Projektiranje stambeno poslovne zgrade P+5 od CLT-a

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Sveučilište u Zagrebu

GRAĐEVINSKI FAKULTET

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Mentor: prof. dr. sc. Vlatka Rajčić

Komentor: mag.ing.aedif. Jure Barbalić

Zagreb, 2024.

University of Zagreb

FACULTY OF CIVIL ENGINEERING

Monika Spajić

DESIGN OF THE RESIDENTAL - OFFICE BUILDING FROM CLT

MASTER THESIS

Supervisor: prof. dr. sc. Vlatka Rajčić

Co-supervisor: mag.ing.aedif. Jure Barbalić

Zagreb, 2024.

ZAHVALE

Da stavim krunu na svoje „đačko doba“ i na ovaj diplomski rad, želim se iskreno zahvaliti svima koji su na bilo koji način bili uz mene na svakom koraku ovog putovanja.

Posebnu zahvalnost upućujem svojim roditeljima i sestrama, koji su mi uvijek bili najveća životna podrška i kritika. Vaša vjera u mene, čak i kad sam sama sumnjala u sebe i svoje sposobnosti, bila je temelj na kojem sam gradila svoj uspjeh. Ovaj rad posvećujem vama, kao zahvalu za sve što ste učinili za mene i omogućili mi da postanem osoba kakva jesam. Sve što jesam i sve što ću ikad biti, vama dugujem!

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prof. dr. sc. Vlatki Rajčić i komentoru mag.ing.aedif. Juri Barbaliću na pomoći prilikom izrade ovog diplomskog rada.

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I da, ovo nije kraj, nego tek početak…

SAŽETAK

Ovaj rad se bazira na projektu konstrukcije visoke zgrade katnosti P+5K od križnolameliranog drva i lijepljenog lameliranog drva koja se jednim zidom oslanja na već postojeću zgradu. Kao uvod u projektni zadatak obrađena je teorijska podloga u kojoj su opisani materijali na osnovi drva, križnolamelirano drvo i lijepljeno lamelirano drvo, kroz osvrt na bitne mehaničke karakteristike i teorije proračuna. Konstrukcija je proračunata na sva granična stanja u koja spadaju granično stanje nosivosti (GSN), granično stanje nosivosti u slučaju požara i granično stanje uporabivosti (GSU) s racionalnom iskoristivosti. Konstrukcija je modelirana u softveru DLUBAL RFEM. Lokalni proračun ploča te proračun spojeva, koji u drvenim konstrukcijama imaju bitnu ulogu kod ponašanja konstrukcije pod različitim djelovanjima, je napravljen u softveru Calculatis. Cijeli projekt je usklađen sa skupom europskih normi – Eurokodom te nacionalnim dodatkom Slovenije.

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HRN 1995 EN

HRN 1998 EN

NA SLOVENIJE

EN 16351

Ključne riječi: križnolijepljeno lamelirano drvo, lijepljeno lamelirano drvo, projekt konstrukcija, obnovljivi materijali, održivost, zelena gradnja

SUMMARY

This project is based on the design of the construction of a high-rise building of P+5K of cross laminated timber (CLT) and glued laminated timber (GLT), which is supported by one wall on an existing building. As an introduction to the project task, the theoretical basis about timber-based materials (CLT and GLT) was explained through a review of essential mechanical characteristics and calculation theories. The construction is designed for all limit states, which include the limit state of load (GSN), the limit state of load in case of fire and the limit state of use (GSU) with rational usability. The construction was modeled in the DLUBAL RFEM software. The local calculation of panels and walls and the calculation of joints, which play an important role in the behavior of the timber structures under different actions, was made in the Calculatis software. The entire project is harmonized with a set of European norms - the Eurocode and the national supplement of Slovenia.

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Key words: cross-glued laminated timber, glued laminated timber, construction project, renewable sources, sustainability , green buildings

SADRŽAJ

1. UVOD

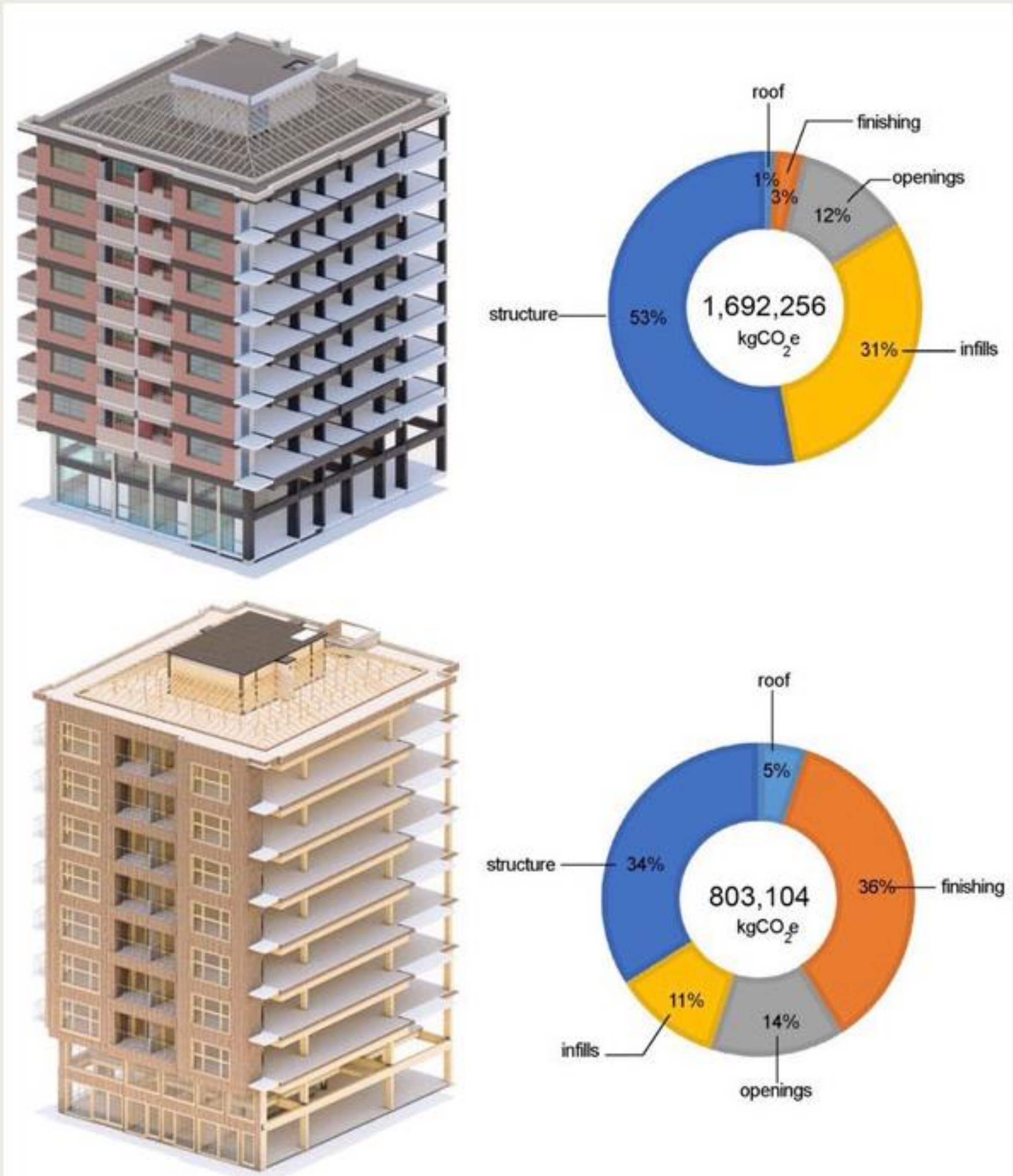
Jedno od najstarijih i najranije korištenih konstrukcijskih materijala je drvo jer je bilo dostupno i lako za upotrebu . Krajem 19. i početkom 20.-tog stoljeća dolazi do snažnog napretka znanosti i tehnologije te razvoja novih materijala: čelika, betona i opeke. Industrijska revolucija, poboljšanje gospodarske moći društva te loša iskustva s dotadašnjim velikim požarima dovela su do zamjene tradiocionalne drvene konstrukcije (konstrukcija od balvana ili greda ili rešetkastih nosača) novim materijalima, barem u Europi.

