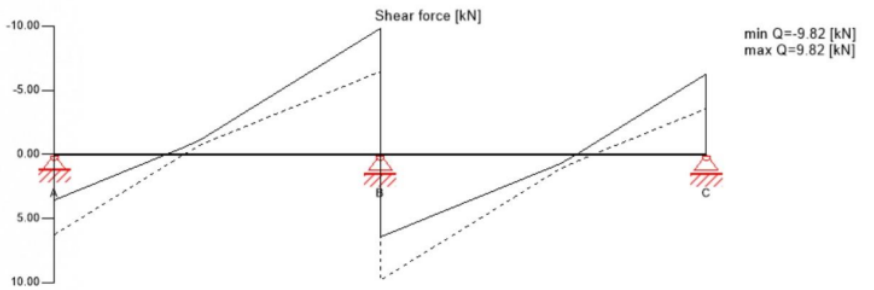
Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Rolling shear analysis

V_d =	-25.46	kN		$f_{r,k}$ =	1.25	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
$\tau_{r,d}$ =	0.20	N/mm²	<	$f_{r,d}$ =	0.80	N/mm²	✓
Utilization ratio							25%

Ultimate limit state (ULS) fire design - results





ULS Fire Flexural design

Field	Dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	k_{fi}	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]		
1	4.5	24.00	1.00	1.00	1.10	1.15	30.36	-8.74	-5.28	17%	LCO12
2	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-8.74	-5.28	17%	LCO12

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

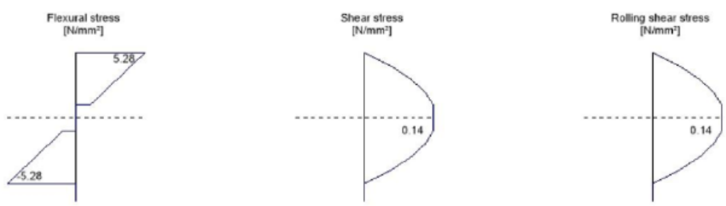
ULS Fire Shear analysis

Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	k_{fi}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	4.5	4.00	1.00	1.00	1.15	4.60	-9.82	0.14	3%	LCO12
2	0.0	4.00	1.00	1.00	1.15	4.60	9.82	0.14	3%	LCO12

ULS Fire Rolling shear

Field	Dist.	$f_{r,k}$	γ_m	k_{mod}	k_{fi}	$f_{r,d}$	V_d	$\tau_{r,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	4.5	1.25	1.00	1.00	1.15	1.44	-9.82	0.14	10%	LCO12
2	0.0	1.25	1.00	1.00	1.15	1.44	9.82	0.14	10%	LCO12

Stress diagram



Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Flexural stress analysis Fire

$M_{y,d}$ =	-8.74	kNm		$f_{m,k}$ =	24.00	N/mm²	
$M_{z,d}$ =	0.00	kNm		$f_{m,k,z}$ =	24.00	N/mm²	
$N_{t,d}$ =	0.00	kN		γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{sys,y}$ =	1.10	-	
				$k_{h,m,y}$ =	1.00	-	
				$k_{h,m,z}$ =	1.00	-	
				k_l =	1.00	-	
				k_{fi} =	1.15	-	
$\sigma_{t,d}$ =	0.00	N/mm²		$f_{t,0,d}$ =	16.10	N/mm²	
$\sigma_{m,y,d}$ =	-5.28	N/mm²		$f_{m,y,d}$ =	30.36	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							17%

Shear stress analysis Fire

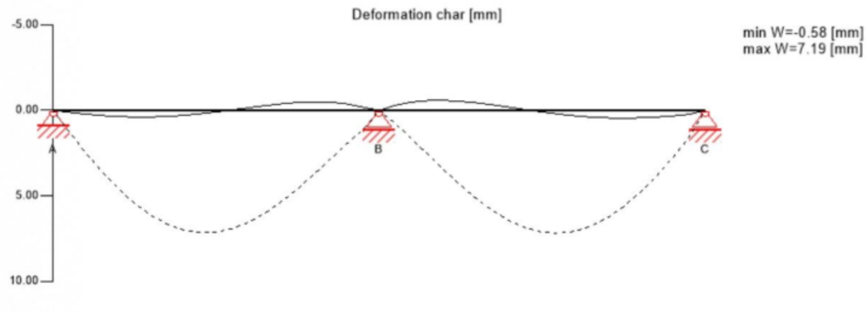
V_d =	-9.82	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{h,v}$ =	0.00	-	
				k_{fi} =	1.15	-	
$\tau_{v,d}$ =	0.14	N/mm²	<	$f_{v,d}$ =	4.60	N/mm²	✓
Utilization ratio							3%

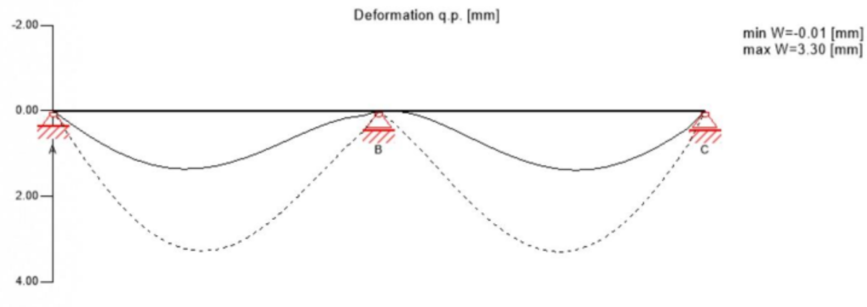
Rolling shear analysis Fire

V_d =	-9.82	kN		$f_{r,k}$ =	1.25	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				k_{fi} =	1.15	-	
$\tau_{r,d}$ =	0.14	N/mm²	<	$f_{r,d}$ =	1.44	N/mm²	✓
Utilization ratio							10%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Service limit state design (SLS) - design results





w_{inst} = w[char]

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	15.0	7.2	48%
2	0.8	L/300	15.0	7.2	48%

w_{fin} = w[char] + w[q.p.]*kdef

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/250	18.0	9.8	54%
2	0.8	L/250	18.0	9.8	55%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

$w_{net,fin}$ = w[q.p.] + w[q.p.]*kdef

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	15.0	5.9	39%
2	0.8	L/300	15.0	5.9	40%

Vibration analysis

General

Total mass	10.55	[t]
Tributary width	2.4	[m]
Stiffness Longitudinal direction	3648.0	[kNm²]
Stiffness Cross direction	448.0	[kNm²]
Modal damping	1.0	[%]
α	0.0	[-]
Man weight	700.0	[N]
Modal mass	2550.8	[kg]

Analysis

Criterion	Calc.	Class I	Class II	Class I	Class II	Cl. I	Cl. II
Frequency criterion min	9.678 [Hz]	4.5 [Hz]	4.5 [Hz]	46 %	46 %	✓	✓
Frequency criterion	9.678 [Hz]	8.0 [Hz]	6.0 [Hz]	83 %	62 %		
Acceleration criterion	0.114 [m/s²]	0.05 [m/s²]	0.1 [m/s²]	229 %	114 %		
Stiffness criterion	0.215 [mm]	0.25 [mm]	0.5 [mm]	86 %	43 %	✓	✓

Support reaction

Load case category	k_{mod}	A_V	B_V	C_V
			[kN]	
self-weight structure	0.6	1.36	4.47	1.36
		1.36	4.47	1.36
dead load	0.6	2.56	8.39	2.56
		2.56	8.39	2.56
live load cat. A: domestic, residential areas	0.8	7.91	22.37	7.91
		-1.09	0.00	-1.09
snow load altitude < 1.000 m a.s.l.	0.9	1.70	5.59	1.70
		0.00	0.00	0.00
wind load	0.9	0.34	1.12	0.34
		0.00	0.00	0.00

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Reference documents for this analysis	
English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
ETA-14/0349	European Technical Assessment ETA-14/0349
Expertise Rolling shear - no edge gluing, H.J. Blass	Expertise on Rolling shear for CLT
EN 1995-1-2	EN 1995-1-2 - Eurocode 5 — Design of timber structures — Part 1-2: General — Structural fire design
Technical expertise 122/2011/02: analysis of load bearing capacity and separation performance of CLT elements	Verification of the load bearing capacity and the insulation criterion of CLT structures with Stora Enso CLT
Technical expertise 2434/2012 - BB: failure time tf of gypsum fire boards (GKF) according to ON B 3410	Expertise on failure time tf of gypsum wall fire boards according to ON B3410 and gypsum wall boards type DF according to EN 520
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
Fire safety in timber buildings - technical guildeline for Europe	Fire safety in timber buildings - technical guideline for Europe; publishes by SP Technical Research Institute of Sweden
National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12	ÖNORM EN 1995-1-2 - National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12
Expertise Rolling shear, H.J. Blass	Expertise on rolling shear strength and rolling shear modulus of CLT panels
ÖNORM EN 1995-1-1_NA, chapter 7.3	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings; chapter 7.3

Disclaimer

2.5.2 Međukatna konstrukcija

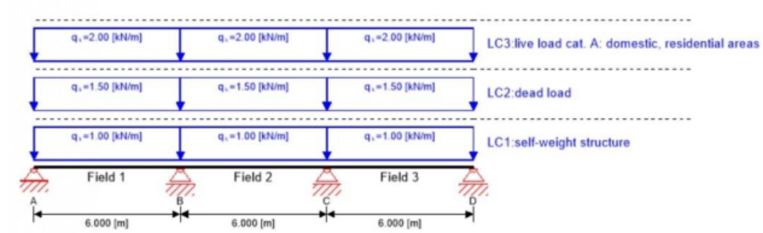
2.5.2.1 Kontinuirano oslonjena ploča

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

1/12

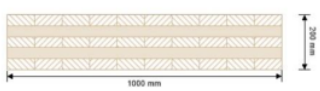
System



Global utilization ratio									73%
ULS	27%	ULS Fire	16%	SLS	58%	Vibration	73%	Support	-1%

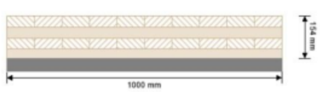
Product data

Section: CLT 200 L5s



Layer	Thickness	Orientation	Material
1	40.0 mm	0°	C24 spruce ETA (2022)
2	40.0 mm	90°	C24 spruce ETA (2022)
3	40.0 mm	0°	C24 spruce ETA (2022)
4	40.0 mm	90°	C24 spruce ETA (2022)
5	40.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**200.0 mm**		

Section Fire: CLT 200 L5s



Layer	Thickness	Orientation	Material
1	40.0 mm	0°	C24 spruce ETA (2022)
2	40.0 mm	90°	C24 spruce ETA (2022)
3	40.0 mm	0°	C24 spruce ETA (2022)
4	34.0 mm	90°	C24 spruce ETA (2022)
t_{CLT}	**154.0 mm**		
Time	**60 min**		

Fire resistance class: R 60

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Section Fire: CLT 200 L5s

Fire protection layering:
no additional fire protection

k_0	d_0	$d_{char,0,h}$	$d_{ef,h}$	$d_{char,0,v}$	$d_{ef,v}$
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
1	7	39.0	46.0	0.0	0.0

Material values

Material	$f_{m,k}$	$f_{t,0,k}$	$f_{t,90,k}$	$f_{c,0,k}$	$f_{c,90,k}$	$f_{v,k}$	$f_{r,k\,min}$	$E_{0,mean}$	G_{mean}	$G_{r,mean}$
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
C24 spruce ETA (2022)	24.00	14.00	0.12	21.00	2.50	4.00	1.25	12,000.00	690.00	50.00

Load

Load case groups

	Load case category	Type	Duration	Kmod	γ_{inf}	γ_{sup}	Ψ_0	Ψ_1	Ψ_2
LC1	self-weight structure	G	permanent	0.6	1	1.35	1	1	1
LC2	dead load	G	permanent	0.6	1	1.35	1	1	1
LC3	live load cat. A: domestic, residential areas	Q	medium term	0.8	0	1.5	0.7	0.5	0.3

LC1:self-weight structure

continuous load

Field	Load at start
	[kN/m]
1	1.00
2	1.00
3	1.00

LC2:dead load

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

continuous load	
Field	Load at start [kN/m]
1	1.50
2	1.50
3	1.50

LC3:live load cat. A: domestic, residential areas

continuous load	
Field	Load at start [kN/m]
1	2.00
2	2.00
3	2.00

ULS Combinations	
	Combination rule
LCO1	1.35/1.00 * LC1 + 1.35/1.00 * LC2
LCO2	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3

ULS Combinations Fire	
	Combination rule
LCO3	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO4	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3

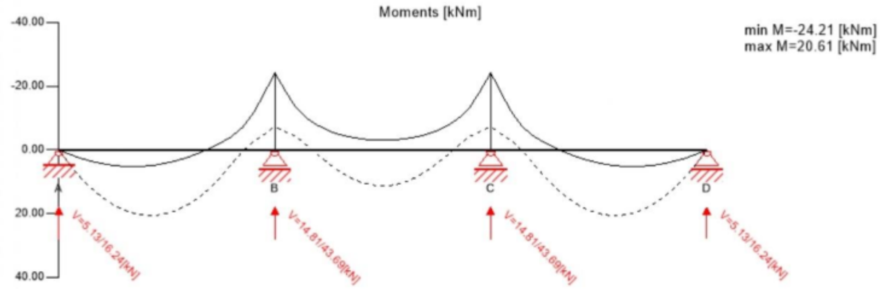
SLS Characteristic Combination	
	Combination rule
LCO5	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO6	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC3

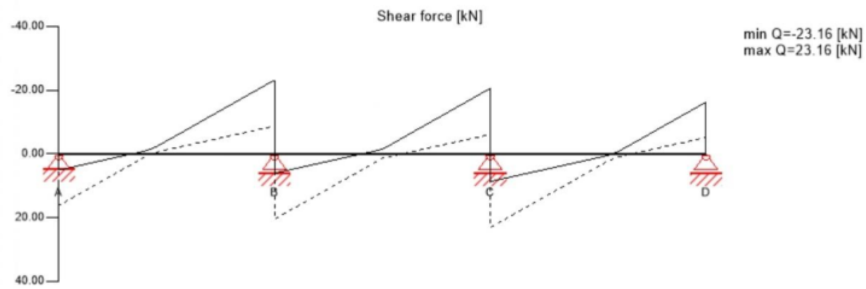
Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

SLS Quasi-permanent Combination

	Combination rule
LCO7	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO8	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3

Ultimate limit state (ULS) - design results





ULS Flexural design

Field	Dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]		
1	6.0	24.00	1.25	0.80	1.10	16.90	-24.21	4.58	27%	LCO2
2	0.0	24.00	1.25	0.80	1.10	16.90	-24.21	4.58	27%	LCO2
3	0.0	24.00	1.25	0.80	1.10	16.90	-24.21	4.58	27%	LCO2

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

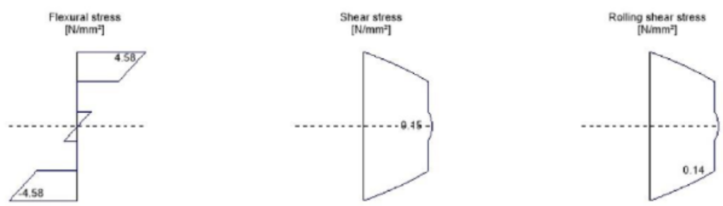
ULS Shear analysis

Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	6.0	4.00	1.25	0.80	2.56	-23.16	0.15	6%	LCO2
2	6.0	4.00	1.25	0.80	2.56	-20.53	0.13	5%	LCO2
3	0.0	4.00	1.25	0.80	2.56	23.16	0.15	6%	LCO2

ULS Rolling shear

Field	Dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	6.0	1.05	1.25	0.80	0.67	-23.16	0.14	21%	LCO2
2	6.0	1.05	1.25	0.80	0.67	-20.53	0.12	19%	LCO2
3	0.0	1.05	1.25	0.80	0.67	23.16	0.14	21%	LCO2

Stress diagram



Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

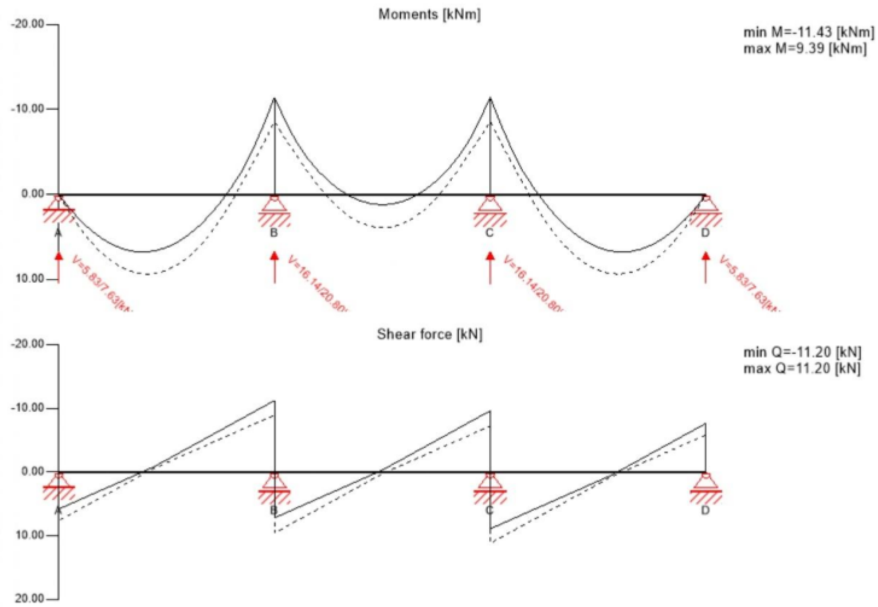
Flexural stress analysis							
$M_{y,d}$ =	-24.21	kNm		$f_{m,k}$ =	24.00	N/mm²	
$M_{z,d}$ =	0.00	kNm		$f_{m,k,z}$ =	24.00	N/mm²	
$N_{t,d}$ =	0.00	kN		γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{sys,y}$ =	1.10	-	
				$k_{h,m,y}$ =	1.00	-	
				$k_{h,m,z}$ =	1.00	-	
				k_l =	1.00	-	
$\sigma_{t,d}$ =	0.00	N/mm²		$f_{t,0,d}$ =	8.96	N/mm²	
$\sigma_{m,y,d}$ =	4.58	N/mm²		$f_{m,y,d}$ =	16.90	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							27%

Shear stress analysis							
V_d =	-23.16	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{h,v}$ =	0.00	-	
$\tau_{v,d}$ =	0.15	N/mm²	<	$f_{v,d}$ =	2.56	N/mm²	✓
Utilization ratio							6%

Rolling shear analysis							
V_d =	-23.16	kN		$f_{r,k}$ =	1.05	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
$\tau_{r,d}$ =	0.14	N/mm²	<	$f_{r,d}$ =	0.67	N/mm²	✓
Utilization ratio							21%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Ultimate limit state (ULS) fire design - results



ULS Fire Flexural design

Field	Dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	k_{fi}	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]		
1	6.0	24.00	1.00	1.00	1.10	1.15	30.36	-11.43	4.94	16%	LCO4
2	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-11.43	4.94	16%	LCO4
3	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-11.43	4.94	16%	LCO4

ULS Fire Shear analysis

Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	k_{fi}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	6.0	4.00	1.00	1.00	1.15	4.60	-11.20	0.13	3%	LCO4
2	6.0	4.00	1.00	1.00	1.15	4.60	-9.59	0.11	2%	LCO4

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

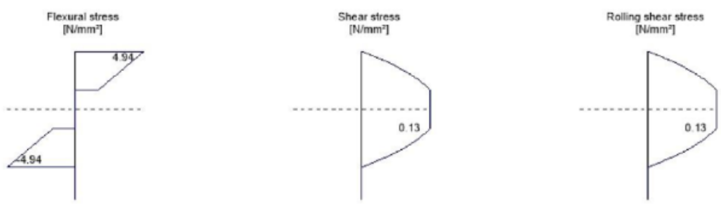
ULS Fire Shear analysis

Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	k_{fi}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
3	0.0	4.00	1.00	1.00	1.15	4.60	11.20	0.13	3%	LCO4

ULS Fire Rolling shear

Field	Dist.	$f_{r,k}$	γ_m	k_{mod}	k_{fi}	$f_{r,d}$	V_d	$\tau_{r,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	6.0	1.05	1.00	1.00	1.15	1.21	-11.20	0.13	11%	LCO4
2	6.0	1.05	1.00	1.00	1.15	1.21	-9.59	0.11	9%	LCO4
3	0.0	1.05	1.00	1.00	1.15	1.21	11.20	0.13	11%	LCO4

Stress diagram



storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

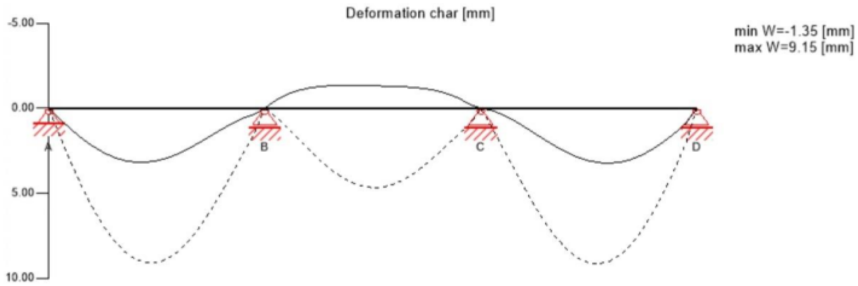
Flexural stress analysis Fire							
$M_{y,d}$ =	-11.43	kNm		$f_{m,k}$ =	24.00	N/mm²	
$M_{z,d}$ =	0.00	kNm		$f_{m,k,z}$ =	24.00	N/mm²	
$N_{t,d}$ =	0.00	kN		γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{sys,y}$ =	1.10	-	
				$k_{h,m,y}$ =	1.00	-	
				$k_{h,m,z}$ =	1.00	-	
				k_l =	1.00	-	
				k_{fi} =	1.15	-	
$\sigma_{t,d}$ =	0.00	N/mm²		$f_{t,0,d}$ =	16.10	N/mm²	
$\sigma_{m,y,d}$ =	4.94	N/mm²		$f_{m,y,d}$ =	30.36	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							16%