Ti, danas najčešće korišteni materijali, zbog svoje ekonomičnosti i potrebe za gradnjom visokih građevina, doživjeli su nagli procvat u prošlom stoljeću te je drvo kao građevinski materijal svedeno na tržišni udio od svega nekoiko postotaka i prvenstveno se koristilo u laganim drvenim konstrukcijama (rešetke ili okviri), za podizanje obiteljskih i stambenih objekata, za atraktivne kosntrukcije.

Međutim, u posljednjih 30-ak godina drvo je preuzelo tržišne udjele od čvrstih građevinskih materijala na bazi minerala, posebice u područjima stambenih zgrada, poslovnih zgrada, škola i dječjih vrtića, ali i u drugim područjima gradnje. Očigledno, ovo ponovno povećanje tržišnog udjela također je posljedica renesanse drva u gradovima u kojima se stoljećima bojalo ovog prirodnog i održivog građevinskog materijala zbog njegove zapaljivosti.

U posljednje vrijeme velik je interes javnosti te se više obraća pozornost na drastične klimatske promjene koje na dugoročno utječu na kvalitetu života ljudi.

Za upotrebu drva kao građevinskog materijala potrebna je sječa šuma, ali korištenje umjetnih materijala (beton; čelik) ima posljedicu ispuštanje stakleničkih plinova, tj. onečišćenje okoliša. Drvo ima prednost zbog svoje održivosti, šume se obnavljaju i na to možemo utjecati. Veći problem je kako očistiti atmosferu od stakleničkih plinova čija emisija se povećava konstantno?



Slika 1.1. Oslobađanje CO_2 – konvencionalna gradnja / drvena gradnja

Ekolške prednosti CLT značajno mu daju prednost naspram ostalih materijala. Analizom emisije ugljika (tijekom proizvodnje i upotrebe drva, čelika i betona) drvo se pokazalo kao najblaži utjecatelj. U nastavku su prikazani okvirni utjecaji pojedinog materijala.

- „Beton:

  Proizvodnja jedne tone cementa, ključnog sastojka betona, emitira otprilike jednu tonu CO2 u atmosferu. Globalno, industrija cementa odgovorna je za 7% svih emisija

CO2. Proizvodnja betona odgovorna je za otprilike 8% svjetskih emisija ugljičnog dioksida.

- Čelik:
  Čelična industrija jedan je od najvećih industrijskih izvora emisija CO_2. Za svaku tonu proizvedenog čelika emitira se otprilike dvije tone CO_2. Proizvodnja čelika čini otprilike 7-9% ukupnih svjetskih emisija ugljičnog dioksida.
- Drvo
  Drvo je neutralno prema ugljiku, budući da stabla apsorbiraju CO_2 tijekom svog rasta. Ukupni ugljični otisak u CLT-u znatno je manji od onog u betonu ili čeliku. CLT ima potencijal smanjiti emisije CO_2 u građevinarstvu za značajnu mjeru.“ [7]

Prednosti gradnje drvetom su sljedeće :

• Manja težina konstrukcije što rezultira manjim opterećenjem i jednostavnijim zahtjevima za temeljenje

• Brža izgradnja

• Manja ogranočenja u arhitektonskom oblikovanju

• Smanjeni troškovi prijevoza – transport samo gotovih elemenata iz tvornice do gradilišta

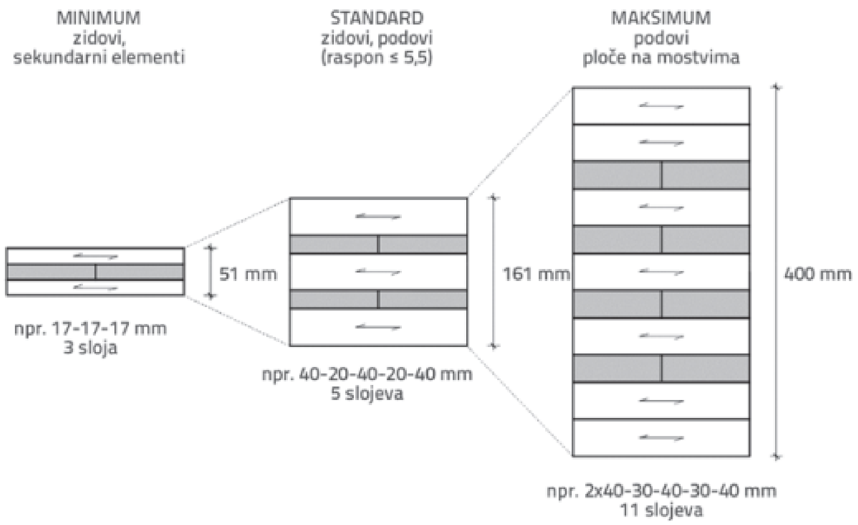
• Smanjeno osobađanje CO_2

• Odlična izolacijska svojstva

• Održiva gradnja – obnovljivi materijal izgradnje

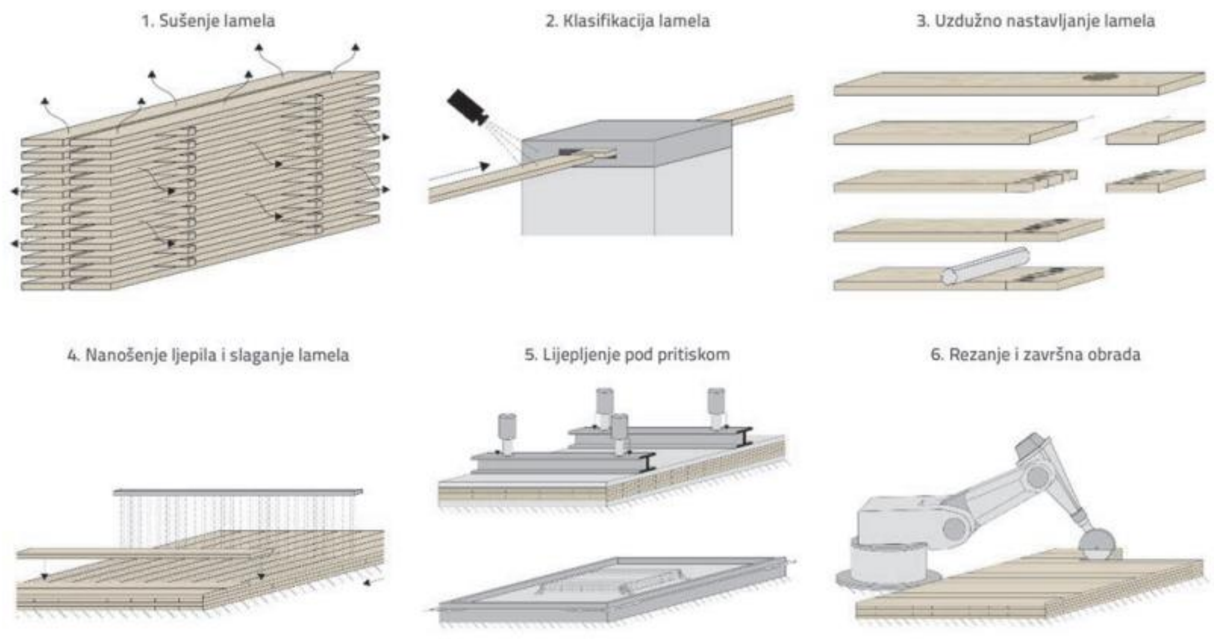
Povratak na gradnju drvom može se većim dijelom pripisati izumu novih materijala – križnolijepljenog lameliranog drva i lijepljenog lameliranog drva.
CLT nazivaju beton budućnosti jer ograničenja u izgradnji po pitanju CLT-a ili lameliranog lijepljenog drveta ne postoji. Može se napraviti sve ono što se može isprojektirati.
Križnolijepljeno lamelirano drvo (engl. cross laminated timber - CLT) predstavlja proizvod od strukturalnog kompozitnog drva koji je dobiven specifičnim slaganjem i lijepljenjem lamela jedne za drugu. Iako CLT svoje korijene ima u Europi, zbog odličnih seizmičkih i požarnih svojstava, vrlo brzo se počeo primijenjivati i van granica Europe. Tako su npr. zemlje poput SAD, Kanade, Kine i Japana počele koristiti CLT proizvode. CLT i lijepljeno lamelirano drvo (LLD) najčešće dolaze u kombinaciji u konstrukcijskom sustavu građevina i to obično su pločasti elementi (zidovi i stropne ploče) od CLT-a, a linijski elementi (grede i stupovi) od LLD-a .

„CLT se sastoji od više slojeva dimenzioniranih dasaka od drva, obično tri do sedam slojeva, koji su sustavno orijentirani okomito jedan na drugog. Slojevi se lijepe zajedno ekološki prihvatljivim ljepilima, rezultirajući snažnom, inženjerskom drvenom pločom s izvanrednim mehaničkim svojstvima. Mjesto uporabe panela ovisi o načinu proizvodnje, orijentacije lamela i lijepljenja slojeva. Paneli koji se izrađuju na način da im je završni sloj okomit na proizvodnu duljinu najčešće se koriste u izradi zidova. Dok se paneli kojima je završni sloj paralelan na proizvodnu duljinu najčešće koriste za ploče i krovove.“ [7]



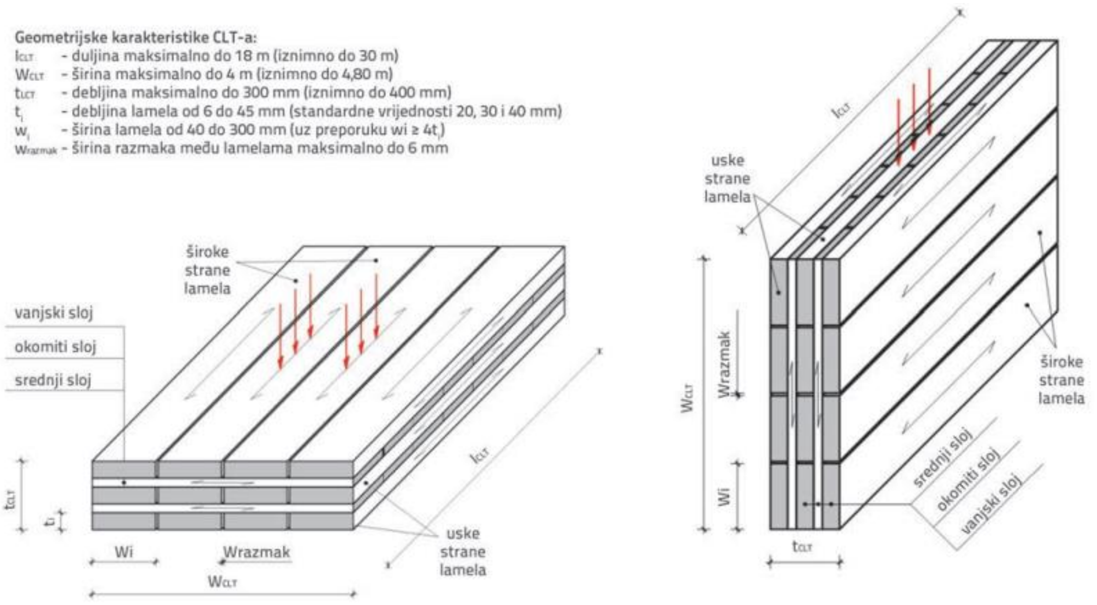
Slika 1.2. Slaganje lamela u CLT panelu ovisno o vrsti elementa za koji je korišten

Debljina pojedine lamele može biti od 16 do 51 mm, a širine se kreću u rasponu od 60 do 240 mm. Uobičajene dimenzije CLT panela su duljina do 18 m (ili čak 30 m), širina do 3,0 m (ili čak 4,8 m) i debljina rijetko veća od 300-400 mm.