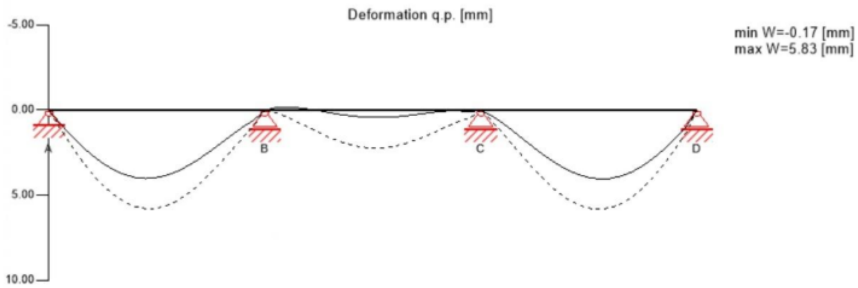
Shear stress analysis Fire							
V_d =	-11.20	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{h,v}$ =	0.00	-	
				k_{fi} =	1.15	-	
$\tau_{v,d}$ =	0.13	N/mm²	<	$f_{v,d}$ =	4.60	N/mm²	✓
Utilization ratio							3%

Rolling shear analysis Fire							
V_d =	-11.20	kN		$f_{r,k}$ =	1.05	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				k_{fi} =	1.15	-	
$\tau_{r,d}$ =	0.13	N/mm²	<	$f_{r,d}$ =	1.21	N/mm²	✓
Utilization ratio							11%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Service limit state design (SLS) - design results





w_{inst} = w[char]

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	20.0	9.1	45%
2	0.8	L/300	20.0	4.7	23%
3	0.8	L/300	20.0	9.1	46%

w_{fin} = w[char] + w[q.p.]*kdef

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/250	24.0	13.7	57%
2	0.8	L/250	24.0	6.5	27%

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

w_{fin} = w[char] + w[q.p.]*kdef					
Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
3	0.8	L/250	24.0	13.8	58%

$w_{net,fin}$ = w[q.p.] + w[q.p.]*kdef					
Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	20.0	10.4	52%
2	0.8	L/300	20.0	4.0	20%
3	0.8	L/300	20.0	10.5	52%

Vibration analysis

General		
Total mass	45.87	[t]
Tributary width	3.9	[m]
Stiffness Longitudinal direction	6336.0	[kNm²]
Stiffness Cross direction	1664.0	[kNm²]
Modal damping	4.0	[%]
α	0.1	[-]
Man weight	700.0	[N]
Modal mass	8935.2	[kg]

Analysis

Criterion	Calc.	Class I	Class II	Class I	Class II	Cl. I	Cl. II
Frequency criterion min	6.882 [Hz]	4.5 [Hz]	4.5 [Hz]	65 %	65 %	✓	✓
Frequency criterion	6.882 [Hz]	8.0 [Hz]	6.0 [Hz]	116 %	87 %		
Acceleration criterion	0.025 [m/s²]	0.05 [m/s²]	0.1 [m/s²]	50 %	25 %	✓	
Stiffness criterion	0.182 [mm]	0.25 [mm]	0.5 [mm]	73 %	36 %	✓	✓

Support reaction					
Load case category	k_{mod}	A_V	B_V	C_V	D_V
			[kN]		
self-weight structure	0.6	2.41	6.59	6.59	2.41
		2.41	6.59	6.59	2.41
dead load	0.6	3.61	9.89	9.89	3.61
		3.61	9.89	9.89	3.61
live load cat. A: domestic, residential areas	0.8	5.41	14.30	14.30	5.41
		-0.59	-1.11	-1.11	-0.59

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Reference documents for this analysis	
English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
ETA-14/0349	European Technical Assessment ETA-14/0349
Expertise Rolling shear - no edge gluing, H.J. Blass	Expertise on Rolling shear for CLT
EN 1995-1-2	EN 1995-1-2 - Eurocode 5 — Design of timber structures — Part 1-2: General — Structural fire design
Technical expertise 122/2011/02: analysis of load bearing capacity and separation performance of CLT elements	Verification of the load bearing capacity and the insulation criterion of CLT structures with Stora Enso CLT
Technical expertise 2434/2012 - BB: failure time tf of gypsum fire boards (GKF) according to ON B 3410	Expertise on failure time tf of gypsum wall fire boards according to ON B3410 and gypsum wall boards type DF according to EN 520
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
Fire safety in timber buildings - technical guildeline for Europe	Fire safety in timber buildings - technical guideline for Europe; publishes by SP Technical Research Institute of Sweden
National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12	ÖNORM EN 1995-1-2 - National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12
Expertise Rolling shear, H.J. Blass	Expertise on rolling shear strength and rolling shear modulus of CLT panels
ÖNORM EN 1995-1-1_NA, chapter 7.3	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings; chapter 7.3

Disclaimer

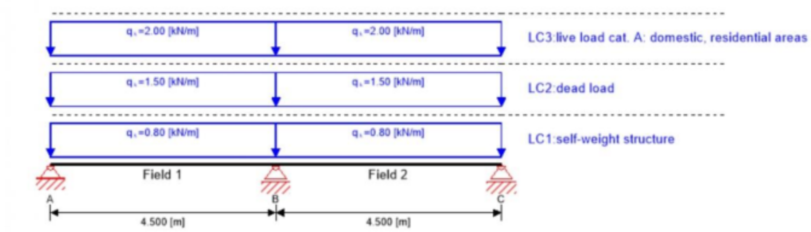
2.5.2.2 Ploča velikog raspona

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

1/12

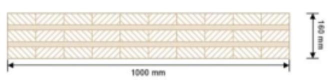
System



Global utilization ratio									86%
ULS	23%	ULS Fire	14%	SLS	35%	Vibration	86%	Support	-1%

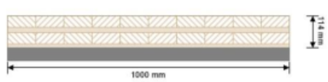
Product data

Section: CLT 160 L5s



Layer	Thickness	Orientation	Material
1	40.0 mm	0°	C24 spruce ETA (2022)
2	20.0 mm	90°	C24 spruce ETA (2022)
3	40.0 mm	0°	C24 spruce ETA (2022)
4	20.0 mm	90°	C24 spruce ETA (2022)
5	40.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**160.0 mm**		

Section Fire: CLT 160 L5s



Layer	Thickness	Orientation	Material
1	40.0 mm	0°	C24 spruce ETA (2022)
2	20.0 mm	90°	C24 spruce ETA (2022)
3	40.0 mm	0°	C24 spruce ETA (2022)
4	14.0 mm	90°	C24 spruce ETA (2022)
t_{CLT}	**114.0 mm**		
Time	**60 min**		

Fire resistance class: R 60

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Section Fire: CLT 160 L5s

Fire protection layering:
no additional fire protection

k_0	d_0	$d_{char,0,h}$	$d_{ef,h}$	$d_{char,0,v}$	$d_{ef,v}$
[-]	[mm]	[mm]	[mm]	[mm]	[mm]
1	7	39.0	46.0	0.0	0.0

Material values

Material	$f_{m,k}$	$f_{t,0,k}$	$f_{t,90,k}$	$f_{c,0,k}$	$f_{c,90,k}$	$f_{v,k}$	$f_{r,k\ min}$	$E_{0,mean}$	G_{mean}	$G_{r,mean}$
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
C24 spruce ETA (2022)	24.00	14.00	0.12	21.00	2.50	4.00	1.25	12,000.00	690.00	50.00

Load

Load case groups

	Load case category	Type	Duration	Kmod	γ_{inf}	γ_{sup}	Ψ_0	Ψ_1	Ψ_2
LC1	self-weight structure	G	permanent	0.6	1	1.35	1	1	1
LC2	dead load	G	permanent	0.6	1	1.35	1	1	1
LC3	live load cat. A: domestic, residential areas	Q	medium term	0.8	0	1.5	0.7	0.5	0.3

LC1:self-weight structure

continuous load

Field	Load at start
	[kN/m]
1	0.80
2	0.80

LC2:dead load

continuous load

Field	Load at start
	[kN/m]
1	1.50

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

continuous load	
Field	Load at start [kN/m]
2	1.50

LC3:live load cat. A: domestic, residential areas

continuous load	
Field	Load at start [kN/m]
1	2.00
2	2.00

ULS Combinations

	Combination rule
LCO1	1.35/1.00 * LC1 + 1.35/1.00 * LC2
LCO2	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3

ULS Combinations Fire

	Combination rule
LCO3	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO4	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3

SLS Characteristic Combination

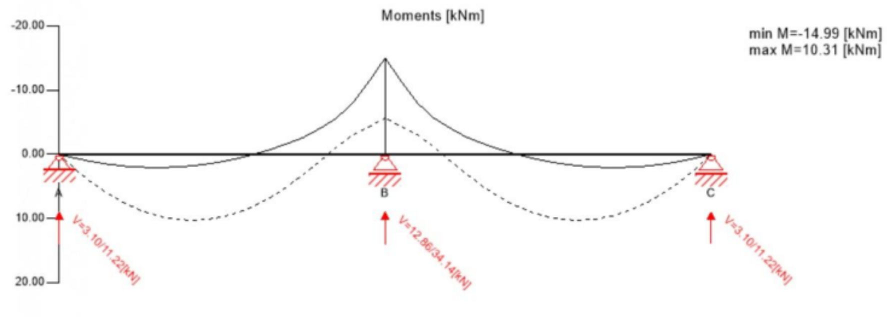
	Combination rule
LCO5	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO6	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC3

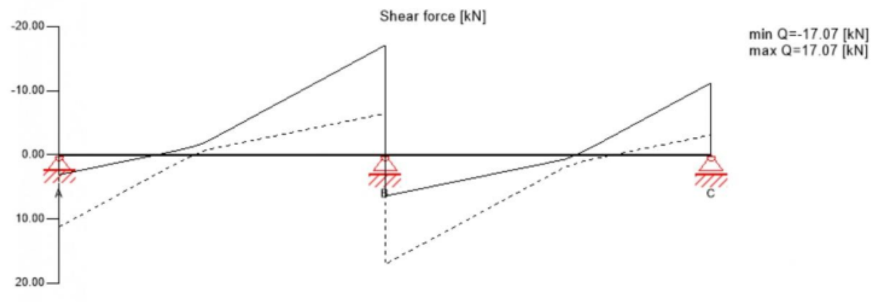
SLS Quasi-permanent Combination

	Combination rule
LCO7	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO8	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Ultimate limit state (ULS) - design results





ULS Flexural design

Field	Dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]		
1	4.5	24.00	1.25	0.80	1.10	16.90	-14.99	-3.95	23%	LCO2
2	0.0	24.00	1.25	0.80	1.10	16.90	-14.99	-3.95	23%	LCO2

ULS Shear analysis

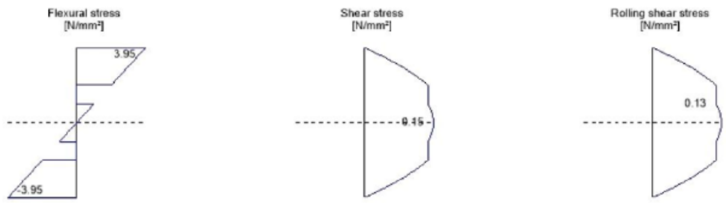
Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	4.5	4.00	1.25	0.80	2.56	-17.07	0.15	6%	LCO2
2	0.0	4.00	1.25	0.80	2.56	17.07	0.15	6%	LCO2

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

ULS Rolling shear

Field	Dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	4.5	1.25	1.25	0.80	0.80	-17.07	0.13	17%	LCO2
2	0.0	1.25	1.25	0.80	0.80	17.07	0.13	17%	LCO2

Stress diagram



Flexural stress analysis

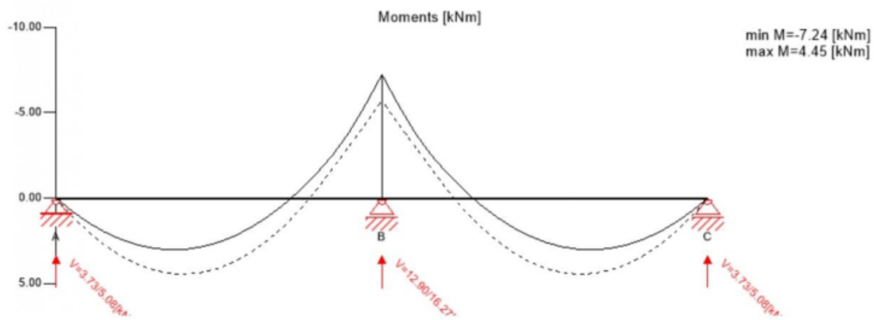
$M_{y,d}$ =	-14.99	kNm		$f_{m,k}$ =	24.00	N/mm²	
$M_{z,d}$ =	0.00	kNm		$f_{m,k,z}$ =	24.00	N/mm²	
$N_{t,d}$ =	0.00	kN		γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{sys,y}$ =	1.10	-	
				$k_{h,m,y}$ =	1.00	-	
				$k_{h,m,z}$ =	1.00	-	
				k_l =	1.00	-	
$\sigma_{t,d}$ =	0.00	N/mm²		$f_{t,0,d}$ =	8.96	N/mm²	
$\sigma_{m,y,d}$ =	-3.95	N/mm²		$f_{m,y,d}$ =	16.90	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							23%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Shear stress analysis							
V_d =	17.07	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{h,v}$ =	0.00	-	
$\tau_{v,d}$ =	0.15	N/mm²	<	$f_{v,d}$ =	2.56	N/mm²	✓
Utilization ratio							6%

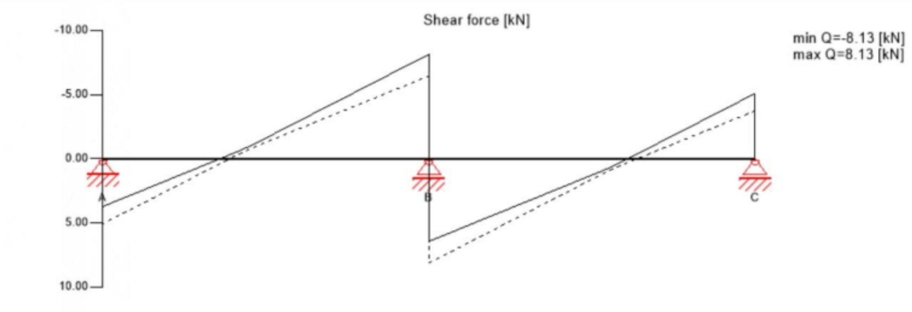
Rolling shear analysis							
V_d =	17.07	kN		$f_{r,k}$ =	1.25	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
$\tau_{r,d}$ =	0.13	N/mm²	<	$f_{r,d}$ =	0.80	N/mm²	✓
Utilization ratio							17%

Ultimate limit state (ULS) fire design - results



Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Ultimate limit state (ULS) fire design - results



ULS Fire Flexural design

Field	Dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	k_{fi}	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[-]	[N/mm²]	[kNm]	[N/mm²]		
1	4.5	24.00	1.00	1.00	1.10	1.15	30.36	-7.24	-4.38	14%	LCO4
2	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-7.24	-4.38	14%	LCO4

ULS Fire Shear analysis

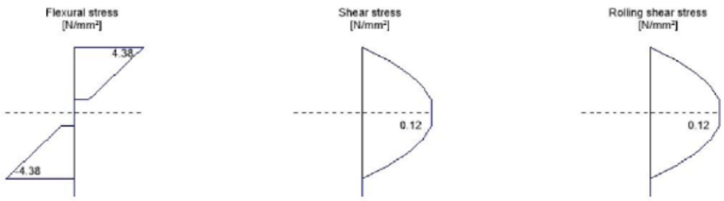
Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	k_{fi}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	4.5	4.00	1.00	1.00	1.15	4.60	-8.13	0.12	3%	LCO4
2	0.0	4.00	1.00	1.00	1.15	4.60	8.13	0.12	3%	LCO4

ULS Fire Rolling shear

Field	Dist.	$f_{r,k}$	γ_m	k_{mod}	k_{fi}	$f_{r,d}$	V_d	$\tau_{r,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	4.5	1.25	1.00	1.00	1.15	1.44	-8.13	0.12	8%	LCO4
2	0.0	1.25	1.00	1.00	1.15	1.44	8.13	0.12	8%	LCO4

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Stress diagram



Flexural stress analysis Fire

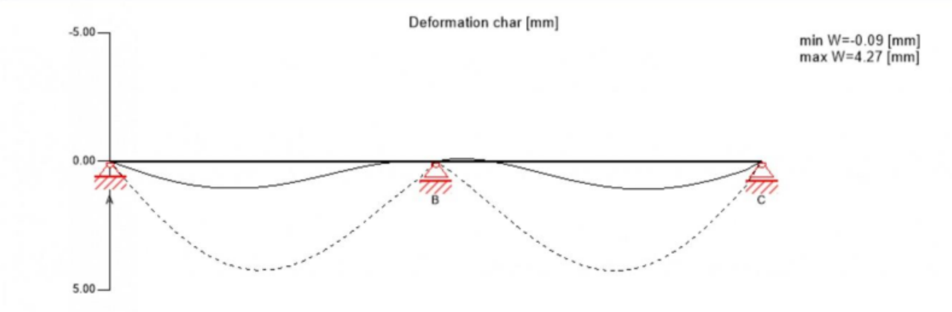
$M_{y,d}$ =	-7.24	kNm		$f_{m,k}$ =	24.00	N/mm²	
$M_{z,d}$ =	0.00	kNm		$f_{m,k,z}$ =	24.00	N/mm²	
$N_{t,d}$ =	0.00	kN		γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{sys,y}$ =	1.10	-	
				$k_{h,m,y}$ =	1.00	-	
				$k_{h,m,z}$ =	1.00	-	
				k_l =	1.00	-	
				k_{fi} =	1.15	-	
$\sigma_{t,d}$ =	0.00	N/mm²		$f_{t,0,d}$ =	16.10	N/mm²	
$\sigma_{m,y,d}$ =	-4.38	N/mm²		$f_{m,y,d}$ =	30.36	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							14%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Shear stress analysis Fire							
V_d =	-8.13	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{h,v}$ =	0.00	-	
				k_{fi} =	1.15	-	
$\tau_{v,d}$ =	0.12	N/mm²	<	$f_{v,d}$ =	4.60	N/mm²	✓
Utilization ratio							3%

Rolling shear analysis Fire							
V_d =	-8.13	kN		$f_{r,k}$ =	1.25	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				k_{fi} =	1.15	-	
$\tau_{r,d}$ =	0.12	N/mm²	<	$f_{r,d}$ =	1.44	N/mm²	✓
Utilization ratio							8%

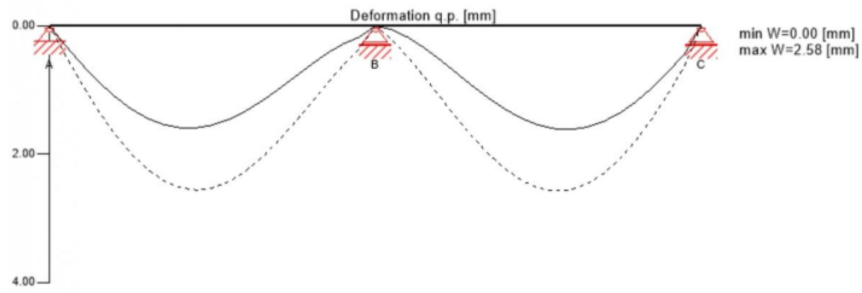
Service limit state design (SLS) - design results



storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Service limit state design (SLS) - design results



w_{inst} = w[char]

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	15.0	4.2	28%
2	0.8	L/300	15.0	4.3	28%

w_{fin} = w[char] + w[q.p.]*kdef

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/250	18.0	6.3	35%
2	0.8	L/250	18.0	6.3	35%

$w_{net,fin}$ = w[q.p.] + w[q.p.]*kdef

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	15.0	4.6	31%
2	0.8	L/300	15.0	4.6	31%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Vibration analysis

General

Total mass	10.55	[t]
Tributary width	2.4	[m]
Stiffness Longitudinal direction	3648.0	[kNm²]
Stiffness Cross direction	448.0	[kNm²]
Modal damping	1.0	[%]
α	0.0	[-]
Man weight	700.0	[N]
Modal mass	2550.8	[kg]

Analysis

Criterion	Calc.	Class I	Class II	Class I	Class II	Cl. I	Cl. II
Frequency criterion min	9.678 [Hz]	4.5 [Hz]	4.5 [Hz]	46 %	46 %	✓	✓
Frequency criterion	9.678 [Hz]	8.0 [Hz]	6.0 [Hz]	83 %	62 %		
Acceleration criterion	0.114 [m/s²]	0.05 [m/s²]	0.1 [m/s²]	229 %	114 %		
Stiffness criterion	0.215 [mm]	0.25 [mm]	0.5 [mm]	86 %	43 %	✓	✓

Support reaction

Load case category	k_{mod}	A_V	B_V	C_V
			[kN]	
self-weight structure	0.6	1.36	4.47	1.36
		1.36	4.47	1.36
dead load	0.6	2.56	8.39	2.56
		2.56	8.39	2.56
live load cat. A: domestic, residential areas	0.8	3.95	11.18	3.95
		-0.55	0.00	-0.55

Reference documents for this analysis

English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
ETA-14/0349	European Technical Assessment ETA-14/0349
Expertise Rolling shear - no edge gluing, H.J. Blass	Expertise on Rolling shear for CLT
EN 1995-1-2	EN 1995-1-2 - Eurocode 5 — Design of timber structures — Part 1-2: General — Structural fire design
Technical expertise 122/2011/02: analysis of load bearing capacity and separation performance of CLT elements	Verification of the load bearing capacity and the insulation criterion of CLT structures with Stora Enso CLT

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Reference documents for this analysis