Slika 1.3. Postupak proizvodnje CLT elementa

CLT se uglavnom proizvodi od mekog drva klase C24. Sama proizvodnja započinje sušenjem lamela i klasifikacijom materijala. Vlaga u materijalu je ograničena na 9% do 15%. Time sprječavamo pojavu pukotina. Slaganje i lijepljenje lamela jednog panela traje otprilike 15 do 60 minuta. Lijepila koja se koriste su poliuretanska ljepila, emulzijska polimerna izocijantna ljepila ili melanim-urea-formaldehid. Postupak lijepljenja, količina nanesenog ljepila, sadržaj vlage u prianjanju i drugi, temelje se na iskustvu s lijepljenim pločama. U međuvremenu su neki proizvođači ljepila prilagodili svoje propise za CLT. Parametri kao što su tlak lijepljenja i primijenjena količina su od posebne važnosti. Pritisci lijepljenja od 0,10–1,00 N/mm^2 pa čak i viši mogu se osigurati pomoću hidrauličke opreme, dok vakuumske preše i prešanje vijcima, spajalicama ili čavlima postižu pritiske lijepljenja u rasponu od 0,05–0,10 odnosno 0,01–0,20 N/mm^2. Potreban pritisak lijepljenja bočne strane može se definirati kao funkcija sustava ljepila, vrste drva, geometrije ljepila u pogledu hrapavosti i ravnosti površine i dopuštenih tolerancija u debljini, sustav nanošenja ljepila i nanesenu količinu ljepila. Sama nanesena količina ovisi o hrapavosti površine ljepila, a time i o vrsti drva. Kad je ljepilo postiglo željeno očvršćavanje, geometrija panela se korigira te se oni režu na određene dimenzije. Za rezanje se koriste CNC strojevi koji imaju jako veliku preciznost. Nakon rezanja još je potrebna završna obrada, ovisno o mjestu ugradnje panela.



Slika 1.4. Geometrijske karakteristike CLT elementa za djelovanje okomito na ravninu elementa (lijevo) i djelovanje u ravnini elementa (desno)

Najviša zgrada na svijetu izgrađena od materijala na osnovi drva je visoka 85 metara, a to je 18-etažna zgrada Mjøstårnet u Norveškoj. Struktura i fasada zgrade izrađeni su od drveta, dok su se na sedam najviših etaža koristile betonske podne ploče kako bi se povećala njihova težina i usporilo njihanje zgrade pri horizontanom djelovanju. Zgrada je usidrena u zemlju s podzemnim stupovima do dubine od 50 metara.

Primarni nosivi sustav (stubovi, grede i dijagonale) je od LLD nosača, nadopunjenih sa križno-uslojenim (CLT) pločama (za otvore za liftove i balkone, ploče), LVL elementima (za uređenje enterijera) i drugim proizvodima od drveta.

Slika 1.5. Mjøstårnet u Norveškoj – vanjski dizajn i stepenište

Hoho toranj u Austriji je još jedan ogledni primjer suvremenih drvenih konstrukcija.

Sa svojih 24 kata i visinom od 84 metra je najviši hibridni drveni neboder na svijetu.

Hoho toranj je hibridna konstrukcija od drva i betona. Nosivi elementi kao što su zidovi, stupovi i stropovi izrađeni su od drveta.

Slika 1.6. Hoho toranj u Beču, Austrija

Gradnja visokih zgrada od drveta nije se razmatrala godinama zbog usporedbi slabijih mehaničkih karakteristika drveta s armiranom betonom i čelikom. Problem stabilizacije drvene konstrukcije na horizontalna djelovanja (snijeg, vjetar) je znatno veći nego kod armiranobetonske ili čelične konstrukcije jer je manja krutost materijala, tj. manji je modul elastičnosti drva u odnosu na čelik i beton. Zbog navedenog, horizontalna djelovanja na drvenu konstrukciju mogu uzrokovati značajnije deformacije, ali se one mogu i ograničiti dovoljno krutim sustavom. Modul elastičnosti drva okomito na smjer pružanja vlakana je izrazito mali te je izvođenje krutih spojeva u drvenim konstrukcijama daleko izazovnije nego u armiranobetonskim i čeličnim.

Osim izgradnje novih konstrukcija na bazi drva kao konstrukcijskog materijala, u posljednje vrijeme se kao najoptimalnije rješenje vertikalne nadogradnje na postojeće zgrade pokazala upravo gradnja CLT-om i LLD-om. Svojom značajno manjom težinom i načinom (suha gradnja) i brzinom izvedbe ima prednost u usporedbi s tradiocionalnom AB gradnjom jer se može nadograditi veći broj etaža bez velikog ojačavanja postojeće konstrukcije, gdje AB gradnja brzo dostiže limit. Primjer toga je vertikalna drvena nadogradnja hotela od 10 katova na vrhu već postojećeg komercijalnog centra u Melbourne-u u Australiji.

Slika 1.7. Southbank building – Melbourne, Australija

Na šesterokatnoj poslovnoj zgradi podignutoj 1989. bilo je potrebno povećati kapacitet dodavanjem deset dodatnih katova koristeći CLT, što daje 13 000 četvornih metara dodatnog prostora. Visina proširenja je bila ograničena postojećim kapacitetom pilona, isključujući mogućnost ugradnje novih pilona unutar konstrukcije.

Nakon razmatranja različitih opcija uključujući betonske ploče i kompozitne ploče, CLT je odabran zbog svoje sposobnosti da primi deset katova bez nadmašivanja kapaciteta pilota, za razliku od betonskih ploča koje su izvedivo mogle podržati samo proširenje od šest katova.

Postojeći stupovi zgrade su ojačani, a središnji zidovi ojačani da izdrže dodatno opterećenje, uključujući CLT zidove između hotelskih soba. S obzirom na povećana bočna opterećenja, uvedene su dvije nove čelične jezgre, koje uključuju postojeće betonske zidove u sustav stabilnosti i učvršćuju postojeće jezgre. Kako bi se održao panoramski pogled, čelične grede i stupovi dizajnirani su da podupru CLT podne ploče i prilagode veći razmak između zidova oko zakrivljenih dijelova zgrade. Korištenjem predgotovljene lamelirane drvene građe i prihvaćanjem načela kružnog gospodarstva za prenamjenu postojeće zgrade, ušteđeno je vrijeme i novac, a istovremeno smanjen utjecaj na okoliš povezan s rušenjem i rekonstrukcijom.

U zadnjih desetak godina u svijetu je izgrađeno na desetke višeetažnih drvenih zgrada. U njih ubrajamo i zgrade s hibridnim sustavima beton-drvo i čelik-drvo. U takvim sustavima drvo tvori okvire i međukatne ploče, dok su od betona i čelika uglavnom jezgre dizala i stubišta. U potpuno drvenim sustavima nerijetko su potrebni manji ili veći spregovi po vanjskom obodu zgrade jer sama jezgra i posmični zidovi od CLT-a ne omogućavaju dostatnu krutost na horizontalna djelovanja.

Analizom različitih statističkih podataka o emisijama ugljičnih spojeva, možemo vidjeti CLT predstavlja potencijal održivosti, smanjujući utjecaj oslobađanja ugljika u građevinskom sektoru.

Povrh toga, CLT također pruža strukturalno čvrste i energetski učinkovite konstrukcije, te održivu i ekološki odgovornu budućnost za generacije koje dolaze. Prihvaćanje tehnologije CLT-a nije samo tehnološki napredak – to je korak prema zelenijem i otpornijem planetu.

2. METODE I TEHNIKE RADA

Model konstrukcije i dimenzioniranje je napravljeno u softveru Dlubal RFEM 6 uz pomoćni online modul za računanje CLT i LLD elemenata Calculatis - Stora Enso u kojemu je napravljen proračun stropnih ploča, čelične grede na koju se oslanja međukatna konstrukcija te proračun karakterističnih spojeva. Dan je kompletan dokaz nosivosti i uporabivosti prema europskim normama za sve elemente od CLT-a i LLD-a, te za čelične stupove na koje se oslanjaju balkoni s jedne strane konstrukcije. Proračun spojeva je napravljen za sve karakteristične spojeve. Proračun armirano-betonskih zidova i temeljne ploče nije prikazan u ovom diplomskom radu jer se bazira prvenstveno na proračunu materijala na bazi drva – CLT-u i LLD-u.

3. PROJEKT KONSTRUKCIJE STAMBENE ZGRADE

3.1. Arhitektonsko idejno rješenje

Ovaj diplomski rad napravljen je prema podlozi projekta za natjecanje *proHolz Student Trophy 24* u kojem su surađivali studenti Arhitektonskog i Građevinskog fakulteta u Zagrebu. Studentsko natjecanje je bilo fokusirano na potencijal za širenje i konsolidaciju unutar grada koristeći drvo kao građevinski materijal.

Od 3 zadatka, tj. 3 lokacije u Beču (1. Proširenje škole – horizontalna nadogradnja, 2. Dodatak uz rub bloka – vertikalna nadogradnja, 3. Vertikalna nadogradnja postojeće zgrade) odabrali smo 2. lokaciju - projekt nadogradnje uz rub postojeće zgrade.

Dodatak rubu bloka ima za cilj zatvoriti perimetar bloka, nastavljajući tradicionalnu urbanu mrežu i pružajući zajednici dodatne pogodnosti s uličnog pristupa kao što su radni prostori, mala poduzeća, kafići, multifunkcionalni prostori za iznajmljivanje, sobe za sastanke, itd., dok djelomično zatvaranje unutarnjeg prostora u sigurnu zelenu površinu osigurava prostor za društvenu interakciju, a u isto vrijeme djelomično rješava problem smanjenja buke od prometa. Odgovornosti povezane s dizajnom koncentrirane su na suočavanje s postojećim strukturama jer se konstrukcija trebala osloniti jednim zidom na postojeću zgradu.

Slika 3.1. Pogled na konstrukciju - sjeverozapad

Slika 3.2. Pogled na konstrukciju – jug

Slika 3.3. Detalj vanjskih prolaza između stanova na južnoj i istaka zidova na sjevernoj strani

3.2. Tehnički opis

Ovaj projekt konstrukcije obrađuje projekt drvene nosive konstrukcije, tipa masivna gradnja, stambene zgrade od lijepljenog lameliranog drva (LLD) i križno lameliranog drva (CLT) u Zagrebu.

Stambena zgrada se sastoji od 6 etaža: podrum, prizemlje i 5 katova (P+5). Temeljna ploča, armiranobetonska konstrukcija podruma, jezgre dizala i stubišta te nekoliko zidova prizemlja koji su izvedeni kao AB elementi u nastavku će biti uzeti kao pretpostavljene dimenzije te detaljan proračun ije prikazan u ovom radu. Karakteristike AB konstrukcije ne utječu direktno na proračun drvene konstrukcije.

Tlocrt konstrukcije je U oblika sa nepravilno raspoređenim zidovima. Kvadratne tlocrtne dimenzije su 75,35x27,50 m, sa dvorišnim isječkom dimenzija 48x15 m. Ukupna visina građevine je 19,08 m. Posljedna etaža je uža od ostalih te je terasa ispred stanova prohodna. Krovna ploča posljednje etaže je neprohodna.

Temelji su pretpostavljeni kao temeljne trake 100x100 cm ispod zidova. AB ploča preko njih je debljine 50 cm.