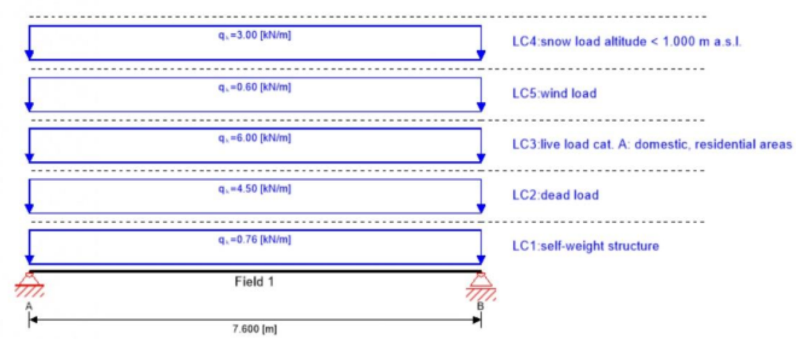
English title	Description
Technical expertise 2434/2012 - BB: failure time tf of gypsum fire boards (GKF) according to ON B 3410	Expertise on failure time tf of gypsum wall fire boards according to ON B3410 and gypsum wall boards type DF according to EN 520
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
Fire safety in timber buildings - technical guildeline for Europe	Fire safety in timber buildings - technical guideline for Europe; publishes by SP Technical Research Institute of Sweden
National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12	ÖNORM EN 1995-1-2 - National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements, chapter 12
Expertise Rolling shear, H.J. Blass	Expertise on rolling shear strength and rolling shear modulus of CLT panels
ÖNORM EN 1995-1-1_NA, chapter 7.3	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings; chapter 7.3

2.5.3 Čelična greda

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

System



Global utilization ratio			78 %
ULS	42 %	SLS	78 %

Section

Name	Height	Width	t_f	t_w	Area	I_y	I_z	W_y	W_z	I_w	I_d	i_y	i_z	$W_{y,pl}$	$W_{z,pl}$
	[mm]	[mm]	[mm]	[mm]	[cm²]	[cm⁴]	[cm⁴]	[cm³]	[cm³]	[cm⁶]	[cm⁴]	[cm]	[cm]	[cm³]	[cm³]
HE-A 280	270	280	13	8	97.26	13670	4763	1013	340.2	785400	62.1	1.186	0.7	1112	518.1

Material values

Material	$f_{m,k}$	$f_{t,0,k}$	$E_{0,mean}$	G_{mean}
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
Steel S355	355.00	510.00	210,000.0	80,700.00

Load

Load case groups

	Load case category	Type	Duration	Kmod	γ_{inf}	γ_{sup}	Ψ_0	Ψ_1	Ψ_2
LC1	self-weight structure	G	permanent	1	1	1.35	1	1	1
LC2	dead load	G	permanent	1	1	1.35	1	1	1

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Load case groups

	Load case category	Type	Duration	Kmod	γ_{inf}	γ_{sup}	Ψ_0	Ψ_1	Ψ_2
LC3	live load cat. A: domestic, residential areas	Q	medium term	1	0	1.5	0.7	0.5	0.3
LC4	snow load altitude < 1.000 m a.s.l.	Q	short term	1	0	1.5	0.5	0.2	0
LC5	wind load	Q	short term	1	0	1.5	0.6	0.2	0

LC1:self-weight structure

continuous load

Field	Load at start [kN/m]
1	0.76

LC2:dead load

continuous load

Field	Load at start [kN/m]
1	4.50

LC3:live load cat. A: domestic, residential areas

continuous load

Field	Load at start [kN/m]
1	6.00

LC4:snow load altitude < 1.000 m a.s.l.

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

continuous load	
Field	Load at start [kN/m]
1	3.00

LC5:wind load

continuous load	
Field	Load at start [kN/m]
1	0.60

ULS Combinations

	Combination rule
LCO1	1.35/1.00 * LC1 + 1.35/1.00 * LC2
LCO2	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3
LCO3	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3 + 1.50/0.00 * 0.50 * LC4
LCO4	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3 + 1.50/0.00 * 0.50 * LC4 + 1.50/0.00 * 0.60 * LC5
LCO5	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC4
LCO6	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC4 + 1.50/0.00 * 0.70 * LC3
LCO7	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC4 + 1.50/0.00 * 0.70 * LC3 + 1.50/0.00 * 0.60 * LC5
LCO8	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC5
LCO9	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC5 + 1.50/0.00 * 0.70 * LC3
LCO10	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC5 + 1.50/0.00 * 0.70 * LC3 + 1.50/0.00 * 0.50 * LC4

ULS Combinations Fire

	Combination rule
LCO11	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO12	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3
LCO13	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4
LCO14	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.00 * LC5

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

ULS Combinations Fire	
	Combination rule
LCO15	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC4
LCO16	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.30 * LC3
LCO17	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC5
LCO18	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC5
LCO19	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC5 + 1.00/0.00 * 0.30 * LC3
LCO20	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC5 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4

SLS Characteristic Combination	
	Combination rule
LCO21	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO22	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC3 + 1.00/0.00 * 0.50 * LC4 + 1.00/0.00 * 0.60 * LC5
LCO23	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC4 + 1.00/0.00 * 0.70 * LC3 + 1.00/0.00 * 0.60 * LC5
LCO24	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC5 + 1.00/0.00 * 0.70 * LC3 + 1.00/0.00 * 0.50 * LC4

SLS Quasi-permanent Combination	
	Combination rule
LCO25	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO26	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.00 * LC5
LCO27	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC4 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC5
LCO28	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * LC5 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 * LC4

Flexural design							
Qkl =	3			Comb.	LCO4		
M_{Ed} =	136.43	kNm		M_{Rd} =	359.62	kNm	
Ratio	38	%	<		100	%	✓
Utilization ratio							38%

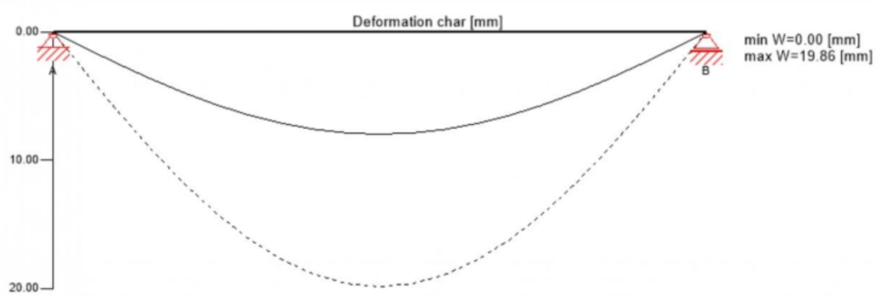
Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Shear analysis							
Qkl =	3			Comb.	LCO4		
V_{Ed} =	71.80	kN		V_{Rd} =	650.54	kN	
Ratio	11	%	<		100	%	✓
Utilization ratio							11%

Flexural design + Shear analysis							
Qkl =	3			Comb.	LCO4		
V_{Ed} =	7.18	kN		V_{Rd} =	650.54	kN	
M_{Ed} =	135.06	kNm		M_{Rd} =	359.62	kNm	
Ratio	38	%	<		100	%	✓
Utilization ratio							38%

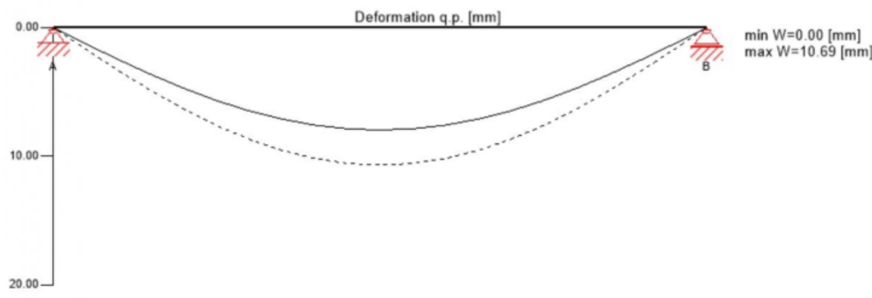
Lateral torsional buckling design							
Qkl =	3			Comb.	LCO4		
N y_{Ed} =	0.00	kN		N y_{Rd} =	0.00	kN	
N z_{Ed} =	0.00	kN		N z_{Rd} =	0.00	kN	
M y_{Ed} =	136.43	kNm		M y_{Rd} =	322.69	kNm	
Ratio	42	%	<		100	%	✓
Utilization ratio							42%

Service limit state design (SLS) - design results



Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Service limit state design (SLS) - design results



w_{inst} = w[char]

Field	Limit	w_{limit}	$w_{calc.}$	Ratio
	[-]	[mm]	[mm]	
1	L/300	25.3	19.9	78%

Support reaction

Load case category	k_{mod}	A_V	B_V
		[kN]	
self-weight structure	1	2.90	2.90
		2.90	2.90
dead load	1	17.10	17.10
		17.10	17.10
live load cat. A: domestic, residential areas	1	22.80	22.80
		0.00	0.00
snow load altitude < 1.000 m a.s.l.	1	11.40	11.40
		0.00	0.00
wind load	1	2.28	2.28
		0.00	0.00

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Reference documents for this analysis	
English title	Description
EN 1993-1-1	EN 1993-1-1 - Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
EN 1990	EN 1990 - Eurocode ? Basis of structural design

Disclaimer

2.5.4 Zid s otvorom

Marija Gulam	Model: diplomski_zgradaA1	Date 20.8.2024 Page 1/9 Sheet 1
		TIMBER

1 Timber Design

1.1 DESIGN SITUATIONS

DS No.	EN 1990 | Base + Timber | CEN | 2010-0 Design Situation Type	To Design	Active	EN 1995 | HRN | 2015-03 Design Situation Type	Combinations to Design for Enumeration Method
1	ULS ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒	☒	ULS ULS (STR/GEO) - Permanent and transient	All
2	S Ch SLS - Characteristic	☒	☒	S Ch SLS - Characteristic	All
3	S Qp SLS - Quasi-permanent	☒	☒	S Qp1 SLS - Quasi-permanent 1	All
4	S Fr SLS - Frequent base	☒	☒	S V SLS - Vibration	All
5	S Qp SLS - Quasi-permanent base	☒	☒	S Qp1 SLS - Quasi-permanent 1	All
6	SE/M Seismic/Mass Combination - psi-E,i	☐	☒	ACC ULS (STR/GEO) - Accidental	
7	SEIS ULS (STR/GEO) - Seismic	☒	☒	ULS ULS (STR/GEO) - Permanent and transient	All

1.2 MATERIALS

Legend
Concrete Settings
Stiffness modification

Material No.	Name	To Design	Material Type	Options	Comment
1	C24 BBS XL	☒	Timber		
2	C24 BBS XL	☒	Timber		
3	GL32h	☒	Timber		
4	C35/45	☒	Concrete		

1.3 THICKNESSES

Thick. No.	Name	Type	Material	To Design	Use Other Thick. d [mm] for Design
1	Layers | d : 220.0 mm | Layers: 7	Layers		☒	--
2	Layers | d : 140.0 mm | Layers: 5	Layers		☒	--
3	Uniform | d : 200.0 mm | 4 - C35/45	Uniform	4	☒	--

1.4 Results

1.4.1 DESIGN RATIOS ON SURFACES BY DESIGN SITUATION

Timber Design

Design Situation	Surface No.	Point No.	Point Coordinates [m] X	Y	Z	Loading No.	Layer No.	Side	Design Check Ratio η [--]	Type	Description
	ULS (STR/GEO) - Permanent and transient - Eq. 6.10										
DS1	103	4869	6.659	21.176	-0.471	CO46	2	Bottom	0.000 ✓	UL0100.00	Ultimate Limit State | Negligible stresses
		4914	6.660	24.176	-2.500	CO2	2	Top	0.061 ✓	UL1100.00	Ultimate Limit State | Tension along grain
		377	6.659	21.176	-3.300	CO3	1	Top	0.247 ✓	UL1300.00	Ultimate Limit State | Compression along grain
			6.659	21.176	-3.300	CO3	2	Top	0.153 ✓	00	
			6.659	21.176	-3.300	CO3	3	Middle	0.063 ✓	UL3020.00	Ultimate Limit State | Shear in xz-plane
		4923	6.659	27.176	-2.829	CO3	5	Bottom	0.121 ✓	UL3110.	Ultimate Limit State | Shear in xy-plane | Failure
		1961	6.660	26.176	-2.500	CO3	2	Bottom	0.009 ✓	UL3400.00	Ultimate Limit State | Shear in xz-plane and xy-plane
		387	6.659	27.176	-3.300	CO2	2	Top	0.128 ✓	UL4100.00	Ultimate Limit State | Bending along grain
		4914	6.660	24.176	-2.500	CO15	2	Top	0.056 ✓	UL5100.00	Ultimate Limit State | Bending and tension along grain
		377	6.659	21.176	-3.300	CO3	1	Top	0.302 ✓	UL6100.00	Ultimate Limit State | Bending and compression along grain
	SLS - Characteristic										
DS2	103	377	6.659	21.176	-3.300	CO48			0.000 ✓	SE0500.00	Serviceability | Negligible deflections
		4914	6.660	24.176	-2.500	CO90			0.026 ✓	SE5000.01	Serviceability | Combination of actions 'Characteristic' | Deflection in z-direction
	SLS - Quasi-permanent										
DS3	103	377	6.659	21.176	-3.300	CO95			0.000 ✓	SE0500.00	Serviceability | Negligible deflections
		4914	6.660	24.176	-2.500	CO137			0.022 ✓	SE5000.02	Serviceability | Combination of actions 'Quasi-permanent 1' | Deflection in z-direction

www.dlubal.com RFEM 6.07.0002 - General 3D structures solved using FEM

Marija Gulam	Model: diplomski_zgradaA1	Date 20.8.2024 · Page 2/9 · Sheet 1
		TIMBER

1.4.1 DESIGN RATIOS ON SURFACES BY DESIGN SITUATION

Timber Design

Design Situation	Surface No.	Point No.	Point Coordinates [m] X	Y	Z	Loading No.	Layer No.	Layer Side	Design Check Ratio η [--]	Design Check Type	Description
	SLS - Frequent base										
DS4	103	377	6.659	21.176	-3.300	CO142			0.000 ✓	SE0500.00	Serviceability | Negligible deflections
		4914	6.660	24.176	-2.500	CO155			0.023 ✓	SE6000.00	Serviceability | Vibration in z-direction
	SLS - Quasi-permanent base										
DS5	103	377	6.659	21.176	-3.300	CO158			0.000 ✓	SE0500.00	Serviceability | Negligible deflections
	ULS (STR/GEO) - Seismic										
DS7	103	4914	6.660	24.176	-2.500	RC1	1	Top	0.000 ✓	UL0100.00	Ultimate Limit State | Negligible stresses
		1963	6.659	26.176	0.000	RC1	1	Top	0.200 ✓	UL1100.00	Ultimate Limit State | Tension along grain
			6.659	26.176	0.000	RC3	1	Top	0.257 ✓	UL1300.00	Ultimate Limit State | Compression along grain
		387	6.659	27.176	-3.300	RC2	2	Top	0.073 ✓	UL3010.00	Ultimate Limit State | Shear in yz-plane
			6.659	27.176	-3.300	RC2	3	Middle	0.030 ✓	UL3020.00	Ultimate Limit State | Shear in xz-plane
		4891	6.659	27.176	-1.414	RC3	1	Top	0.138 ✓	UL3110.00	Ultimate Limit State | Shear in xy-plane | Failure mechanism 1
			6.659	27.176	-1.414	RC3	1	Middle	0.019 ✓	UL3400.00	Ultimate Limit State | Shear in xz-plane and xy-plane
		388	6.659	27.176	0.000	RC3	1	Top	0.040 ✓	UL4100.00	Ultimate Limit State | Bending along grain
		1963	6.659	26.176	0.000	RC1	1	Top	0.225 ✓	UL5100.00	Ultimate Limit State | Bending and tension along grain
			6.659	26.176	0.000	RC3	5	Bottom	0.282 ✓	UL6100.00	Ultimate Limit State | Bending and compression along grain

1.4.2 DESIGN RATIOS ON SURFACES BY THICKNESS

Timber Design

Thick. No.	Surface No.	Point No.	Point Coordinates [m] X	Y	Z	Design Situation	Loading No.	Layer No.	Layer Side	Design Check Ratio η [--]	Design Check Type	Description
	Layers | d : 140.0 mm | Layers: 5											
2	103	4869	6.659	21.176	-0.471	DS1	CO46	2		0.000 ✓	UL0100.00	Ultimate Limit State | Negligible stresses
		1963	6.659	26.176	0.000	DS7	RC1	1	Top	0.200 ✓	UL1100.00	Ultimate Limit State | Tension along grain
			6.659	26.176	0.000	DS7	RC3	1	Top	0.257 ✓	UL1300.00	Ultimate Limit State | Compression along grain
		377	6.659	21.176	-3.300	DS1	CO3	2	Top	0.153 ✓	UL3010.00	Ultimate Limit State | Shear in yz-plane
			6.659	21.176	-3.300	DS1	CO3	3	Middle	0.063 ✓	UL3020.00	Ultimate Limit State | Shear in xz-plane
		4891	6.659	27.176	-1.414	DS7	RC3	1	Top	0.138 ✓	UL3110.00	Ultimate Limit State | Shear in xy-plane | Failure mechanism 1
			6.659	27.176	-1.414	DS7	RC3	1	Middle	0.019 ✓	UL3400.00	Ultimate Limit State | Shear in xz-plane and xy-plane
		387	6.659	27.176	-3.300	DS1	CO2	2	Top	0.128 ✓	UL4100.00	Ultimate Limit State | Bending along grain
		1963	6.659	26.176	0.000	DS7	RC1	1	Top	0.225 ✓	UL5100.	Ultimate Limit State | Bending and tension
		377	6.659	21.176	-3.300	DS1	CO3	1	Top	0.302 ✓	UL6100.00	Ultimate Limit State | Bending and compression along grain
			6.659	21.176	-3.300	DS2	CO48			0.000 ✓	SE0500.00	Serviceability | Negligible deflections
		4914	6.660	24.176	-2.500	DS2	CO90			0.026 ✓	SE5000.	Serviceability | Combination of actions
			6.660	24.176	-2.500	DS3	CO137			0.022 ✓	SE5000.02	Serviceability | Combination of actions 'Quasi-permanent 1' | Deflection in z-direction
			6.660	24.176	-2.500	DS4	CO155			0.023 ✓	SE6000.00	Serviceability | Vibration in z-direction

1.4.3 DESIGN RATIOS ON SURFACES BY SURFACE

Timber Design

Surface No.	Point No.	Point Coordinates [m] X	Y	Z	Design Situation	Loading No.	Layer No.	Layer Side	Design Check Ratio η [--]	Design Check Type	Description
	520,527,2933,2931,2932,2940,534,2604 | Standard | Plane | 2 - Layers | d : 140.0 mm | Layers: 5										
103	4869	6.659	21.176	-0.471	DS1	CO46	2	Bottom	0.000 ✓	UL0100.00	Ultimate Limit State | Negligible stresses
	1963	6.659	26.176	0.000	DS7	RC1	1	Top	0.200 ✓	UL1100.	Ultimate Limit State | Tension along grain

Marija Gulam

Dlubal

Model:
diplomski_zgradaA1

Date 20.8.2024 Page 3/9
Sheet 1

TIMBER

1.4.3 DESIGN RATIOS ON SURFACES BY SURFACE

Timber Design

Surface No.	Point No.	Point Coordinates [m] X	Y	Z	Design Situation	Loading No.	Layer No.	Side	Design Check Ratio η [--]	Type	Description
103										00	
		6.659	26.176	0.000	DS7	RC3	1	Top	0.257 ✓	UL1300.00	Ultimate Limit State | Compression along grain
	377	6.659	21.176	-3.300	DS1	CO3	2	Top	0.153 ✓	UL3010.00	Ultimate Limit State | Shear in yz-plane
		6.659	21.176	-3.300	DS1	CO3	3	Middle	0.063 ✓	UL3020.00	Ultimate Limit State | Shear in xz-plane
	4891	6.659	27.176	-1.414	DS7	RC3	1	Top	0.138 ✓	UL3110.00	Ultimate Limit State | Shear in xy-plane | Failure mechanism 1
		6.659	27.176	-1.414	DS7	RC3	1	Middle	0.019 ✓	UL3400.00	Ultimate Limit State | Shear in xz-plane and xy-plane
	387	6.659	27.176	-3.300	DS1	CO2	2	Top	0.128 ✓	UL4100.00	Ultimate Limit State | Bending along grain
	1963	6.659	26.176	0.000	DS7	RC1	1	Top	0.225 ✓	UL5100.00	Ultimate Limit State | Bending and tension along grain
	377	6.659	21.176	-3.300	DS1	CO3	1	Top	0.302 ✓	UL6100.00	Ultimate Limit State | Bending and compression along grain
		6.659	21.176	-3.300	DS2	CO48			0.000 ✓	SE0500.00	Serviceability | Negligible deflections
	4914	6.660	24.176	-2.500	DS2	CO90			0.026 ✓	SE5000.01	Serviceability | Combination of actions 'Characteristic' | Deflection in z-direction
		6.660	24.176	-2.500	DS3	CO137			0.022 ✓	SE5000.02	Serviceability | Combination of actions 'Quasi-permanent 1' | Deflection in z-direction
		6.660	24.176	-2.500	DS4	CO155			0.023 ✓	SE6000.00	Serviceability | Vibration in z-direction