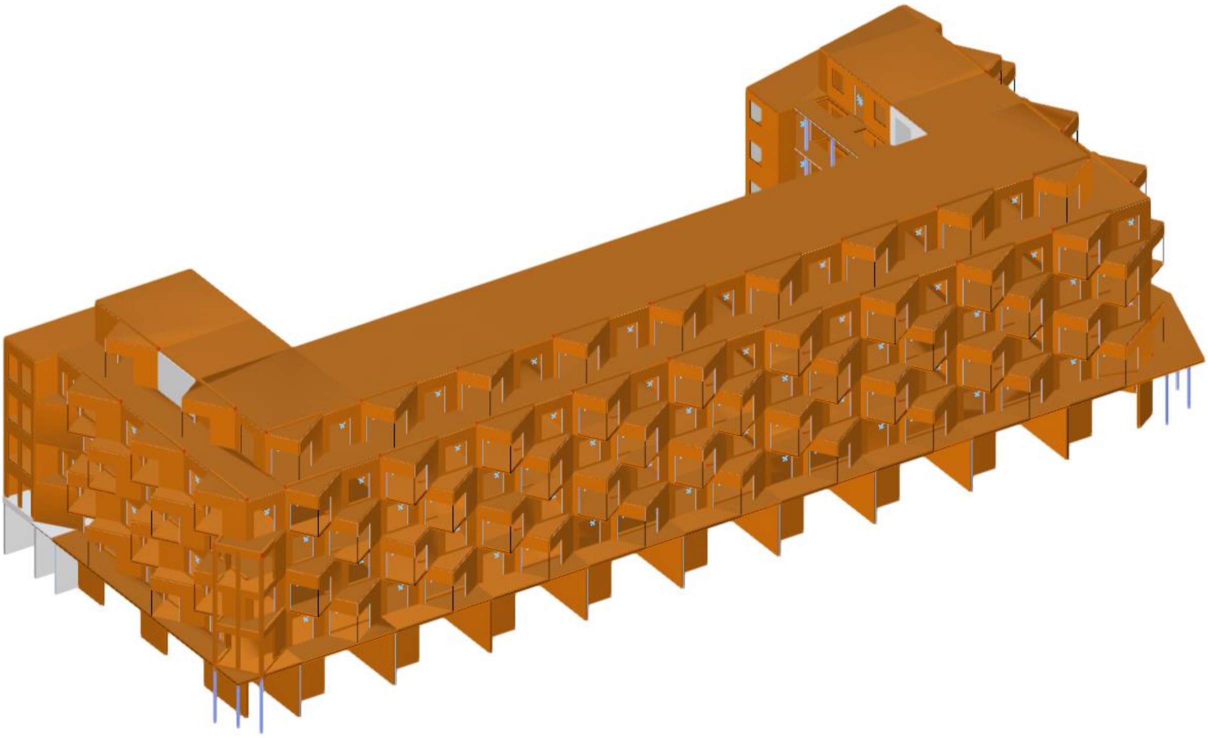
Temeljno tlo je kruta glina i spada u tip C temeljnog tla. Podrumska etaža, te pojedini zidni elementi prizemlja, cijeli zid koji se oslanja na postojeću zgradu te jezgre stubišta i dizala izvedene su od armiranog betona (dalje AB) klase C35/40, dok su svi ostali elementi izvedeni od LLD-a i CLT-a . Kvaliteta CLT-a je C24, dok je kvaliteta LLD-a GL32h.

AB zidovi podruma su debljine 30 cm i stupova dimenzija 30x30 cm na koje su povezane AB grede dimenzija b/h=30/40 cm . Podrumska etaža je u potpunosti ukopana. Strop podrumske etaže izveden je kao AB ploča debljine 30 cm. Visina podrumske etaže je 3,80 m, a visina prizemlja je 3,48 m. Visina svih etaža iznad je 2,88 m. Etaže od 1. do 5. kata izvedene su od CLT zidova i stropnih poča te LLD greda različitih dimenzija.

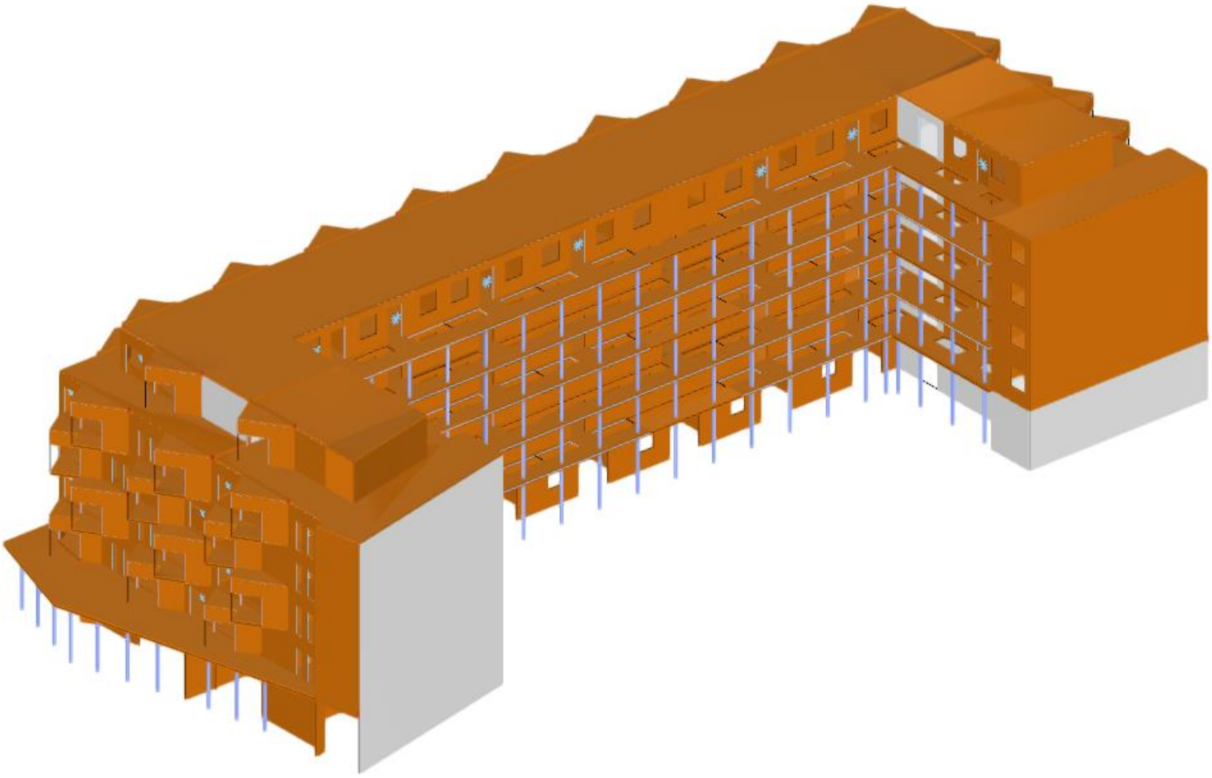
CLT paneli koji će se koristiti u izvedbi su od proizvođača *Stora Enso*. Klasa drveta korištena za lamele u panelima je C24. Grede su od LLD-a su različitih dimenzija te su svi prikazani u proračunu i u nacrtima. Grede i stupovi proizvedeni su od klase drva GL32h. Na krovni panel, nakon izolacijskih materijala, naknadno dolazi šljunak kao pokrov. Paneli i grede spajaju se modernim spojnim sredstvima proizvođača Rothoblaas. Stubište i jezgra dizala je planirana u izvedbi od armiranog betona.