1.4.4 GOVERNING INTERNAL FORCES BY SURFACE

Timber Design

Surface No.	Point No.	Point Coordinates [m] X	Y	Z	Design Situation	Loading No.	Moments [kNm/m] m_x	m_y	m_{xy}	Shear F. [kN/m] v_x	v_y	Axial Forces [kN/m] n_x	n_y	n_{xy}	Design Check Ratio η [--	Type	Description
103	4869	6.659	21.176	-0.471	DS1	CO46	0.016	-0.016	-0.007	-0.069	0.011	-106.9755	-0.624	0.110	0.000	UL0100.00	Ultimate Limit State | Negligible stresses
	1963	6.659	26.176	0.000	DS7	RC1	0.730	0.010	-0.024	0.040	0.003	266.1044	37.612	38.499	0.200	UL1100.00	Ultimate Limit State | Tension along grain
		6.659	26.176	0.000	DS7	RC3	0.722	0.009	0.032	0.036	0.003	240.7866	37.189	-40.935	0.257	UL1300.00	Ultimate Limit State | Compression along grain
	377	6.659	21.176	-3.300	DS1	CO3	2.616	-0.437	-0.651	-10.766	-0.337	-346.4244	-10.224	8.133	0.153	UL3010.00	Ultimate Limit State | Shear in yz-plane
		6.659	21.176	-3.300	DS1	CO3	2.616	-0.437	-0.651	-10.766	-0.337	-346.4244	-10.224	8.133	0.063	UL3020.00	Ultimate Limit State | Shear in xz-plane
	4891	6.659	27.176	-1.414	DS7	RC3	0.332	0.195	0.059	0.935	0.591	38.153	2.704	-49.930	0.138	UL3110.00	Ultimate Limit State | Shear in xy-plane | Failure mechanism 1
		6.659	27.176	-1.414	DS7	RC3	0.332	0.195	0.059	0.935	0.591	38.153	2.704	-49.930	0.019	UL3400.00	Ultimate Limit State | Shear in xz-plane and xy-plane
	387	6.659	27.176	-3.300	DS1	CO2	-0.309	1.181	0.523	-7.914	0.141	-290.6799	-12.106	-10.525	0.128	UL4100.00	Ultimate Limit State | Bending along grain
	1963	6.659	26.176	0.000	DS7	RC1	0.730	0.010	-0.024	0.040	0.003	266.1044	37.612	38.499	0.225	UL5100.00	Ultimate Limit State | Bending and tension along grain
	377	6.659	21.176	-3.300	DS1	CO3	2.616	-0.437	-0.651	-10.766	-0.337	-346.4244	-10.224	8.133	0.302	UL6100.00	Ultimate Limit State | compression along grain
		6.659	21.176	-3.300	DS2	CO48	0.867	-0.145	-0.246	-3.682	-0.118	-129.6744	-3.797	2.798	0.000	SE0500.00	Serviceability | Negligible deflections
	4914	6.660	24.176	-2.500	DS2	CO90	0.009	0.029	0.000	-0.035	-0.001	-0.080	14.081	-0.007	0.026	SE5000.01	Serviceability | Combination

1.4.4 GOVERNING INTERNAL FORCES BY SURFACE

Timber Design

Surface No.	Point No.	Point Coordinates [m] X	Y	Z	Design Situation	Loading No.	Moments [kNm/m] m_x	m_y	m_{xy}	Shear F. [kN/m] v_x	v_y	Axial Forces [kN/m] n_x	n_y	n_{xy}	Design Check Ratio η [--]	Type	Description
103																	of actions 'Characteristic' | Deflection in z-direction
						CO137	0.009	0.029	0.000	-0.035	-0.002	-0.113	20.899	-0.010	0.022	SE500 0.02	Serviceability | Combination of actions 'Quasi-permanent 1' | Deflection in z-direction
		6.660	24.176	-2.500	DS4	CO155	0.002	0.005	0.000	-0.007	-0.001	-0.052	11.344	-0.005	0.023	SE600 0.00	Serviceability | Vibration in z-direction

1.5 **SURFACE NO. 103 | DS7 | RC3 | MESH NODE NO. 1963 | ELEMENT NO. 4196 | UL6100** **Timber Design**

Design Check UL6100 | EN 1995 | HRN | 2015-03

Ultimate Limit State
Bending and compression along grain

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 1.10 \cdot \frac{21.000\ \text{N/mm}^2}{1.20} = 19.250\ \text{N/mm}^2$$

$$f_{m,0,d} = k_{mod} \cdot \frac{f_{m,0,k}}{\gamma_M} = 1.10 \cdot \frac{24.000\ \text{N/mm}^2}{1.20} = 22.000\ \text{N/mm}^2$$

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} + \frac{|\sigma_{b,0,d}|}{f_{m,0,d}} = \frac{|-4.945\ \text{N/mm}^2|}{19.250\ \text{N/mm}^2} + \frac{|-0.531\ \text{N/mm}^2|}{22.000\ \text{N/mm}^2} = 0.281$$

$\eta = 0.281 \leq 1$ ✓

$f_{c,0,d}$	Design compressive strength along grain
k_{mod}	Modification factor
$f_{c,0,k}$	Characteristic compressive strength along grain
γ_M	Partial factor
$f_{m,0,d}$	Design bending strength along grain
$f_{m,0,k}$	Characteristic bending strength along grain
$\sigma_{c,0,d}$	Design compressive stress along grain
$\sigma_{b,0,d}$	Design bending stress along grain

1.6 SURFACE NO. 103 | DS7 | RC3 | MESH NODE NO. 1963 | ELEMENT NO. 4196 | UL1300 — Timber Design

Design Check UL1300 | EN 1995 | HRN | 2015-03

Ultimate Limit State
Compression along grain

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 1.10 \cdot \frac{21.000\,N/mm^2}{1.20} = 19.250\,N/mm^2$$

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} = \frac{|-4.945\,N/mm^2|}{19.250\,N/mm^2} = 0.257$$

$$\eta = 0.257 \leq 1 \checkmark$$

$f_{c,0,d}$	Design compressive strength along grain
k_{mod}	Modification factor
$f_{c,0,k}$	Characteristic compressive strength along grain
γ_M	Partial factor
$\sigma_{c,0,d}$	Design compressive stress along grain

1.7 **SURFACE NO. 103 | DS2 | CO90 | MESH NODE NO. 4914 | ELEMENT NO. 4219 | SE5000.01** **Timber Design**

Design Check SE5000.01 | EN 1995 | HRN | 2015-03

Serviceability
Combination of actions 'Characteristic' | Deflection in z-direction

Design situation: Characteristic
Surface type: Double-supported

$$w_{inst,limit,z} = \frac{l}{l/w_{inst,limit,z}} = \frac{6.000\ m}{300.00} = 20.0\ mm$$

$$\eta = \frac{|w_{inst,z}|}{w_{inst,limit,z}} = \frac{|0.5\ mm|}{20.0\ mm} = 0.026$$

$$\eta = 0.026 \leq 1 ✓$$

$w_{inst,limit,z}$	Limit value of deflection
l	Reference length
$l / w_{inst,limit,z}$	Limit value criterion
$w_{inst,z}$	Deflection

1.8 SURFACE NO. 103 | DS1 | CO1 | MESH NODE NO. 1963 | ELEMENT NO. 4196 | UL6100 — Timber Design

Design Check UL6100 | EN 1995 | HRN | 2015-03

Ultimate Limit State
Bending and compression along grain

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.60 \cdot \frac{21.000\ \mathrm{N/mm^2}}{1.20} = 10.500\ \mathrm{N/mm^2}$$

$$f_{m,0,d} = k_{mod} \cdot \frac{f_{m,0,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\ \mathrm{N/mm^2}}{1.20} = 12.000\ \mathrm{N/mm^2}$$

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} + \frac{|\sigma_{b,0,d}|}{f_{m,0,d}} = \frac{|-1.371\ \mathrm{N/mm^2}|}{10.500\ \mathrm{N/mm^2}} + \frac{|-0.015\ \mathrm{N/mm^2}|}{12.000\ \mathrm{N/mm^2}} = 0.132$$

$$\eta = 0.132 \leq 1$$ ✓

$f_{c,0,d}$	Design compressive strength along grain
k_{mod}	Modification factor
$f_{c,0,k}$	Characteristic compressive strength along grain
γ_M	Partial factor
$f_{m,0,d}$	Design bending strength along grain
$f_{m,0,k}$	Characteristic bending strength along grain
$\sigma_{c,0,d}$	Design compressive stress along grain
$\sigma_{b,0,d}$	Design bending stress along grain

1.9 SURFACE NO. 103 | DS1 | CO1 | MESH NODE NO. 1963 | ELEMENT NO. 4196 | UL1300 — Timber Design

Design Check UL1300 | EN 1995 | HRN | 2015-03

Ultimate Limit State
Compression along grain

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.60 \cdot \frac{21.000\ N/mm^2}{1.20} = 10.500\ N/mm^2$$

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} = \frac{|-1.371\ N/mm^2|}{10.500\ N/mm^2} = 0.131$$

$$\eta = 0.131 \leq 1 \checkmark$$

$f_{c,0,d}$	Design compressive strength along grain
k_{mod}	Modification factor
$f_{c,0,k}$	Characteristic compressive strength along grain
γ_M	Partial factor
$\sigma_{c,0,d}$	Design compressive stress along grain

2.5.5 Stupovi

Marija Gulam

Model: diplomski_zgradaA1

Date 20.8.2024 Page 1/6 Sheet 1

MODEL

1 Types for Timber Design

1.1 SERVICE CLASSES

Class No.	Assigned to Members	Member Sets	Surfaces	Surface Sets	Service Class Type	Comment
1	Service Class 1 (Members : 1-13 | Surfaces : 1-14,20-31,43-53,70-78,97-104,106-114,116-118,120-129,139-142,154-157,159-192,204-206,208-214,216-223,225-231,233-236,257,258,262-273,298-304,315-343,348-364,366-381,383-427,526)					
	1-13		1-14,20-31,43-53,70-78,97-104,106-114,116-118,120-129,139-142,154-157,159-192,204-206,208-214,216-223,225-231,233-236,257,258,262-273,298-304,315-343,348-364,366-381,383-427,526		1 - Dry	

2 Timber Design

2.1 DESIGN SITUATIONS

DS No.	EN 1990 | Base + Timber | CEN | 2010-0 Design Situation Type	To Design	Active	EN 1995 | HRN | 2015-03 Design Situation Type	Combinations to Design for Enumeration Method
1	ULS ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒	☒	ULS ULS (STR/GEO) - Permanent and transient	All
2	S Ch SLS - Characteristic	☒	☒	S Ch SLS - Characteristic	All
3	S Qp SLS - Quasi-permanent	☒	☒	S Qp1 SLS - Quasi-permanent 1	All
4	S Fr SLS - Frequent base	☒	☒	S V SLS - Vibration	All
5	S Qp SLS - Quasi-permanent base	☒	☒	S Qp1 SLS - Quasi-permanent 1	All
6	SE/M Seismic/Mass Combination - psi-E,i	☐	☒	ACC ULS (STR/GEO) - Accidental	
7	SEIS ULS (STR/GEO) - Seismic	☒	☒	ULS ULS (STR/GEO) - Permanent and transient	All

2.2 SECTIONS

Section No.	Name	Material	To Design	Section Type	Use Other Section for Design	Options
1	R_M1 200/200	3	☒	Parametric - Massive I	--	⅀

Legend
⅀ Warping stiffness deactivated

2.3 Results

2.3.1 DESIGN RATIOS ON MEMBERS BY MEMBER

Timber Design

Member No.	Location x [m]	Stress Point No.	Design Situation	Loading No.	Design Check Ratio η [--]	Type	Description
	Beam | 1 - R_M1 200/200 | L : 3.300 m						
1	0.000	1	DS1	CO3	0.778 ✓		
		4	DS7	RC3	0.015 ✓	SP3100.00	Section Proof | Shear in z-axis acc. to 6.1.7 | Rectangular section
	1.238	2	DS1	CO210	0.049 ✓	SP3200.00	Section Proof | Shear in y-axis acc. to 6.1.7 | Rectangular section
	0.000	1	DS7	RC2	0.297 ✓	SP6100.00	Section Proof | Bending about y-axis and compressive axial force acc. to 6.2.4
	3.300	1	DS1	CO3	0.747 ✓	SP6200.00	Section Proof | Bending about z-axis and compressive axial force acc. to 6.2.4
	2.888	1	DS1	CO3	0.722 ✓	SP6300.00	Section Proof | Biaxial bending and compressive axial force acc. to 6.2.4
	0.000		DS2	CO48	0.000 ✓	SE0100.01	Serviceability | Negligible deflection | Combination of actions 'Characteristic'
			DS3	CO95	0.000 ✓	SE0100.02	Serviceability | Negligible deflection | Combination of actions 'Quasi-permanent 1'
			DS4	CO142	0.000 ✓	SE0100.10	Serviceability | Negligible deflection of vibration
	2.063		DS2	CO212	0.065 ✓	SE1100.01	Serviceability | Combination of actions 'Characteristic' | y-direction acc. to 7.2
			DS3	CO104	0.068 ✓	SE1100.02	Serviceability | Combination of actions 'Quasi-permanent 1' | y-direction acc. to 7.2
	1.650 ½		DS2	CO212	0.008 ✓	SE1200.01	Serviceability | Combination of actions 'Characteristic' | z-direction acc. to 7.2
	1.238		DS3	CO104	0.008 ✓	SE1200.02	Serviceability | Combination of actions 'Quasi-permanent 1' | z-direction acc. to 7.2
	2.063		DS4	CO144	0.097 ✓	SE2100.00	Serviceability | Vibration in y-direction
	1.238		DS4	CO144	0.011 ✓	SE2200.00	Serviceability | Vibration in z-direction

2.4 MEMBER NO. 1 | DS1 | CO3 | 0.000 M | STRESS POINT NO. 1 | SP1200 — Timber Design

Design Check SP1200 | EN 1995 | HRN | 2015-03

Section Proof
Compression along grain acc. to 6.1.4

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.80 \cdot \frac{32.000\,N/mm^2}{1.25} = 20.480\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} = \frac{|-15.935\,N/mm^2|}{20.480\,N/mm^2} = 0.778$$ 6.1.4, Eq. 6.2

$$\eta = 0.778 \leq 1$$ ✓

$f_{c,0,d}$ Design compressive strength
k_{mod} Modification factor
$f_{c,0,k}$ Characteristic compressive strength
γ_M Partial factor
$\sigma_{c,0,d}$ Design compressive stress

2.5 MEMBER NO. 1 | DS1 | CO3 | 0.000 M | STRESS POINT NO. 3 | SP6300 Timber Design

Design Check SP6300 | EN 1995 | HRN | 2015-03

Section Proof
Biaxial bending and compressive axial force acc. to 6.2.4

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.80 \cdot \frac{32.000\,N/mm^2}{1.25} = 20.480\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.80 \cdot \frac{32.000\,N/mm^2}{1.25} = 20.480\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.80 \cdot \frac{32.000\,N/mm^2}{1.25} = 20.480\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta_1 = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-15.935\,N/mm^2}{20.480\,N/mm^2}\right)^2 + \frac{-0.213\,N/mm^2}{20.480\,N/mm^2} + 0.70 \cdot \frac{-1.320\,N/mm^2}{20.480\,N/mm^2} \right| = 0.661$$ 6.2.4, Eq. 6.19

$$\eta_2 = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-15.935\,N/mm^2}{20.480\,N/mm^2}\right)^2 + 0.70 \cdot \frac{-0.213\,N/mm^2}{20.480\,N/mm^2} + \frac{-1.320\,N/mm^2}{20.480\,N/mm^2} \right| = 0.677$$ 6.2.4, Eq. 6.20

$$\eta = \max(\eta_1, \eta_2) = \max(0.661,\ 0.677) = 0.677$$ 6.2.4

$\eta = 0.677 \leq 1$ ✓

$f_{c,0,d}$	Design compressive strength
k_{mod}	Modification factor
$f_{c,0,k}$	Characteristic compressive strength
γ_M	Partial factor
$f_{m,y,d}$	Design bending strength
$f_{m,y,k}$	Characteristic bending strength
$f_{m,z,d}$	Design bending strength
$f_{m,z,k}$	Characteristic bending strength
η_1	Design ratio 1
$\sigma_{c,0,d}$	Design compressive stress
$\sigma_{m,y,d}$	Design bending stress
k_m	Redistribution factor
$\sigma_{m,z,d}$	Design bending stress
η_2	Design ratio 2

2.6 MEMBER NO. 1 | DS2 | CO212 | 2.063 M | SE1100.01 — Timber Design

Design Check SE1100.01 | EN 1995 | HRN | 2015-03

Serviceability
Combination of actions 'Characteristic' | y-direction acc. to 7.2

Segment type in y-axis: Beam

$$w_{inst,limit,y} = \frac{l}{l/w_{inst,limit,y}} = \frac{3.300\ \text{m}}{300.00} = 11.0\ \text{mm}$$

$$\eta = \frac{|w_{inst,y}|}{w_{inst,limit,y}} = \frac{|0.7\ \text{mm}|}{11.0\ \text{mm}} = 0.065$$ 7.2

$\eta = 0.065 \leq 1$ ✓

$w_{inst,limit,y}$	Limit value of deflection
l	Reference length
$l / w_{inst,limit,y}$	Limit value criterion
$w_{inst,y}$	Deflection

2.7 MEMBER NO. 1 | DS7 | RC1 | 0.000 M | STRESS POINT NO. 1 | SP1200 — Timber Design

Design Check SP1200 | EN 1995 | HRN | 2015-03

Section Proof
Compression along grain acc. to 6.1.4

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 1.10 \cdot \frac{32.000\,N/mm^2}{1.25} = 28.160\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} = \frac{|-12.361\,N/mm^2|}{28.160\,N/mm^2} = 0.439$$ 6.1.4, Eq. 6.2

$$\eta = 0.439 \leq 1$$ ✓

$f_{c,0,d}$	Design compressive strength
k_{mod}	Modification factor
$f_{c,0,k}$	Characteristic compressive strength
γ_M	Partial factor
$\sigma_{c,0,d}$	Design compressive stress

2.8 MEMBER NO. 1 | DS7 | RC1 | 0.000 M | STRESS POINT NO. 3 | SP6300 — Timber Design

Design Check SP6300 | EN 1995 | HRN | 2015-03

Section Proof
Biaxial bending and compressive axial force acc. to 6.2.4

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 1.10 \cdot \frac{32.000\,N/mm^2}{1.25} = 28.160\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 1.10 \cdot \frac{32.000\,N/mm^2}{1.25} = 28.160\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 1.10 \cdot \frac{32.000\,N/mm^2}{1.25} = 28.160\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta_1 = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-12.361\,N/mm^2}{28.160\,N/mm^2}\right)^2 + \frac{-1.981\,N/mm^2}{28.160\,N/mm^2} + 0.70 \cdot \frac{-1.116\,N/mm^2}{28.160\,N/mm^2} \right| = 0.291$$ 6.2.4, Eq. 6.19

$$\eta_2 = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-12.361\,N/mm^2}{28.160\,N/mm^2}\right)^2 + 0.70 \cdot \frac{-1.981\,N/mm^2}{28.160\,N/mm^2} + \frac{-1.116\,N/mm^2}{28.160\,N/mm^2} \right| = 0.282$$ 6.2.4, Eq. 6.20

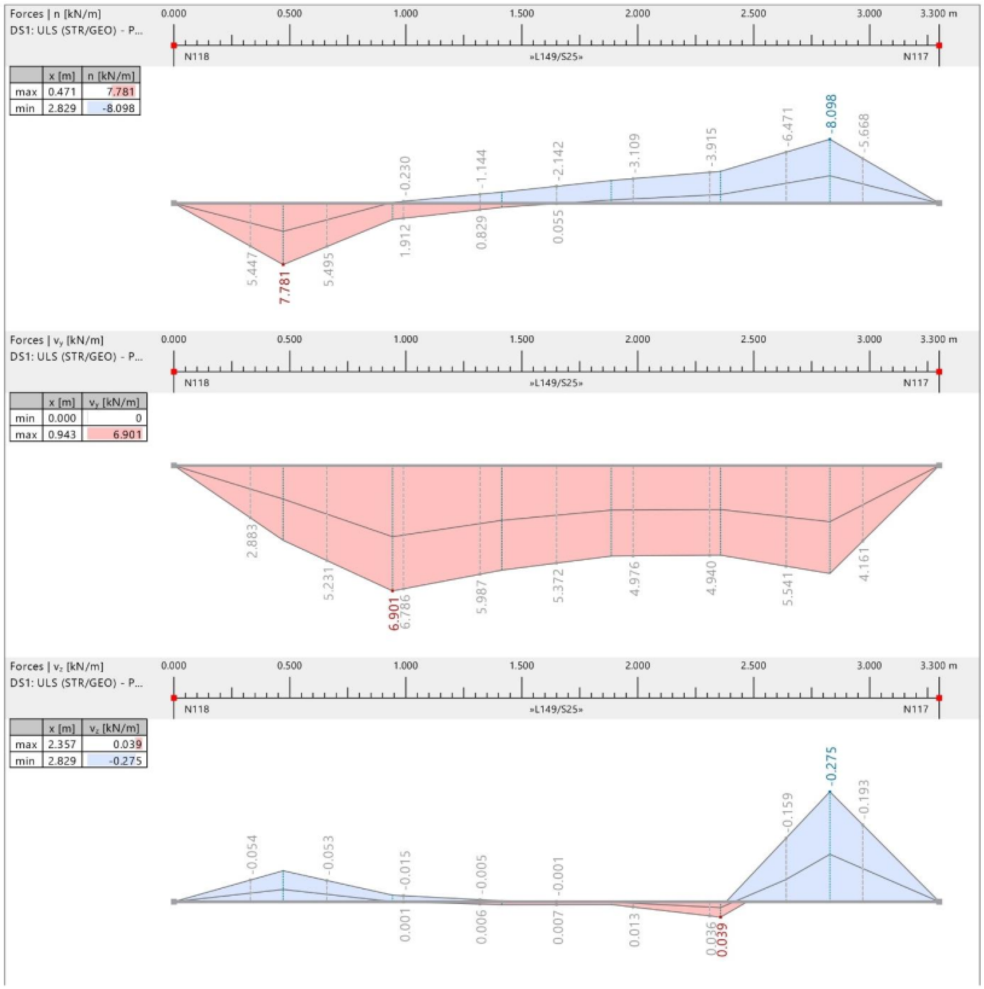
$$\eta = \max(\eta_1, \eta_2) = \max(0.291, 0.282) = 0.291$$ 6.2.4

$$\eta = 0.291 \leq 1$$ ✓

$f_{c,0,d}$	Design compressive strength
k_{mod}	Modification factor
$f_{c,0,k}$	Characteristic compressive strength
γ_M	Partial factor
$f_{m,y,d}$	Design bending strength
$f_{m,y,k}$	Characteristic bending strength
$f_{m,z,d}$	Design bending strength
$f_{m,z,k}$	Characteristic bending strength
η_1	Design ratio 1
$\sigma_{c,0,d}$	Design compressive stress
$\sigma_{m,y,d}$	Design bending stress
k_m	Redistribution factor
$\sigma_{m,z,d}$	Design bending stress
η_2	Design ratio 2