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, HRN EN 1998 i EN 16351 te pripadajući nacionalni dodaci za RH i Sloveniju. Za potrebe cjelokupnog proračuna korišteni su programi Dlubal RFEM 6 s pripadajućim modulima te *Calculatis – Stora Enso,* a izvedbena dokumentacija je napravljena u AutoCAD-u . Izometrijski prikaz modela prikazan je na slikama 3.4. i 3.5.



Slika 3.4. Prikaz modela – Dlubal RFEM



Slika 3.5. Prikaz modela – Dlubal RFEM

3.3. Analiza opterećenja

3.3.1. Stalno opterećenje

Strop 1. - 5. kata	$\boldsymbol{kN/m^2}$
Vlastita težina svih elemenata	**Dlubal RFEM**
Dodatno stalno	**1,50**

$$\sum \boldsymbol{g_{st}} = \mathbf{1,50}\ kN/m^2$$

3.3.2. Uporabno opterećenje

Karakteristične vrijednosti opterećenja iz HRN EN 1991-1-1 i dodatka HRN EN 1991-1-1/NA

<u>Uporabno opterećenje etaža:</u> $q = 2\ kN/m^2$

<u>Uporabno opterećenje etaža:</u> $q = 4\ kN/m^2$

<u>Uporabno opterećenje na krovu (neprohodan):</u> $q = 0{,}6\ kN/m^2$

<u>Uporabno opterećenje stubišta:</u> 3 kN/m^2

NAPOMENA: Opterećenje stubišta se zadaje kao linijsko opterećenje duž otvora na koji se oslanja stubište te ono iznosi 7,50 kN/m'.

3.3.3. Snijeg

Opterećenja snijegom određena prema HRN EN 1991-1-3 te pripadnom nacionalnom dodatku HRN EN 1991-1-3/NA.

<u>Opterećenje snijegom na krovne površine:</u>

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

s_k – karakteristična vrijednost opterećenja snijegom na tlo (kN/m^2)

μ_i – koeficijent oblika opterećenja snijegom $(\alpha - nagib\ krova)$

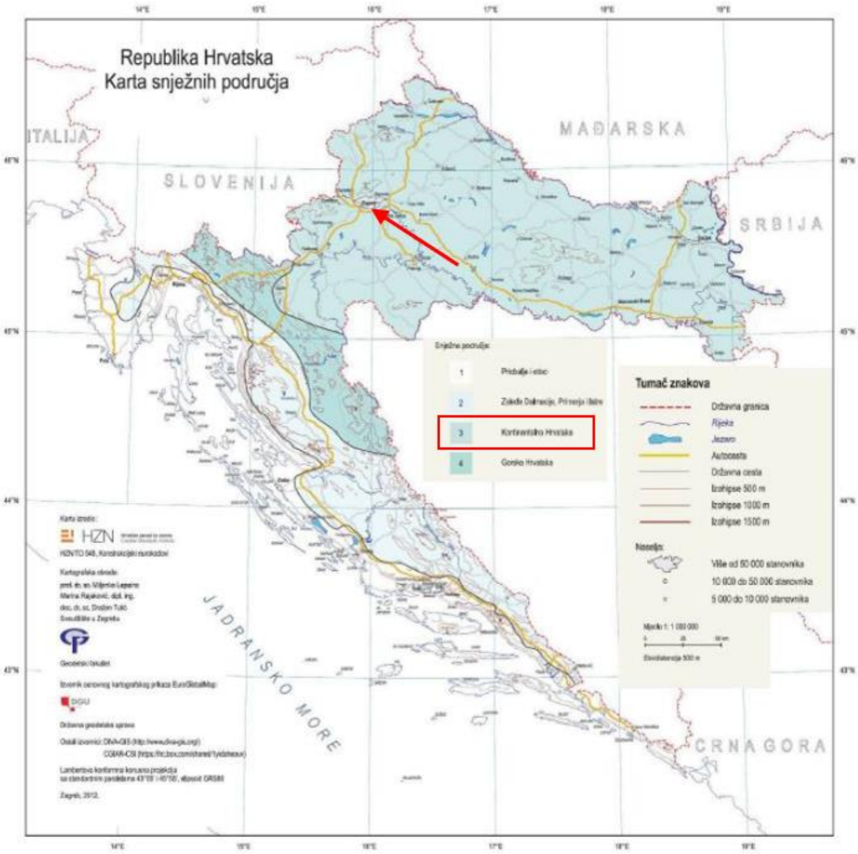
C_e- koeficijent izloženosti

C_t- toplinski koeficijent

$C_e = 1\ (preporučena\ vrijednost)$

$C_t = 1\ (preporučena\ vrijednost)$

$\mu_i = 0{,}8\ (0° < \alpha < 30°)$



Slika 3.3.1. Karta snježnih područja

Nadmorska visina do [m]	1. područje – priobalje i otoci [kN/m²]	2. područje – zaleđe Dalmacije, Primorja i Istre [kN/m²]	3. područje – kontinentalna Hrvatska [kN/m²]	4. područje – gorska Hrvatska [kN/m²]
100	0,50	0,75	1,00	1,25
200	0,50	0,75	1,25	1,50
300	0,50	0,75	1,50	1,75
400	0,50	1,00	1,75	2,00
500	0,50	1,25	2,00	2,50
600	0,50	1,50	2,25	3,00
700	0,50	2,00	2,50	3,50
800	0,50	2,50	2,75	4,00
900	1,00	3,00	3,00	4,50
1 000	2,00	4,00	3,50	5,00
1 100	3,00	5,00	4,00	5,50
1 200	4,00	6,00	4,50	6,00
1 300	5,00	7,00		7,00
1 400	6,00	8,00		8,00
1 500		9,00		9,00
1 600		10,00		10,00
1 700		11,00		11,00
1 800		12,00		

Slika 3.3.2. Karakteristična opterećenja snijegom za snježna područja i pripadajuće nadmorske visine

$s_k = 1{,}25\ kN/m^2$

$s = \mu_i \cdot C_e \cdot C_t \cdot s_k = 0{,}8 \cdot 1 \cdot 1 \cdot 1{,}25 = 1{,}00\ kN/m^2$

Koeficijent izloženosti i toplinski koeficijent uzeti prema usvojenim preporukama u nacionalnom dodatku (vrijednost 1,0). Koeficijentom izloženosti može se smanjiti opterećenje snijegom zbog učinka jakog vjetra dok se toplinskim koeficijentom uzima u obzir gubitak topline preko krovne plohe. Koeficijent oblika krova ima minimalnu vrijednost (0,8) s obzirom da je krov ravan. Karakteristično opterećenje snijegom djeluje vertikalno na horizonalne projekcije površina krova. Karakteristično opterećenje snijegom na tlo očitano je preko tablice karakterističniih opterećenja snijegom za RH (Slika 4.2.8.). Zona i nadmorska visina potrebni za tablicu očitani su sa slike 4.2.7. Opterećenje snijegom naneseno je na krovnu plohu, otvorenu terasu zadnje etaže i balkon zadnje etaže.