2.6 Dimenzioniranje karakterističnih spojeva

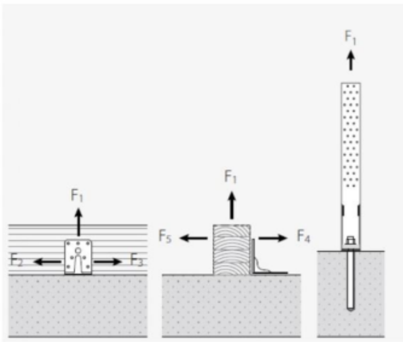
2.6.1 Spoj CLT zida s betonskom pločom



Slika 27. Dijagrami unutarnjih sila na spoju između CLT zida i betonske ploče

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Connection



F_1	7.78	kN
F_{23}	6.91	kN
F_{45}	0.275	kN
K_{mod}	0.8	-
Connectors	AG922 / Nail CNA 4,0x50	
e_{45}		mm

Design F_1							
$F_{k,1}$ =	7.8	kN		$R_{k,1,Holz}$ =	15.3	kN	
				$R_{k,1,Stahl}$ =		kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,1}$ =	7.8	kN	<	$R_{d,1}$ =	9.4	kN	✓
Utilization ratio							83%

Design F_{23}							
$F_{k,23}$ =	6.9	kN		$R_{k,23,Holz}$ =	24.1	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,23}$ =	6.9	kN	<	$R_{d,23}$ =	14.8	kN	✓
Utilization ratio							47%

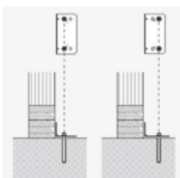
storaenso

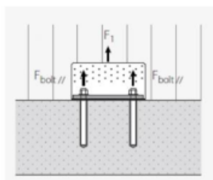
Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

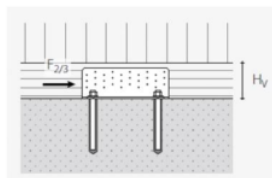
Design F_{45}							
$F_{k,45}$ =	0.3	kN		$R_{k,45,Holz}$ =	24.8	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,45}$ =	0.3	kN	<	$R_{d,45}$ =	15.3	kN	✓
Utilization ratio							2%

Design forces for anchorage to concrete

Design values, having "in" in the index refer to an inner anchor position
Design values, having "out" in the index refer to an outer anchor position
See technical approvals and assessment documents







Reference documents for this analysis

English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
ETA-11/0030	ETA-11/0030 European Technical Approval; Rothoblaas; Self-tapping screws for use in timber structures
ETA-12/0063	SFS intec AG; Self-tapping screws for use in timber constructions
ETA-12/0062	SFA intec AG; ETA-12/0062; selftapping screws for use in timber constructions

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

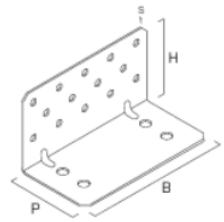
Reference documents for this analysis	
English title	Description
ETA-11/0086	GH Various Angle Brackets
ETA-09/0322	GH Various Angle Brackets
ETA-11/0496	Rotho Blaas TITAN Angle Brackets
ETA-11/0190	selftaping screw by Würth
ETA-12/0373	Schmid - Screws for use in timber constructions
ETA-12/0114	SPAX - Screws for use in timber constructions
ETA-21/0670	Simpson Strong-Tie® Structural screws SWW, SWC, TTUFS, TTSFS and TTZNFS
ETA-13/0796	Simpson Strong-Tie® screws ESCR/ESCR-S, ESCRC/ESCRC-S,, ESCRS, ESCRFTC, ESCRFT/FTZ, ESCRHD/HRD, ESCRT2R, SSTA and ESCRH
ETA-20/0773	Würth - DENEB Angle Brackets and plate connectors
ETA-08/0183	Würth - Typ A + Typ V Angle Bracket
ETA-14/0274	Würth - Hold down and storey connector

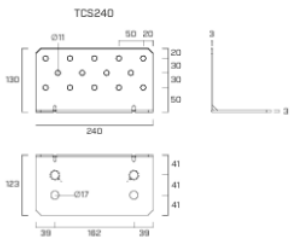
Disclaimer

CODES AND DIMENSIONS

TITAN S - TCS | CONCRETE-TO-TIMBER JOINTS

CODE	B	P	H	holes	n_V Ø11	s		pcs
	[mm]	[mm]	[mm]	[mm]	*n_V Ø0.44*	[mm]		
	[in]	*[in]*	*[in]*	*[in]*	[pcs]	*[in]*		
TCS240	240 *9 1/2*	123 *4 13/16*	130 *5 1/8*	4 x Ø17 *4 x Ø0.67*	14	3 *0.12*	•	10

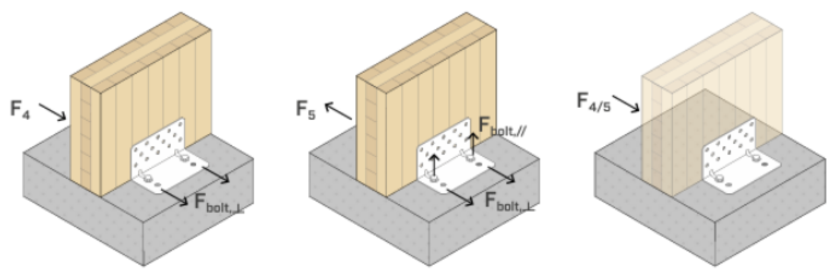




FASTENERS

type	description	d [mm]	support
HBS PLATE	pan head screw	8	
HBS PLATE EVO	C4 EVO pan head screw	8	
AB1	CE1 expansion anchor	16	
SKR	screw-in anchor	16	
VIN-FIX	vinyl ester chemical anchor	M16	
HYB-FIX	hybrid chemical anchor	M16	
EPO-FIX	epoxy chemical anchor	M16	

STRUCTURAL VALUES | **TCS240** | TIMBER-TO-CONCRETE | F_4 | F_5 | $F_{4/5}$



	TIMBER				STEEL		CONCRETE			
F_4	fastening holes Ø11			$R_{4,k\ timber}$	$R_{4,k\ steel}$		fastening holes		IN[1]	
	type	Ø x L	n_V				Ø	n_H	$k_{t\perp}$	$k_{t//}$
		[mm]	[pcs]	[kN]	[kN]	γ_{steel}	[mm]	[pcs]		
TCS240	HBS PLATE	Ø8 x 80	14	**21,1**	**18,1**	γ_{M0}	M16	2	0,5	-

The group of 2 anchors must be verified for: $V_{Sd,y} = 2 \times k_{t\perp} \times F_{4,d}$

	TIMBER				STEEL		CONCRETE			
F_5	fastening holes Ø11			$R_{5,k\ timber}$	$R_{5,k\ steel}$		fastening holes		IN[1]	
	type	Ø x L	n_V				Ø	n_H	$k_{t\perp}$	$k_{t//}$
		[mm]	[pcs]	[kN]	[kN]	γ_{steel}	[mm]	[pcs]		
TCS240	HBS PLATE	Ø8 x 80	14	**17,1**	**4,3**	γ_{M0}	M16	2	0,5	0,36

The group of 2 anchors must be verified for: $V_{Sd,y} = 2 \times k_{t\perp} \times F_{5,d}$; $N_{Sd,z} = 2 \times k_{t//} \times F_{5,d}$

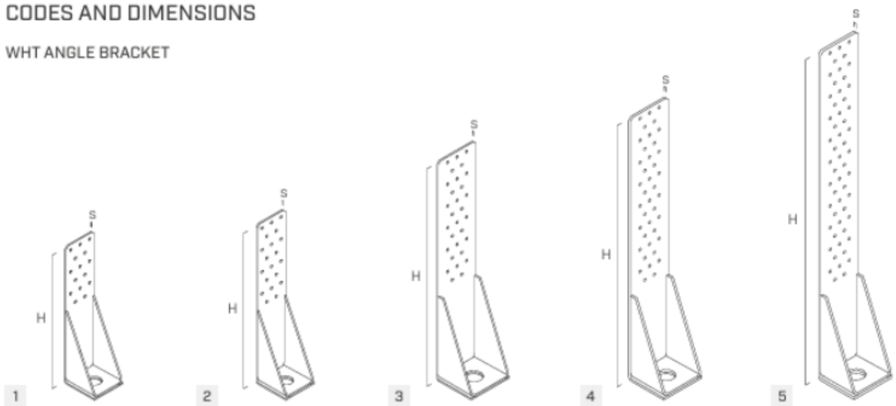
	TIMBER				STEEL		CONCRETE			
$F_{4/5}$	fastening holes Ø11			$R_{4/5,k\ timber}$	$R_{4/5,k\ steel}$		fastening holes		IN[1]	
TWO ANGLE BRACKETS	type	Ø x L	n_V				Ø	n_H	$k_{t\perp}$	$k_{t//}$
		[mm]	[pcs]	[kN]	[kN]	γ_{steel}	[mm]	[pcs]		
TCS240	HBS PLATE	Ø8 x 80	14 + 14	**27,4**	**18,8**	γ_{M0}	M16	2 + 2	0,39	0,08

The group of 2 anchors must be verified for: $V_{Sd,y} = 2 \times k_{t\perp} \times F_{4/5,d}$; $N_{Sd,z} = 2 \times k_{t//} \times F_{4/5,d}$

Slika 28. Karakteristike odabranog spojnog sredstva TCS240 iz Rothoblaas kataloga

CODES AND DIMENSIONS

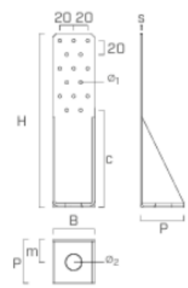
WHT ANGLE BRACKET



	CODE	H [mm]	s [mm]	n_V Ø5 [pcs]	hole [mm]	*H [in]*	*s [in]*	*n_V Ø.20 [pcs]*	*hole [in]*	pcs
1	**WHT15**	250	2,5	15	Ø23	*10*	*0.10*	*15*	*Ø0.91*	20
2	**WHT20**	290	3	20	Ø23	*11 7/16*	*0.12*	*20*	*Ø0.91*	20
3	**WHT30**	400	3	30	Ø29	*15 3/4*	*0.12*	*30*	*Ø1.14*	10
4	**WHT40**	480	4	40	Ø29	*19*	*0.16*	*40*	*Ø1.14*	10
5	**WHT55**	600	5	55	Ø29	*23 5/8*	*0.20*	*55*	*Ø1.14*	1

GEOMETRY

WHT			WHT15	WHT20	WHT30	WHT40	WHT55
Height	**H**	[mm]	250	290	400	480	600
Base	**B**	[mm]	60	60	80	80	80
Depth	**P**	[mm]	62,5	63	73	74	75
Vertical flange thickness	**s**	[mm]	2,5	3	3	4	5
Hole position in timber	**c**	[mm]	140	140	170	170	170
Hole position in concrete	**m**	[mm]	32,5	33	38	39	40
Flange holes	**$Ø_1$**	[mm]	5	5	5	5	5
Base hole	**$Ø_2$**	[mm]	23	23	29	29	29

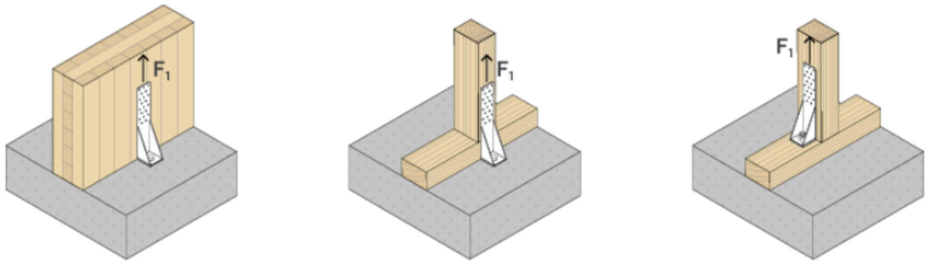


FASTENERS

type	description		d [mm]	support
LBA	high bond nail		4	
LBS	round head screw		5	
LBS HARDWOOD	round head screw on hardwoods		5	
VIN-FIX	vinyl ester chemical anchor		M16-M20-M24	
HYB-FIX	hybrid chemical anchor		M16-M20-M24	
EPO-FIX	epoxy chemical anchor		M16-M20-M24	
KOS	hexagonal head bolt		M16-M20-M24	

Slika 29. Karakteristike odabranog spojnog sredstva WHT20 iz Rothoblaas kataloga

STRUCTURAL VALUES | TIMBER-TO-CONCRETE | F_1



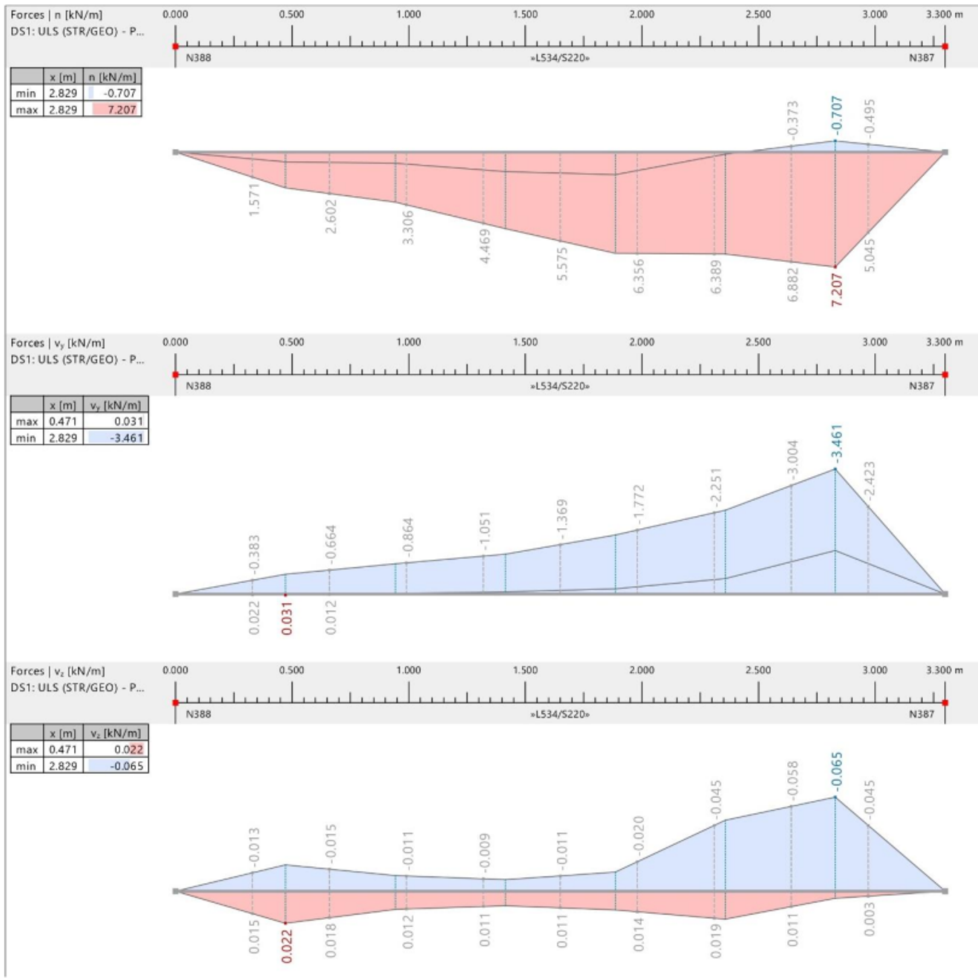
STRENGTH ON TIMBER SIDE | WIDE PATTERN | total fastening

	TIMBER				STEEL				
	fastening holes Ø5				no washer	washer		no washer	washer
CODE	type	Ø x L	n_V	$R_{1,k\ timber}$	$R_{1,k\ steel}$	$R_{1,k\ steel}$	γ_{steel}	$K_{1,ser}$	$K_{1,ser}$
		[mm]	[pcs]	[kN]	[kN]	[kN]		[N/mm]	[N/mm]
	LBA	Ø4 x 60		36,8					
WHT15	LBS	Ø5 x 70	15	35,6	**30,0**	**40,0**	γ_{M0}	5000	5880
	LBSH	Ø5 x 50		35,3					
	LBA	Ø4 x 60		48,1					
WHT20	LBS	Ø5 x 70	20	48,3	**40,0**	**50,0**	γ_{M0}	6667	7980
	LBSH	Ø5 x 50		47,9					
	LBA	Ø4 x 60		76,4					
WHT30	LBS	Ø5 x 70	30	73,7	-	**70,0**	γ_{M0}	-	11667
	LBSH	Ø5 x 50		73,1					
	LBA	Ø4 x 60		101,9					
WHT40	LBS	Ø5 x 70	40	96,5	-	**90,0**	γ_{M0}	-	15000
	LBSH	Ø5 x 50		95,8					
	LBA	Ø4 x 60		141,5					
WHT55	LBS	Ø5 x 70	55	132,1	-	**120,0**	γ_{M0}	-	20000
	LBSH	Ø5 x 50		131,0					

Slika 30. Karakteristike odabranog spojnog sredstva WHT20 iz Rothoblaas kataloga

Odabrana spojna sredstva TCS240 postavljaju se na razmaku od 50 cm, dok se kutnik WHT20 postavlja na rubovima, oko otvora te na svakom 5. razmaku.

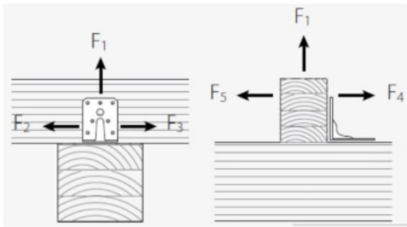
2.6.2 Spoj CLT zidova



Slika 31. Dijagrami unutarnjih sila na spoju između zidova

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Connection



F_1	7.207	kN
F_{23}	3.461	kN
F_{45}	0.065	kN
K_{mod}	0.8	-
Connectors	ABR255 / Nail CNA 4,0x50	

Design F_1							
$F_{k,1}$ =	7.2	kN		$R_{k,1,Holz}$ =	17.1	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,1}$ =	7.2	kN	<	$R_{d,1}$ =	10.5	kN	✓
Utilization ratio							**69%**

Design F_{23}							
$F_{k,23}$ =	3.5	kN		$R_{k,23,Holz}$ =	28.6	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,23}$ =	3.5	kN	<	$R_{d,23}$ =	17.6	kN	✓
Utilization ratio							**20%**

Design F_{45}							
$F_{k,45}$ =	0.1	kN		$R_{k,45,Holz}$ =	11.5	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,45}$ =	0.1	kN	<	$R_{d,45}$ =	7.1	kN	✓
Utilization ratio							**1%**

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Reference documents for this analysis	
English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General-Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
ETA-11/0030	ETA-11/0030 European Technical Approval; Rothoblaas; Self-tapping screws for use in timber structures
ETA-12/0063	SFS intec AG; Self-tapping screws for use in timber constructions
ETA-12/0062	SFA intec AG; ETA-12/0062; selftapping screws for use in timber constructions
ETA-11/0086	GH Various Angle Brackets
ETA-09/0322	GH Various Angle Brackets
ETA-11/0496	Rotho Blaas TITAN Angle Brackets
ETA-11/0190	selftaping screw by Würth
ETA-12/0373	Schmid - Screws for use in timber constructions
ETA-12/0114	SPAX - Screws for use in timber constructions
ETA-21/0670	Simpson Strong-Tie® Structural screws SWW, SWC, TTUFS, TTSFS and TTZNFS
ETA-13/0796	Simpson Strong-Tie® screws ESCR/ESCR-S, ESCRC/ESCRC-S,, ESCRS, ESCRFTC, ESCRFT/FTZ, ESCRHD/HRD, ESCRT2R, SSTA and ESCRH
ETA-20/0773	Würth - DENEB Angle Brackets and plate connectors
ETA-08/0183	Würth - Typ A + Typ V Angle Bracket
ETA-14/0274	Würth - Hold down and storey connector

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Disclaimer

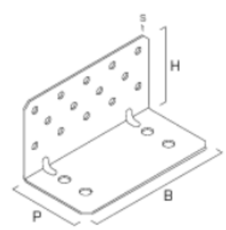
The software was created to assist engineers in their daily business. The software is an engineering software that is dealing with a very complex matter of structural analysis and building physics analysis. Therefore, this software shall only be operated by skilled, experienced engineers, with a deep understanding of structural engineering and building physics related to timber structures. The user of the software is obliged to check all input values, no matter if they were given by the user or given by default by the software and all results for plausibility.
The use of the results of the software should not be relied upon as the basis for any decision or action. Any use of results of the software is only allowed, if the results have been verified and approved regarding completeness and correctness by a project structural/building physics engineer. The user has the possibility to make print-outs from the software. Any modification of those are not allowed.
Stora Enso Wood Products GmbH does not assume any warranty regarding the software. The software has been developed with utmost diligence, nevertheless Stora Enso Wood Products GmbH, neither expressly nor implicitly, provides any warranty in terms of accuracy, validity, timeliness and completeness of information and data created by the software. Stora Enso Wood Products GmbH does also not assume any warranty for the general usability of the software, its suitability for a special purpose or for the compatibility of the software with the ones of third party producers or providers.
Stora Enso Wood Products GmbH is only liable for damages caused by gross negligence or intent through Stora Enso Wood Products GmbH; the liability for slight negligence is excluded. This does not apply to personal injury. Under the aforementioned conditions Stora Enso Wood Products GmbH is as well not liable for operational failures or the loss of programs and/or data of the user's data processing system.
Applicable Law: These terms of use shall be governed by the laws of Austria excluding however any conflict of laws rules and any laws regarding the Convention of the International Sale of Goods (CISG).

Slika 32. Prikaz izvedenog spoja zidova i ploča od CLT-a sa spojnim sredstvom TCS240

CODES AND DIMENSIONS

TITAN S - TCS | CONCRETE-TO-TIMBER JOINTS

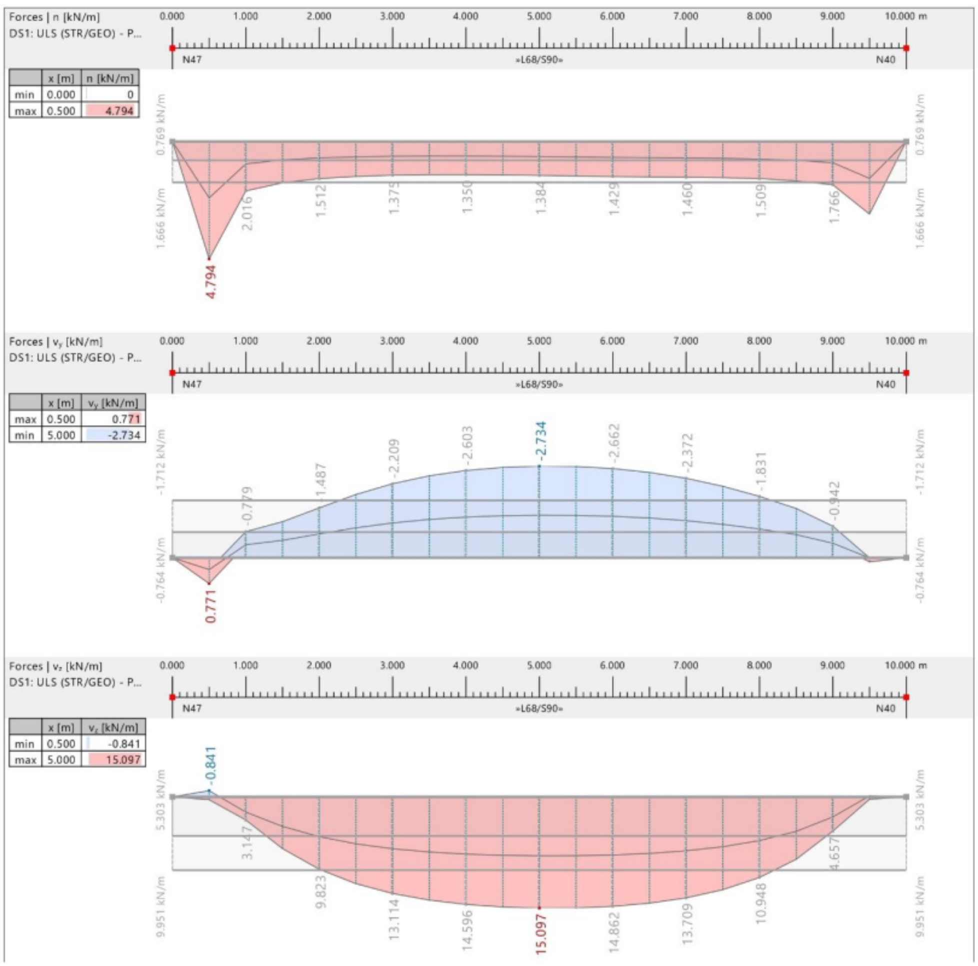
CODE	B [mm] [in]	P [mm] [in]	H [mm] [in]	holes [mm] [in]	n_V Ø11 n_V Ø0.44 [pcs]	s [mm] [in]		pcs
TCS240	240 9 1/2	123 4 13/16	130 5 1/8	4 x Ø17 4 x Ø0.67	14	3 0.12	•	10



Slika 33. Karakteristike odabranog spojnog sredstva

Odabrano spojno sredstvo TCS240 postavlja se na razmaku od 50 cm.

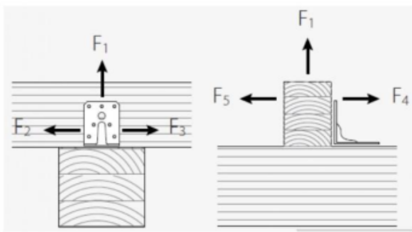
2.6.3 Spoj CLT zida s CLT pločom



Slika 34. Dijagrami unutarnjih sila na spoju između CLT zida i ploče

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Connection



F_1	1.666	kN
F_{23}	1.712	kN
F_{45}	9.951	kN
K_{mod}	0.8	-
Connectors	AG922 / Nail CNA 4,0x50	

Design F_1

$F_{k,1}$ =	1.7	kN		$R_{k,1,Holz}$ =	9.2	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,1}$ =	1.7	kN	<	$R_{d,1}$ =	5.7	kN	✓
Utilization ratio							**29%**

Design F_{23}

$F_{k,23}$ =	1.7	kN		$R_{k,23,Holz}$ =	14.7	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,23}$ =	1.7	kN	<	$R_{d,23}$ =	9.0	kN	✓
Utilization ratio							**19%**

Design F_{45}

$F_{k,45}$ =	10.0	kN		$R_{k,45,Holz}$ =	22.6	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,45}$ =	10.0	kN	<	$R_{d,45}$ =	13.9	kN	✓
Utilization ratio							**72%**

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Reference documents for this analysis

English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General- Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
ETA-11/0030	ETA-11/0030 European Technical Approval; Rothoblaas; Self-tapping screws for use in timber structures
ETA-12/0063	SFS intec AG; Self-tapping screws for use in timber constructions
ETA-12/0062	SFA intec AG; ETA-12/0062; selftapping screws for use in timber constructions
ETA-11/0086	GH Various Angle Brackets
ETA-09/0322	GH Various Angle Brackets
ETA-11/0496	Rotho Blaas TITAN Angle Brackets
ETA-11/0190	selftaping screw by Würth
ETA-12/0373	Schmid - Screws for use in timber constructions
ETA-12/0114	SPAX - Screws for use in timber constructions
ETA-21/0670	Simpson Strong-Tie® Structural screws SWW, SWC, TTUFS, TTSFS and TTZNFS
ETA-13/0796	Simpson Strong-Tie® screws ESCR/ESCR-S, ESCRC/ESCRC-S,, ESCRS, ESCRFTC, ESCRFT/FTZ, ESCRHD/HRD, ESCRT2R, SSTA and ESCRH
ETA-20/0773	Würth - DENEB Angle Brackets and plate connectors
ETA-08/0183	Würth - Typ A + Typ V Angle Bracket
ETA-14/0274	Würth - Hold down and storey connector

storaenso

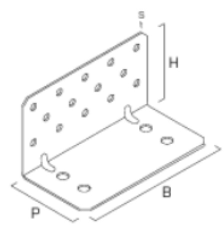
Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Disclaimer

CODES AND DIMENSIONS

TITAN S - TCS | CONCRETE-TO-TIMBER JOINTS

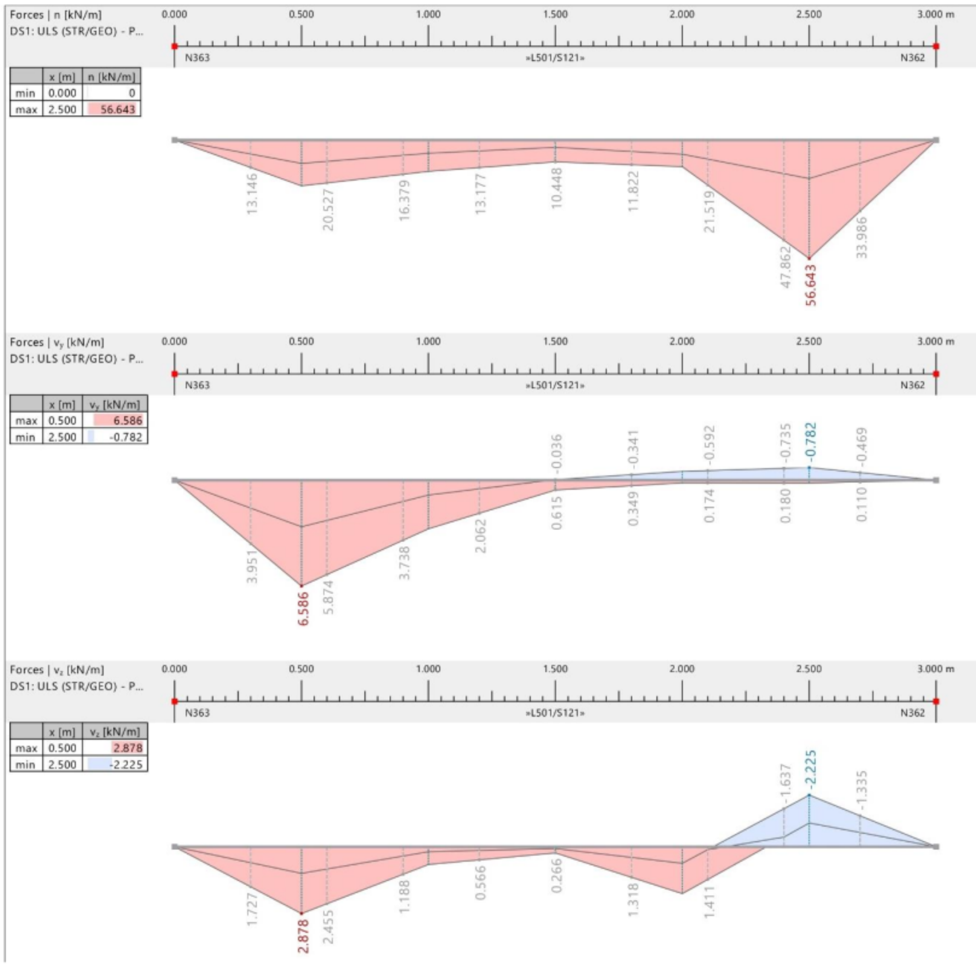
CODE	B [mm] [in]	P [mm] [in]	H [mm] [in]	holes [mm] [in]	n_V Ø11 n_V Ø0.44 [pcs]	s [mm] [in]		pcs
TCS240	240 *9 1/2*	123 *4 13/16*	130 *5 1/8*	4 x Ø17 *4 x Ø0.67*	14	3 *0.12*	●	10



Slika 35. Karakterisike odabranog spojnog sredstva

Odabrano spojno sredstvo TCS240 postavlja se na razmaku od 50 cm.

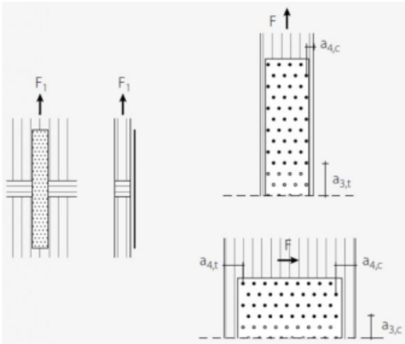
2.6.4 Spoj zid – ploča – zid



Slika 36. Dijagrami unutarnjih sila na spoju između dva zida i ploče

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Connection



F_1	56.643	kN
K_{mod}	0.8	-
Connectors	LBV1801200 / Nail 4,0x60	
Space		mm

Design F_1

$F_{k,1}$ =	56.6	kN		$R_{k,1,Holz}$ =		kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,1}$ =	56.6	kN	<	$R_{d,1}$ =	64.2	kN	✓
Utilization ratio							88%

Reference documents for this analysis

English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General- Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
ETA-11/0030	ETA-11/0030 European Technical Approval; Rothoblaas; Self-tapping screws for use in timber structures
ETA-12/0063	SFS intec AG; Self-tapping screws for use in timber constructions

storaenso

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

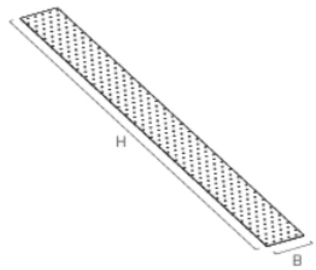
Reference documents for this analysis

English title	Description
ETA-12/0062	SFA intec AG; ETA-12/0062; selftapping screws for use in timber constructions
ETA-11/0086	GH Various Angle Brackets
ETA-09/0322	GH Various Angle Brackets
ETA-11/0496	Rotho Blaas TITAN Angle Brackets
ETA-11/0190	selftaping screw by Würth
ETA-12/0373	Schmid - Screws for use in timber constructions
ETA-12/0114	SPAX - Screws for use in timber constructions
ETA-21/0670	Simpson Strong-Tie® Structural screws SWW, SWC, TTUFS, TTSFS and TTZNFS
ETA-13/0796	Simpson Strong-Tie® screws ESCR/ESCR-S, ESCRC/ESCRC-S,, ESCRS, ESCRFTC, ESCRFT/FTZ, ESCRHD/HRD, ESCRT2R, SSTA and ESCRH
ETA-20/0773	Würth - DENEB Angle Brackets and plate connectors
ETA-08/0183	Würth - Typ A + Typ V Angle Bracket
ETA-14/0274	Würth - Hold down and storey connector

Disclaimer

LBV 2,0 x 1200 mm

CODE	B [mm]	H [mm]	s [mm]	B [in]	H [in]	s [in]	n Ø5 n Ø0.20 [pcs]		pcs
LBV401200	40	1200	2,0	1 9/16	47 1/4	0.08	90	•	20
LBV601200	60	1200	2,0	2 3/8	47 1/4	0.08	150	•	20
LBV801200	80	1200	2,0	3 1/8	47 1/4	0.08	210	•	20
LBV1001200	100	1200	2,0	4	47 1/4	0.08	270	•	10
LBV1201200	120	1200	2,0	4 3/4	47 1/4	0.08	330	•	10
LBV1401200	140	1200	2,0	5 1/2	47 1/4	0.08	390	•	10
LBV1601200	160	1200	2,0	6 1/4	47 1/4	0.08	450	•	10
LBV1801200	180	1200	2,0	7 1/8	47 1/4	0.08	510	•	10
LBV2001200	200	1200	2,0	8	47 1/4	0.08	570	•	5
LBV2201200	220	1200	2,0	8 5/8	47 1/4	0.08	630	•	5
LBV2401200	240	1200	2,0	9 1/2	47 1/4	0.08	690	•	5
LBV2601200	260	1200	2,0	10 1/4	47 1/4	0.08	750	•	5
LBV2801200	280	1200	2,0	11	47 1/4	0.08	810	•	5
LBV3001200	300	1200	2,0	11 3/4	47 1/4	0.08	870	•	5
LBV4001200	400	1200	2,0	15 3/4	47 1/4	0.08	1170	•	5



LBA

HIGH BOND NAIL

CODES AND DIMENSIONS

Zn

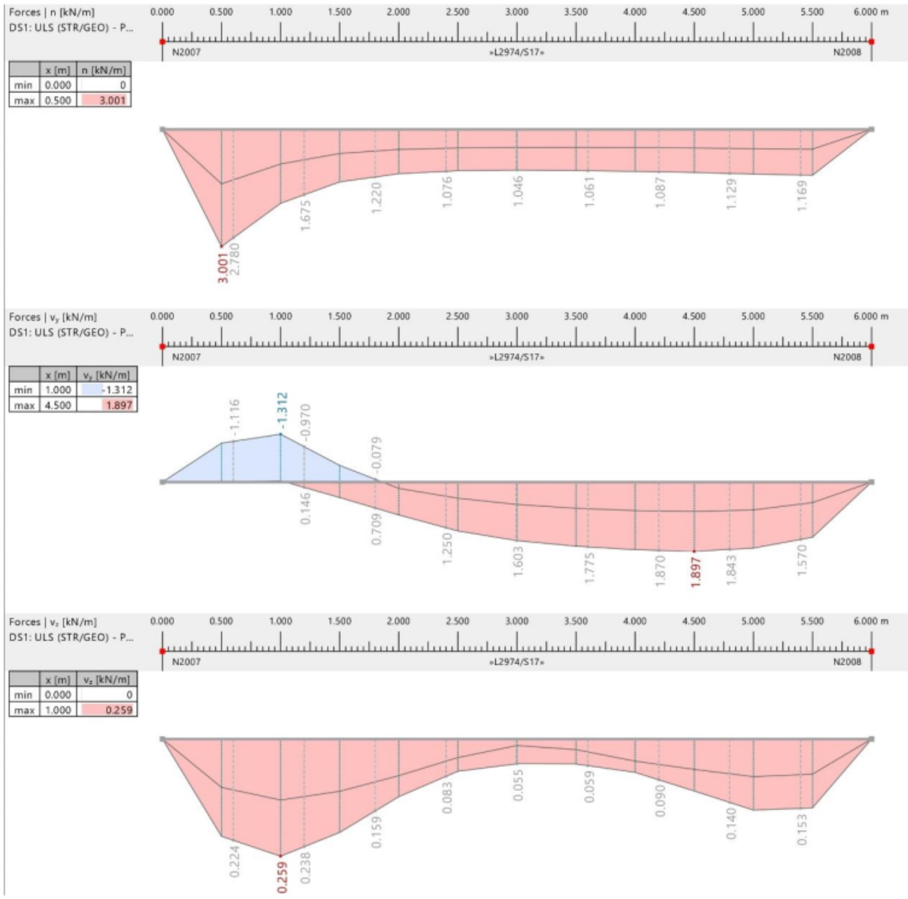
LBA - loose nails

d_1 [mm]	CODE	L [mm]	b [mm]	pcs
4	LBA440	40	30	250
	LBA450	50	40	250
	LBA460	60	50	250
	LBA475	75	65	250
	LBA4100	100	85	250
6	LBA660	60	50	250
	LBA680	80	70	250
	LBA6100	100	85	250

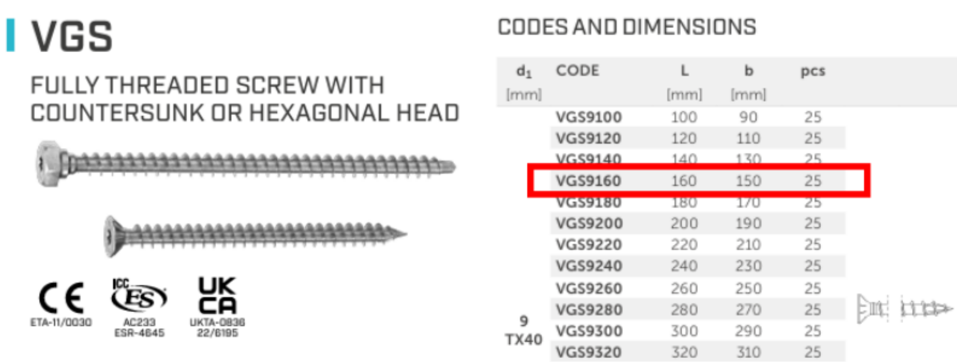
Slika 37. Karakteristike odabranog spojnog sredstva LBV iz Rothoblaas kataloga

Odabrano spojno sredstvo postavlja se na razmaku od 50 cm.

2.6.5 Nastavak ploče



Slika 38. Dijagrami unutarnjih sila na spoju između dvije ploče

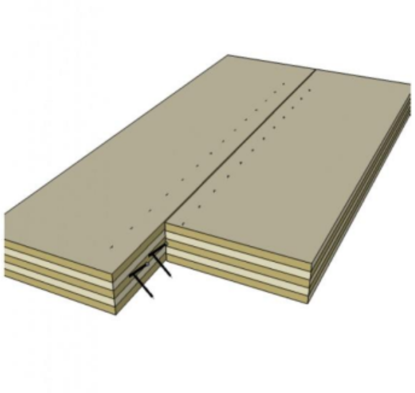


d1 [mm]	CODE	L [mm]	b [mm]	pcs
9 TX40	VGS9100	100	90	25
	VGS9120	120	110	25
	VGS9140	140	130	25
	VGS9160	160	150	25
	VGS9180	180	170	25
	VGS9200	200	190	25
	VGS9220	220	210	25
	VGS9240	240	230	25
	VGS9260	260	250	25
	VGS9280	280	270	25
	VGS9300	300	290	25
	VGS9320	320	310	25

Slika 39. Prikaz spojnog sredstva odabranog iz Rothoblaas kataloga

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Connection



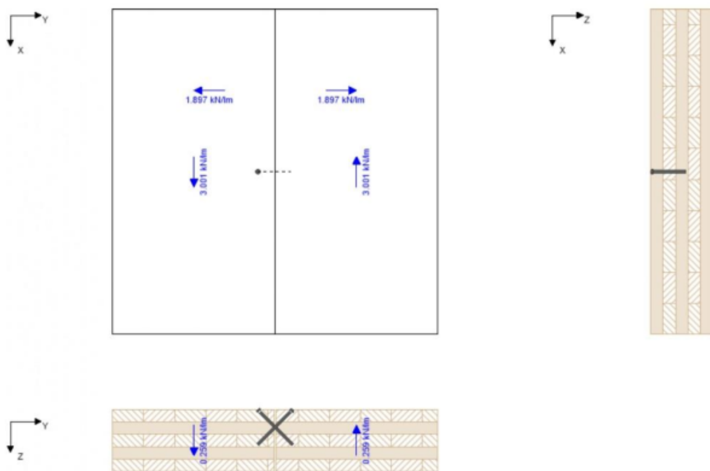
F_x	3.001	kN/lm
F_y	1.897	kN/lm
F_z	0.259	kN/lm
K_{mod}	0.8	-
Material 1	C24 spruce ETA (2022)	
ρ_k	3.85	kN/m³
Panel 1	CLT 200 L5s	
Orientation cover layer	X direction	
Connector type	Rothoblaas VGS	
Connectors	9/160	
Setup	45° / 135° alternating	
Diameter	9	mm
Head diameter	16	mm
Length	160	mm
Thread length	150	mm
Pre-drilled	✓	

Analysis

Analysis	Existing	Limit	Unit	Utilization
Thickness 1	80	48	mm	60%
Thickness 2	80	48	mm	60%
Fv	1500.5	3308.027	N	45%
Fax	1524.522	4366.833	N	35%
Combination	0.328	1	-	33%
Count	1.145	4.684	Count / lm	24%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Structural system



Minimum spacing

Name	$a_{1,min}$ [mm]	$a_{2,min}$ [mm]	$a_{3c,min}$ [mm]	$a_{3t,min}$ [mm]	$a_{4c,min}$ [mm]	$a_{4t,min}$ [mm]
CLT left	45	23	54	54	36	54
CLT right	45	23	54	54	36	54

Result in layers

Element 1

X [mm]	Thick [mm]	Typ	α [°]	l_{eff} [mm]	$l_{eff,v}$ [mm]	$F_{ax,Rk}$ [N]
0	7	L	90	0	0	0
7	33	L	90	46.6	32.9	5292
40	13	C	45	18.4	13	1904
53	27	C	45	0	0	0
80	40	L	90	0	0	0
120	40	C	45	0	0	0
160	40	L	90	0	0	0

Element 2

X [mm]	Thick [mm]	Typ	α [°]	l_{eff} [mm]	$l_{eff,v}$ [mm]	$F_{ax,Rk}$ [N]
0	40	L	90	0	0	0
40	20	C	45	0	0	0
60	20	C	45	28.1	19.9	2907
80	26	L	90	36.9	26.1	4189
106	14	L	90	0	0	0
120	40	C	45	0	0	0
160	40	L	90	0	0	0

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Results

$b_{1,min}$	$b_{2,min}$	$f_{h,k,1}$	$f_{h,k,2}$	β	$t_{pen,1}$	$t_{pen,2}$	$l_{eff,1}$	$l_{eff,2}$	$t_{1,req}$	$t_{2,req}$	$F_{ax,Rk1}$	$F_{ax,Rk2}$
[mm]	[mm]	[N/mm²]	[N/mm²]	[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[N]	[N]
0	0	20.00	20.00	1.00	80.00	80.00	65.00	65.00	48	48	7196.37	7096.10

Results

$M_{y,Rk}$	$F_{ax,Rk}$	$F_{head,Rk}$	$F_{tens,Rk}$	$F_{ki,Rk}$	$F_{v,Rk}$	$F_{v,Rd}$	$F_{v,Ed}$	$F_{ax,Rd}$	$F_{ax,Ed}$	Count	$Count_{max}$	$a_{erf.}$
[Nmm]	[N]	[N]	[kN]	[kN]	[N]	[N]	[kN/lm]	[N]	[kN/lm]	[Stk/m]	[Stk/m]	[mm]
27244.13	7096.10	0.00	25.400	16.178	5375.54	3308.03	3.00	4366.83	3.05	1.14	4.68	500

Reference documents for this analysis

English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General- Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
ETA-11/0030	ETA-11/0030 European Technical Approval; Rothoblaas; Self-tapping screws for use in timber structures
ETA-12/0063	SFS intec AG; Self-tapping screws for use in timber constructions
ETA-12/0062	SFA intec AG; ETA-12/0062; selftapping screws for use in timber constructions
ETA-11/0086	GH Various Angle Brackets
ETA-09/0322	GH Various Angle Brackets
ETA-11/0496	Rotho Blaas TITAN Angle Brackets
ETA-11/0190	selftaping screw by Würth
ETA-12/0373	Schmid - Screws for use in timber constructions
ETA-12/0114	SPAX - Screws for use in timber constructions

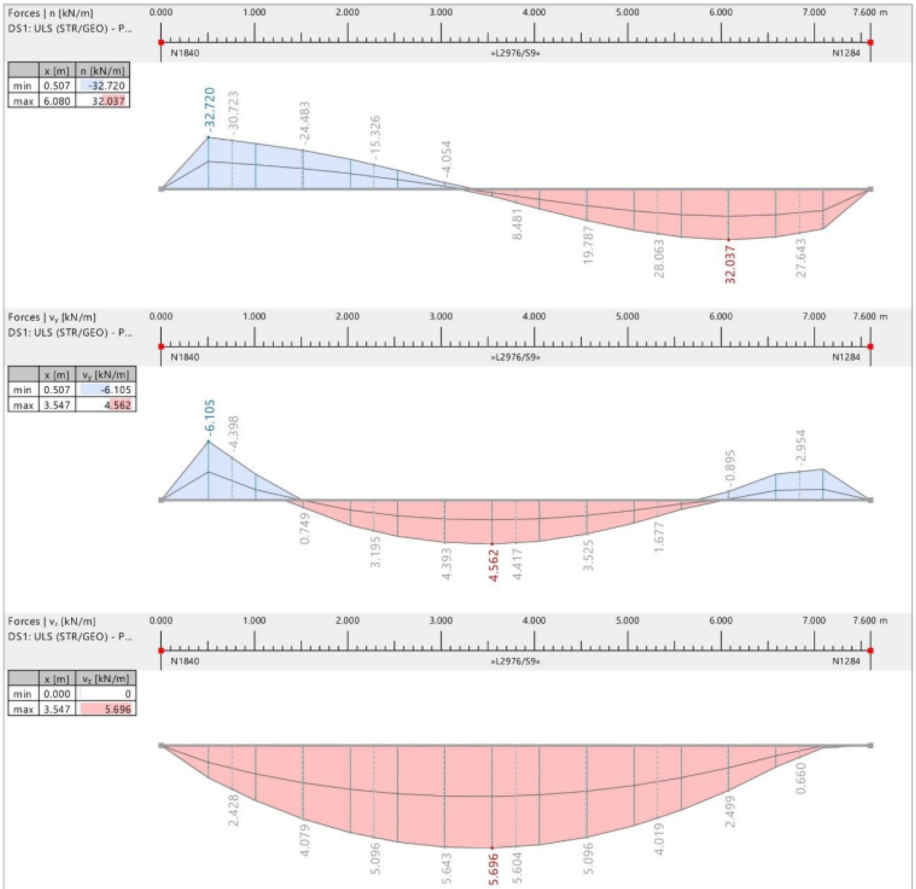
Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Reference documents for this analysis

English title	Description
ETA-21/0670	Simpson Strong-Tie® Structural screws SWW, SWC, TTUFS, TTSFS and TTZNFS
ETA-13/0796	Simpson Strong-Tie® screws ESCR/ESCR-S, ESCRC/ESCRC-S,, ESCRS, ESCRFTC, ESCRFT/FTZ, ESCRHD/HRD, ESCRT2R, SSTA and ESCRH
ETA-20/0773	Würth - DENEB Angle Brackets and plate connectors
ETA-08/0183	Würth - Typ A + Typ V Angle Bracket
ETA-14/0274	Würth - Hold down and storey connector

Disclaimer

2.6.6 Spoj CLT ploče i čelične grede



Slika 40. Dijagrami unutarnjih sila na spoju između CLT ploče i čelične grede

HBS PLATE

PAN HEAD SCREW FOR PLATES

CODES AND DIMENSIONS

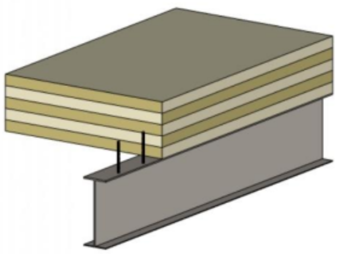
HBS PLATE

d_1 [mm]	CODE	L [mm]	b [mm]	A_P [mm]	pcs
8 TX 40	**HBSPL860**	60	52	1÷10	100
	HBSPL880	80	55	1÷15	100
	HBSPL8100	100	75	1÷15	100
	HBSPL8120	120	95	1÷15	100
	HBSPL8140	140	110	1÷20	100
	HBSPL8160	160	130	1÷20	100

Slika 41. Prikaz spojnog sredstva odabranog iz Rothoblaas kataloga

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Connection



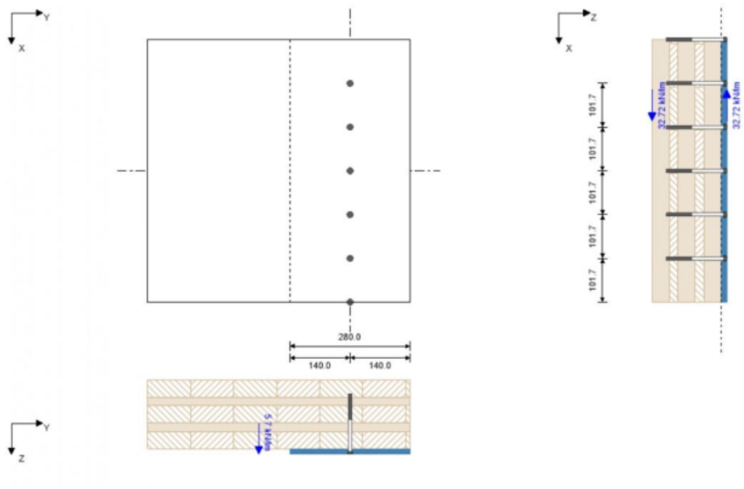
F_x	32.72	kN/lm
F_z	5.7	kN/lm
K_{mod}	0.8	-
Material 1	Steel S355	
ρ_k		kN/m³
Material 2	C24 spruce ETA (2022)	
ρ_k	3.85	kN/m³
Panel 2	CLT 160 L5s	
Orientation cover layer	✓	
Connector type	Rothoblaas HBS	
Connectors	8/140	
Diameter	8	mm
Head diameter	14.5	mm
Length	140	mm
Thread length	60	mm
Number of rows	1	
Steel element width	280	mm
Steel element thickness	13	mm

Analysis

Analysis	Existing	Limit	Unit	Utilization
Width 2	280	48	mm	17%
Thickness 2	127	25	mm	20%
Fv	3328.873	3388.37	N	98%
Fax	579.908	3108.183	N	19%
Combination	1	1	-	100%
Count	9.829	31.25	Count / lm	31%

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Structural system



Minimum spacing

Name	$a_{1,min}$	$a_{2,min}$	$a_{3c,min}$	$a_{3t,min}$	$a_{4c,min}$	$a_{4t,min}$
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
CLT	32	20	48	48	20	48

Result in layers

Element 2

X	Thick	Typ	α	l_{ef}	$l_{ef,v}$	$F_{ax,Rk}$
[mm]	[mm]		[°]	[mm]	[mm]	[N]
0	5	L	90	0	0	0
5	35	L	90	35	35	3536
40	15	C	90	15	15	1515
55	5	C	90	0	0	0
60	40	L	90	0	0	0
100	20	C	90	0	0	0
120	40	L	90	0	0	0

Marija Gulam
University of Zagreb,
Faculty of Civil
Engineering

Results

$b_{1,min}$	$b_{2,min}$	$f_{h,k,1}$	$f_{h,k,2}$	β	$t_{pen,1}$	$t_{pen,2}$	$l_{eff,1}$	$l_{eff,2}$	$t_{1,req}$	$t_{2,req}$	$F_{ax,Rk1}$	$F_{ax,Rk2}$
[mm]	[mm]	[N/mm²]	[N/mm²]	[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[N]	[N]
0	48	0.00	21.21	0.00	13.00	127.00	0.00	50.00	0	25	0.00	5050.80

Results

$M_{y,Rk}$	$F_{ax,Rk}$	$F_{head,Rk}$	$F_{tens,Rk}$	$F_{ki,Rk}$	$F_{v,Rk}$	$F_{v,Rd}$	$F_{v,Ed}$	$F_{ax,Rd}$	$F_{ax,Ed}$	Count	$Count_{max}$	$a_{erf.}$
[Nmm]	[N]	[N]	[kN]	[kN]	[N]	[N]	[kN/lm]	[N]	[kN/lm]	[Stk/m]	[Stk/m]	[mm]
20057.48	5050.80	0.00	20.100	0.000	5506.10	3388.37	32.72	3108.18	5.70	9.83	31.25	102

Reference documents for this analysis

English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
EN 1990	EN 1990 - Eurocode ? Basis of structural design
ÖNorm B 1995-1-1 NA	ÖNORM EN 1995-1-1 - Austria - National Annex – Nationally determined parameters – Eurocode 5: Design of timber structures – Part 1-1: General- Common rules and rules for buildings
ÖNorm B 1995-1-2 NA	ÖNORM EN 1995-1-2 - Austria - National Annex - Eurocode 5: Design of timber structures ? Part 1-2: General ? Structural fire design ? National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements
ETA-11/0030	ETA-11/0030 European Technical Approval; Rothoblaas; Self-tapping screws for use in timber structures
ETA-12/0063	SFS intec AG; Self-tapping screws for use in timber constructions
ETA-12/0062	SFA intec AG; ETA-12/0062; selftapping screws for use in timber constructions
ETA-11/0086	GH Various Angle Brackets
ETA-09/0322	GH Various Angle Brackets
ETA-11/0496	Rotho Blaas TITAN Angle Brackets
ETA-11/0190	selftaping screw by Würth
ETA-12/0373	Schmid - Screws for use in timber constructions
ETA-12/0114	SPAX - Screws for use in timber constructions

Marija Gulam
University of Zagreb, Faculty of Civil Engineering

Reference documents for this analysis	
English title	Description
ETA-21/0670	Simpson Strong-Tie® Structural screws SWW, SWC, TTUFS, TTSFS and TTZNFS
ETA-13/0796	Simpson Strong-Tie® screws ESCR/ESCR-S, ESCRC/ESCRC-S,, ESCRS, ESCRFTC, ESCRFT/FTZ, ESCRHD/HRD, ESCRT2R, SSTA and ESCRH
ETA-20/0773	Würth - DENEB Angle Brackets and plate connectors
ETA-08/0183	Würth - Typ A + Typ V Angle Bracket
ETA-14/0274	Würth - Hold down and storey connector

Disclaimer

2.7 Iskaz materijala

Tablica 1. Količine AB površina za zgradu A

Thickness Name	Surfaces No.	Q [--]	S [m²]	V [m³]	M [kg/m²]	M [t]	S∑ [m²]	V∑ [m³]	M∑ [t]
Uniform | d: 200.0 mm | 4 - C35/45	158	1.00	107.081	21.416	500.00	53.541	107.081	21.416	53.541
Uniform | d: 200.0 mm | 4 - C35/45	115	1.00	90.120	18.024	500.00	45.060	90.120	18.024	45.060
Uniform | d: 200.0 mm | 4 - C35/45	305	1.00	87.801	17.560	500.00	43.901	87.801	17.560	43.901
Uniform | d: 200.0 mm | 4 - C35/45	207,215, 224, 232	4.00	60.000	12.000	500.00	30.000	239.999	48.000	120.000
Uniform | d: 200.0 mm | 4 - C35/45	274	1.00	48.600	9.720	500.00	24.300	48.600	9.720	24.300
Uniform | d: 200.0 mm | 4 - C35/45	153	1.00	29.040	5.808	500.00	14.520	29.040	5.808	14.520
Uniform | d: 200.0 mm | 4 - C35/45	143-152	10.00	26.400	5.280	500.00	13.200	263.999	52.800	132.000
Uniform | d: 200.0 mm | 4 - C35/45	203	1.00	14.850	2.970	500.00	7.425	14.850	2.970	7.425
Uniform | d: 200.0 mm | 4 - C35/45	193-202	10.00	13.500	2.700	500.00	6.750	135.000	27.000	67.500
Uniform | d: 200.0 mm | 4 - C35/45	119	1.00	8.400	1.680	500.00	4.200	8.400	1.680	4.200
Uniform | d: 200.0 mm | 4 - C35/45	42	1.00	7.920	1.584	500.00	3.960	7.920	1.584	3.960
Uniform | d: 200.0 mm | 4 - C35/45	32-41	10.00	7.200	1.440	500.00	3.600	72.000	14.400	36.000
Uniform | d: 200.0 mm | 4 - C35/45	69	1.00	4.950	0.990	500.00	2.475	4.950	0.990	2.475
Uniform | d: 200.0 mm | 4 - C35/45	59-68	10.00	4.500	0.900	500.00	2.250	45.000	9.000	22.500
Uniform | d: 200.0 mm | 4 - C35/45	285,296	2.00	3.960	0.792	500.00	1.980	7.920	1.584	3.960
Uniform | d: 200.0 mm | 4 - C35/45	275-284,286-295	20.00	3.600	0.720	500.00	1.800	72.000	14.400	36.000
∑		75.00					1234.680	246.936	617.340

Tablica 2. Količine CLT ploča d=200 mm za međukatne i krovne konstrukcije zgrade A

Thickness Name	Surfaces No.	Q [--]	S [m²]	V [m³]	M [kg/m²]	M [t]	S∑ [m²]	V∑ [m³]	M∑ [t]
Layers | d : 200.0 mm | CLT 200 L5s |	154-157	4.00	107.081	21.416	84.00	8.995	428.324	85.665	35.979
Layers | d : 200.0 mm | CLT 200 L5s |	303, 304	2.00	87.801	17.560	84.00	7.375	175.603	35.121	14.751
Layers | d : 200.0 mm | CLT 200 L5s |	186-192	7.00	84.107	16.821	84.00	7.065	588.750	117.750	49.455
Layers | d : 200.0 mm | CLT 200 L5s |	175-180	6.00	80.461	16.092	84.00	6.759	482.764	96.553	40.552

Layers | d : 200.0 mm | CLT 200 L5s |	97-99	3.00	75.720	15.144	84.00	6.360	227.159	45.432	19.081
Layers | d : 200.0 mm | CLT 200 L5s |	185	1.00	73.741	14.748	84.00	6.194	73.741	14.748	6.194
Layers | d : 200.0 mm | CLT 200 L5s |	181-184	4.00	70.800	14.160	84.00	5.947	283.199	56.640	23.789
Layers | d : 200.0 mm | CLT 200 L5s |	298-302	5.00	63.435	12.687	84.00	5.329	317.175	63.435	26.643
Layers | d : 200.0 mm | CLT 200 L5s |	204-206,212-214,221, 222,229,230	10.00	60.000	12.000	84.00	5.040	599.998	120.000	50.400
Layers | d : 200.0 mm | CLT 200 L5s |	267-269	3.00	51.802	10.360	84.00	4.351	155.405	31.081	13.054
Layers | d : 200.0 mm | CLT 200 L5s |	270-273	4.00	48.600	9.720	84.00	4.082	194.399	38.880	16.330
Layers | d : 200.0 mm | CLT 200 L5s |	171-174	4.00	44.437	8.887	84.00	3.733	177.749	35.550	14.931
Layers | d : 200.0 mm | CLT 200 L5s |	15,18	2.00	39.000	7.800	84.00	3.276	78.000	15.600	6.552
Layers | d : 200.0 mm | CLT 200 L5s |	12	1.00	33.344	6.669	84.00	2.801	33.344	6.669	2.801
Layers | d : 200.0 mm | CLT 200 L5s |	11	1.00	30.091	6.018	84.00	2.528	30.091	6.018	2.528
Layers | d : 200.0 mm | CLT 200 L5s |	116	1.00	25.800	5.160	84.00	2.167	25.800	5.160	2.167
Layers | d : 200.0 mm | CLT 200 L5s |	20	1.00	22.974	4.595	84.00	1.930	22.974	4.595	1.930
Layers | d : 200.0 mm | CLT 200 L5s |	16,17	2.00	21.000	4.200	84.00	1.764	42.000	8.400	3.528
Layers | d : 200.0 mm | CLT 200 L5s |	71,73,75,77	4.00	10.800	2.160	84.00	0.907	43.200	8.640	3.629
Layers | d : 200.0 mm | CLT 200 L5s |	408-410,413-415,418-420, 423-425	12.00	9.000	1.800	84.00	0.756	108.000	21.600	9.072
Layers | d : 200.0 mm | CLT 200 L5s |	118,526	2.00	6.720	1.344	84.00	0.564	13.440	2.688	1.129
Layers | d : 200.0 mm | CLT 200 L5s |	343	1.00	0.659	0.132	84.00	0.055	0.659	0.132	0.055
∑		80					4101.772	820.354	344.549

Tablica 3. Količine CLT ploča d=140 mm za zidove zgrade A

Thickness Name	Surfaces No.	Q [--]	S [m²]	V [m³]	M [kg/m²]	M [t]	S∑ [m²]	V∑ [m³]	M∑ [t]
Layers | d : 140.0 mm | CLT 140 L5s |	211,220,228	3.00	33.000	4.620	58.80	1.940	99.000	13.860	5.821
Layers | d : 140.0 mm | CLT 140 L5s |	208-210,216-219, 225-227, 233-236	14.00	30.000	4.200	58.80	1.764	419.999	58.800	24.696
Layers | d : 140.0 mm | CLT 140 L5s |	125	1.00	27.964	3.915	58.80	1.644	27.964	3.915	1.644
Layers | d : 140.0 mm | CLT 140 L5s |	257,258	2.00	27.800	3.892	58.80	1.635	55.600	7.784	3.269
Layers | d : 140.0 mm | CLT 140 L5s |	266	1.00	24.750	3.465	58.80	1.455	24.750	3.465	1.455
Layers | d : 140.0 mm | CLT 140 L5s |	126-129	4.00	23.522	3.293	58.80	1.383	94.087	13.172	5.532
Layers | d : 140.0 mm | CLT 140 L5s |	262-265	4.00	22.500	3.150	58.80	1.323	90.000	12.600	5.292
Layers | d : 140.0 mm | CLT 140 L5s |	142	1.00	19.800	2.772	58.80	1.164	19.800	2.772	1.164
Layers | d : 140.0 mm | CLT 140 L5s |	159-164	6.00	18.838	2.637	58.80	1.108	113.026	15.824	6.646
Layers | d : 140.0 mm | CLT 140 L5s |	10	1.00	17.851	2.499	58.80	1.050	17.851	2.499	1.050
Layers | d : 140.0 mm | CLT 140 L5s |	6-9	4.00	16.228	2.272	58.80	0.954	64.914	9.088	3.817
Layers | d : 140.0 mm | CLT 140 L5s |	104,112	2.00	15.300	2.142	58.80	0.900	30.600	4.284	1.799
Layers | d : 140.0 mm | CLT 140 L5s |	14	1.00	13.938	1.951	58.80	0.820	13.938	1.951	0.820
Layers | d : 140.0 mm | CLT 140 L5s |	366-375	10.00	13.861	1.941	58.80	0.815	138.615	19.406	8.151
Layers | d : 140.0 mm | CLT 140 L5s |	13	1.00	13.760	1.926	58.80	0.809	13.760	1.926	0.809
Layers | d : 140.0 mm | CLT 140 L5s |	165-170	6.00	13.300	1.862	58.80	0.782	79.800	11.172	4.692
Layers | d : 140.0 mm | CLT 140 L5s |	26-30,43-53	16.00	13.200	1.848	58.80	0.776	211.199	29.568	12.419
Layers | d : 140.0 mm | CLT 140 L5s |	100-102,106-110, 113,114,139-141	13.00	13.100	1.834	58.80	0.770	170.300	23.842	10.014
Layers | d : 140.0 mm | CLT 140 L5s |	383-386	4.00	12.800	1.792	58.80	0.753	51.200	7.168	3.011

Layers | d : 140.0 mm | CLT 140 L5s |	25	1.00	11.550	1.617	58.80	0.679	11.550	1.617	0.679
Layers | d : 140.0 mm | CLT 140 L5s |	396,405	2.00	10.850	1.519	58.80	0.638	21.700	3.038	1.276
Layers | d : 140.0 mm | CLT 140 L5s |	21-24	4.00	10.500	1.470	58.80	0.617	42.000	5.880	2.470
Layers | d : 140.0 mm | CLT 140 L5s |	325	1.00	9.900	1.386	58.80	0.582	9.900	1.386	0.582
Layers | d : 140.0 mm | CLT 140 L5s |	103,111,117, 391,395,401	6.00	9.800	1.372	58.80	0.576	58.800	8.232	3.457
Layers | d : 140.0 mm | CLT 140 L5s |	31,387-390, 392-394, 397-400,402-404	15.00	9.200	1.288	58.80	0.541	138.000	19.320	8.114
Layers | d : 140.0 mm | CLT 140 L5s |	315-324	10.00	9.000	1.260	58.80	0.529	90.000	12.600	5.292
Layers | d : 140.0 mm | CLT 140 L5s |	376-381	6.00	8.300	1.162	58.80	0.488	49.800	6.972	2.928
Layers | d : 140.0 mm | CLT 140 L5s |	124	1.00	8.250	1.155	58.80	0.485	8.250	1.155	0.485
Layers | d : 140.0 mm | CLT 140 L5s |	120-123	4.00	7.500	1.050	58.80	0.441	30.000	4.200	1.764
Layers | d : 140.0 mm | CLT 140 L5s |	70,72,74,76,78	5.00	5.400	0.756	58.80	0.318	27.000	3.780	1.588
Layers | d : 140.0 mm | CLT 140 L5s |	5	1.00	4.955	0.694	58.80	0.291	4.955	0.694	0.291
Layers | d : 140.0 mm | CLT 140 L5s |	1-4	4.00	4.505	0.631	58.80	0.265	18.020	2.523	1.060
Layers | d : 140.0 mm | CLT 140 L5s |	406,407,411, 412,416,417, 421,422,426,427	10.00	4.500	0.630	58.80	0.265	45.000	6.300	2.646
Layers | d : 140.0 mm | CLT 140 L5s |	336,358	2.00	4.132	0.578	58.80	0.243	8.264	1.157	0.486
Layers | d : 140.0 mm | CLT 140 L5s |	326-335,348-357	20.00	3.756	0.526	58.80	0.221	75.125	10.518	4.417
Layers | d : 140.0 mm | CLT 140 L5s |	337-342,359-364	12.00	3.444	0.482	58.80	0.203	41.330	5.786	2.430
∑		198.00					2416.092	338.253	142.066

Tablica 4. Količine stupova GL32h za zgradu A

Section Name	Members No.	Q [--]	L [m]	Am [m²/m]	V [m³]	M [kg/m]	M [t]	L∑ [m]	Am, ∑ [m²]	V∑ [m³]	M∑ [t]
200/200 GL32h	1,2	2.00	3.300	0.800	0.132	19.6	0.065	6.600	5.440	0.264	0.129
∑		2.00						6.600	5.440	0.264	0.129

Tablica 5. Količine AB površina za zgradu B

Thickness Name	Surfaces No.	Q [--]	S [m²]	V [m³]	M [kg/m²]	M [t]	S∑ [m²]	V∑ [m³]	M∑ [t]
Uniform | d: 200.0 mm | 4 - C35/45	455	1.00	70.200	14.040	500.00	35.100	70.200	14.040	35.100
Uniform | d: 200.0 mm | 4 - C35/45	495	1.00	68.400	13.680	500.00	34.200	68.400	13.680	34.200
Uniform | d: 200.0 mm | 4 - C35/45	92,250,450	3.00	60.000	12.000	500.00	30.000	179.999	36.000	90.000
Uniform | d: 200.0 mm | 4 - C35/45	347	1.00	40.500	8.100	500.00	20.250	40.500	8.100	20.250
Uniform | d: 200.0 mm | 4 - C35/45	501	1.00	29.700	5.940	500.00	14.850	29.700	5.940	14.850
Uniform | d: 200.0 mm | 4 - C35/45	496-500	5.00	27.000	5.400	500.00	13.500	135.000	27.000	67.500
Uniform | d: 200.0 mm | 4 - C35/45	512	1.00	14.850	2.970	500.00	7.425	14.850	2.970	7.425
Uniform | d: 200.0 mm | 4 - C35/45	507-511	5.00	13.500	2.700	500.00	6.750	67.500	13.500	33.750
Uniform | d: 200.0 mm | 4 - C35/45	524	1.00	7.920	1.584	500.00	3.960	7.920	1.584	3.960
Uniform | d: 200.0 mm | 4 - C35/45	519-523	5.00	7.200	1.440	500.00	3.600	36.000	7.200	18.000
Uniform | d: 200.0 mm | 4 - C35/45	469,482	2.00	4.950	0.990	500.00	2.475	9.900	1.980	4.950
Uniform | d: 200.0 mm | 4 - C35/45	464-468, 477-481	10.00	4.500	0.900	500.00	2.250	45.000	9.000	22.500
∑		36.00					704.968	140.994	352.484

Tablica 6. Količine CLT ploča d=200 mm za međukatne i krovne konstrukcije zgrade B

Thickness Name	Surfaces No.	Q [--]	S [m²]	V [m³]	M [kg/m²]	M [t]	S∑ [m²]	V∑ [m³]	M∑ [t]
Layers | d : 200.0 mm | CLT 200 L5s |	93,251,451	3.00	70.800	14.160	84.00	5.947	212.399	42.480	17.842
Layers | d : 200.0 mm | CLT 200 L5s |	88-91,246-249,446-449	12.00	60.000	12.000	84.00	5.040	719.997	143.999	60.480
Layers | d : 200.0 mm | CLT 200 L5s |	429-432	4.00	57.150	11.430	84.00	4.801	228.599	45.720	19.202
Layers | d : 200.0 mm | CLT 200 L5s |	54,261,428	3.00	44.437	8.887	84.00	3.733	133.312	26.662	11.198
Layers | d : 200.0 mm | CLT 200 L5s |	344-346	3.00	40.500	8.100	84.00	3.402	121.500	24.300	10.206
Layers | d : 200.0 mm | CLT 200 L5s |	483,484	2.00	24.750	4.950	84.00	2.079	49.500	9.900	4.158
Layers | d : 200.0 mm | CLT 200 L5s |	485-487	3.00	13.500	2.700	84.00	1.134	40.500	8.100	3.402
Layers | d : 200.0 mm | CLT 200 L5s |	95,255,453	3.00	10.800	2.160	84.00	0.907	32.400	6.480	2.722
Layers | d : 200.0 mm | CLT 200 L5s |	79-81,237-239,437-439	9.00	9.000	1.800	84.00	0.756	81.000	16.200	6.804
∑		42.00					1619.21	323.84	136.01

Tablica 7. Količine CLT ploča d=160 mm za međukatne i krovne konstrukcije zgrade B

Thickness Name	Surfaces No.	Q [--]	S [m²]	V [m³]	M [kg/m²]	M [t]	S∑ [m²]	V∑ [m³]	M∑ [t]
Layers | d : 160.0 mm | CLT 160 L5s |	489-492,494	5.00	68.400	10.944	67.20	4.596	341.999	54.720	22.982
Layers | d : 160.0 mm | CLT 160 L5s |	9	1.00	34.201	5.472	67.20	2.298	34.201	5.472	2.298
Layers | d : 160.0 mm | CLT 160 L5s |	7	1.00	34.199	5.472	67.20	2.298	34.199	5.472	2.298
∑		7.00					410.40	65.66	27.58

V

Tablica 8. Količine CLT ploča d=140 mm za zidove zgrade B

Thickness Name	Surfaces No.	Q [--]	S [m²]	V [m³]	M [kg/m²]	M [t]	S∑ [m²]	V∑ [m³]	M∑ [t]
Layers | d : 140.0 mm | CLT 140 L5s |	18,137,313	3.00	33.000	4.620	58.80	1.940	99.000	13.860	5.821
Layers | d : 140.0 mm | CLT 140 L5s |	13-16,134-136, 308-311,528,531	13.00	30.000	4.200	58.80	1.764	389.999	54.600	22.932
Layers | d : 140.0 mm | CLT 140 L5s |	17,132	2.00	27.800	3.892	58.80	1.635	55.600	7.784	3.269
Layers | d : 140.0 mm | CLT 140 L5s |	463	1.00	25.080	3.511	58.80	1.475	25.080	3.511	1.475
Layers | d : 140.0 mm | CLT 140 L5s |	458-461,529	5.00	22.800	3.192	58.80	1.341	114.000	15.960	6.703
Layers | d : 140.0 mm | CLT 140 L5s |	518	1.00	21.080	2.951	58.80	1.240	21.080	2.951	1.240
Layers | d : 140.0 mm | CLT 140 L5s |	513-516,525	5.00	18.800	2.632	58.80	1.105	94.000	13.160	5.527
Layers | d : 140.0 mm | CLT 140 L5s |	4	1.00	15.950	2.233	58.80	0.938	15.950	2.233	0.938
Layers | d : 140.0 mm | CLT 140 L5s |	252,253	2.00	15.300	2.142	58.80	0.900	30.600	4.284	1.799
Layers | d : 140.0 mm | CLT 140 L5s |	502-506	5.00	14.900	2.086	58.80	0.876	74.500	10.430	4.381
Layers | d : 140.0 mm | CLT 140 L5s |	96,256,454	3.00	13.200	1.848	58.80	0.776	39.600	5.544	2.328
Layers | d : 140.0 mm | CLT 140 L5s |	55-58,259, 260,433-436	10.00	13.100	1.834	58.80	0.770	131.000	18.340	7.703
Layers | d : 140.0 mm | CLT 140 L5s |	1-3,5,6,8	6.00	9.800	1.372	58.80	0.576	58.800	8.232	3.457
Layers | d : 140.0 mm | CLT 140 L5s |	82-86,240-244,440-444	15.00	9.200	1.288	58.80	0.541	137.999	19.320	8.114
Layers | d : 140.0 mm | CLT 140 L5s |	19,138, 314,476	4.00	5.400	0.756	58.80	0.318	21.600	3.024	1.270
Layers | d : 140.0 mm | CLT 140 L5s |	11,12,130,131, 306,307,456,457	8.00	4.500	0.630	58.80	0.265	36.000	5.040	2.117
Layers | d : 140.0 mm | CLT 140 L5s |	475	1.00	2.970	0.416	58.80	0.175	2.970	0.416	0.175
Layers | d : 140.0 mm | CLT 140 L5s |	470-473,530	5.00	2.700	0.378	58.80	0.159	13.500	1.890	0.794
∑		90.00					1361.28	190.58	80.04

Tablica 9. Količine greda HE280A za zgradu B

Section Name	Members No.	Q [--]	L [m]	Am [m²/m]	V [m³]	M [kg/m]	M [t]	L∑ [m]	Am, ∑ [m²]	V∑ [m³]	M∑ [t]
HE 280 A S355	3-8	6.00	7.600	1.603	0.074	76.4	0.580	45.600	73.201	0.444	3.483
∑		6.00						45.600	73.201	0.444	3.483

3 ZAKLJUČAK

U posljednje vrijeme, drvo je postalo ključni materijal u modernoj gradnji, osobito u izgradnji višekatnih zgrada i hibridnih sustava koji kombiniraju drvo s betonom i čelikom. Materijali na bazi drva, na primjer CLT i LLD imaju sve veću primjenu, kako samostalnu, tako i zajedničku radi maksimalne iskoristivosti njihovih prednosti.

Ovaj trend reflektira rastuću potražnju za održivim građevinskim rješenjima koja smanjuju emisiju CO_2 i omogućuju brzu gradnju. Kombinacija drva s tradicionalnim materijalima poput betona i čelika pruža stabilnost i prilagodljivost, osobito u seizmičkim područjima.

U ovom diplomskom radu analizirana je drvena konstrukcija visoke zgrade s betonskom jezgrom i podrumom, koja je prošla sve provjere graničnih stanja nosivosti i uporabivosti. Projekt mi je omogućio bolje razumijevanje prednosti i potencijala drvenih konstrukcija. Drvo nudi održivost, brzu gradnju i estetsku vrijednost, a istraživanje novih materijala ključno je za budućnost građevinarstva.

Iako CLT u Hrvatskoj još uvijek nije široko zastupljen, ova zgrada predstavlja primjer gradnje koji bi mogao postati sve češći u budućnosti. Rastuća svijest o prednostima ovog materijala ukazuje na to da će se CLT sve više primjenjivati u različitim vrstama objekata. S porastom potražnje za održivim rješenjima, očekuje se da će ovakvi projekti, koji kombiniraju inovativnost i funkcionalnost, postati standard u suvremenoj arhitekturi i graditeljstvu u Hrvatskoj.

Zaključno, drvo u kombinaciji s naprednim tehnologijama nudi inovativna, održiva rješenja koja mogu unaprijediti građevinske metode i doprinijeti ekološki prihvatljivijoj budućnosti građevinske industrije.

POPIS LITERATURE

[1] Jeleč, M., Varevac, D., Rajčić, V.: Križno lamelirano drvo (CLT) – pregled stanja područja, *GRAĐEVINAR, 70* (2018) 2, pp. 75-95: https://hrcak.srce.hr/clanak/291371%3F

[2] Bjelinović, A., Rajčić V.: Drvene konstrukcije prema europskim normama, Hrvatska Sveučilišna naklada: Građevinski fakultet Sveučilišta u Zagrebu, Zagreb, 2005.

[3] https://climate.mit.edu/ask-mit/how-does-climate-impact-cross-laminated-timber-compare-steel-or-concrete

[4] https://projects.research-and-innovation.ec.europa.eu/en/horizon-magazine/they-can-capture-more-carbon-they-emit-so-why-arent-wooden-buildings-mainstream

[5] Brandner, R., Flatscher, G., Ringhofer, A., Schickhofer, G., & Thiel, A. (2016). Cross laminated timber (CLT): overview and development. *European Journal of Wood and Wood Products*, *74* (3). https://doi.org/10.1007/s00107-015-0999-5

[6] https://www.dlubal.com/en/solutions/online-services/snow-load-wind-speed-and-seismic-load-maps

[7] Plates and conectors for timber, Rothoblaas

POPIS SLIKA

Slika 1. Slaganje lamela unutar jednog panela ... 1
Slika 2. Geometrijske karakteristike CLT elemenata za djelovanje okomito na ravninu (lijevo) i djelovanje u ravnini (desno) ... 2
Slika 3. Postupak proizvodnje CLT panela ... 3
Slika 4. Pregled emisije ugljikovog dioksida za zgrade od različitih materijala ... 4
Slika 5. Shematski prikaz gradnje s CLT panelima ... 5
Slika 6. Shematski prikaz gradnje sa LLD stupovima i gredama ... 6
Slika 7. Mjøstårnet, Norveška ... 7
Slika 8. Brock Commons Tallwood House, Vancouver, Kanada ... 7
Slika 9. Ascent, SAD ... 8
Slika 10. 55 Southbank Boulevard, Melbourne, Australia ... 8
Slika 11. Situacija ... 9
Slika 12. Mikrolokacija postojećeg bloka ... 9
Slika 13. Pogled na zgradu - sjeverozapad Slika 14. Pogled na zgradu - sjeveroistok ... 10
Slika 15. Pogled na zgradu - sjeveroistok ... 10
Slika 16. Prikaz modela zgrade – Dlubal RFEM ... 12
Slika 17. Karakteristična vrijednost opterećenja snijegom na tlo za lokaciju Zagreb ... 13
Slika 18. Osnovna brzina vjetra za lokaciju Zagreb ... 14
Slika 19. Koeficijent izloženosti ... 15
Slika 20. Koeficijenti vanjskog tlaka za vertikalne zidove građevina pravokutnog tlocrta ... 16
Slika 21. Koeficijenti vanjskog tlaka za ravne krovove ... 16
Slika 22. Koeficijenti vanjskog tlaka za zidove i ravne krovove za zgradu A – Slučaj 1 i 2 ... 18
Slika 23. Koeficijenti vanjskog tlaka za zidove i ravne krovove za zgradu A – Slučaj 3 i 4 ... 19
Slika 24. Koeficijenti vanjskog tlaka za zidove i ravne krovove za zgradu B – Slučaj 1 i 2 ... 21
Slika 25. Koeficijenti vanjskog tlaka za zidove i ravne krovove za zgradu A – Slučaj 3 i 4 ... 22
Slika 26. Prikaz povratnih perioda i ubrzanja tla za Zagreb ... 24
Slika 27. Dijagrami unutarnjih sila na spoju između CLT zida i betonske ploče ... 171
Slika 28. Karakteristike odabranog spojnog sredstva TCS240 iz Rothoblaas kataloga ... 175
Slika 29. Karakteristike odabranog spojnog sredstva WHT20 iz Rothoblaas kataloga ... 176
Slika 30. Karakteristike odabranog spojnog sredstva WHT20 iz Rothoblaas kataloga ... 177
Slika 31. Dijagrami unutarnjih sila na spoju između zidova ... 178
Slika 32. Prikaz izvedenog spoja zidova i ploča od CLT-a sa spojnim sredstvom TCS240 182
Slika 33. Karakteristike odabranog spojnog sredstva ... 182

Slika 34. Dijagrami unutarnjih sila na spoju između CLT zida i ploče 183
Slika 35. Karakterisike odabranog spojnog sredstva 186
Slika 36. Dijagrami unutarnjih sila na spoju između dva zida i ploče 187
Slika 37. Karakteristike odabranog spojnog sredstva LBV iz Rothoblaas kataloga 190
Slika 38. Dijagrami unutarnjih sila na spoju između dvije ploče 191
Slika 39. Prikaz spojnog sredstva odabranog iz Rothoblaas kataloga 191
Slika 40. Dijagrami unutarnjih sila na spoju između CLT ploče i čelične grede 196
Slika 41. Prikaz spojnog sredstva odabranog iz Rothoblaas kataloga 196

POPIS TABLICA

Tablica 1. Količine AB površina za zgradu A........ 201
Tablica 2. Količine CLT ploča d=200 mm za međukatne i krovne konstrukcije zgrade A. 201
Tablica 3. Količine CLT ploča d=140 mm za zidove zgrade A 203
Tablica 4. Količine stupova GL32h za zgradu A........ 204
Tablica 5. Količine AB površina za zgradu B 205
Tablica 6. Količine CLT ploča d=200 mm za međukatne i krovne konstrukcije zgrade B. 205
Tablica 7. Količine CLT ploča d=160 mm za međukatne i krovne konstrukcije zgrade B. 206
Tablica 8. Količine CLT ploča d=140 mm za zidove zgrade B 206
Tablica 9. Količine greda HE280A za zgradu B........ 207

PRILOZI

Nacrt 001 – Tlocrt prizemlje (M 1:250)

Nacrt 002 – Tlocrt 1. i 2. kata (M 1:250)

Nacrt 003 – Tlocrt 3. kata (M 1:250)

Nacrt 004 – Tlocrt 4. kata (M 1:250)

Nacrt 005 – Tlocrt 5. kata (M 1:250)

Nacrt 006 – Tlocrt 6. kata (M 1:250)

Nacrt 007 – Tlocrt 7.-10. kata (M 1:250)

Nacrt 008 – Presjek A-A (M 1:250)

Nacrt 009 – Presjek B-B i presjek C-C (M 1:250)

Nacrt 010 – Plan pozicija zidova prizemlja (M 1:200)

Nacrt 011 – Plan pozicija zidova 1. i 2. kata (M 1:200)

Nacrt 012 – Plan pozicija zidova 3. kata (M 1:200)

Nacrt 013 – Plan pozicija zidova 4. kata (M 1:200)

Nacrt 014 – Plan pozicija zidova 5. kata (M 1:200)

Nacrt 015 – Plan pozicija zidova 6.-10. kata (M 1:200)

Nacrt 016 – Plan pozicija ploče prizemlja do 3. kata (M 1:200)

Nacrt 017 – Plan pozicija ploče 4. kata (M 1:200)

Nacrt 018 – Plan pozicija ploče 5. kata (M 1:200)

Nacrt 019 – Plan pozicija ploče 6. kata (M 1:200)

Nacrt 020 – Plan pozicija ploče 7—10. kata (M 1:200)

Gulam_Marija_Diplomski_rad.pdf

ORIGINALITY REPORT

2%	2%	1%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	repozitorij.gradst.unist.hr Internet Source	1%
2	adoc.pub Internet Source	1%
3	Pierre Gehl, Darius M. Seyedi, John Douglas. "Vector-valued fragility functions for seismic risk evaluation", Bulletin of Earthquake Engineering, 2012 Publication	<1%

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		