3.3.4. **Vjetar**

Osnovna brzina vjetra: $v_b = c_{\mathrm{dir}} \cdot c_{\mathrm{season}} \cdot v_{\mathrm{b,0}}$, gdje je:

c_{dir} koeficijent smjera vjetra, $c_{\mathrm{dir}} = 1$

c_{season} koeficijent godišnjeg doba, $c_{\mathrm{season}} = 1$

$v_{\mathrm{b,0}}$ temeljna vrijednost osnovne brzine vjetra, određuje se iz karte vjetrova

$v_{b,0} = 25$ m/s

$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0} = 1{,}0 \cdot 1{,}0 \cdot 25{,}0 = 25$ m/s

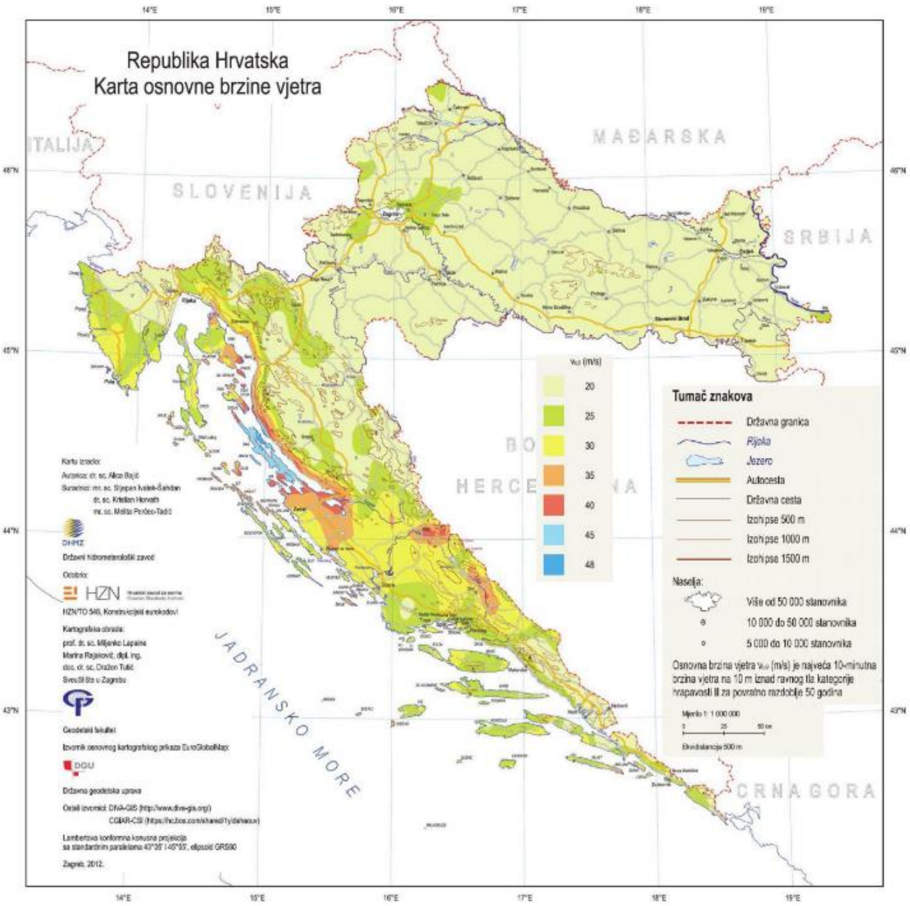
Tlak pri osnovnoj brzini vjetra:

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

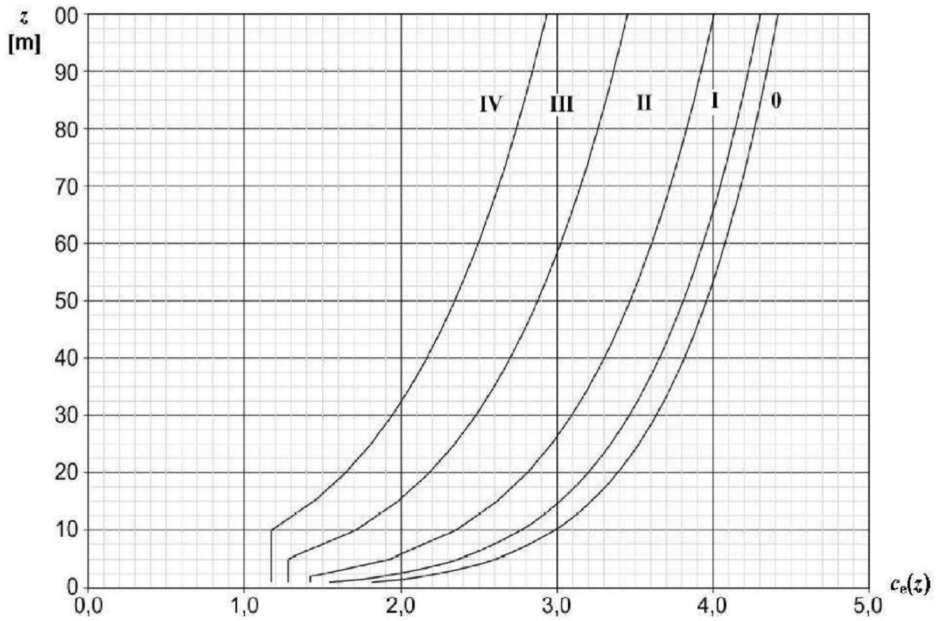
ρ ... gustoća zraka, $\rho = 1{,}25\ \mathrm{kg/m^3}$

$q_b = 0{,}5 \cdot 1{,}25 \cdot 25^2 = 390{,}625$ N/m^2

$q_b = 0{,}391$ kN/m^2



Slika 3.3.3. Karta osnovne brzine vjetra



Slika 3.3.4. Koeficijent izloženosti

3.3.5. **Slučaj 1 – vjetar puše na uzdužnu stranu objekta cpi =+ 0,2**

Vanjski tlak

Vanjski tlak na vertikalne stijene

Referentna visina:

$$z_e = f_c\left(\frac{h}{b}\right)$$

gdje je:

h = 19,08 m

b = 75,25 m (širina površine na koju puše vjetar)

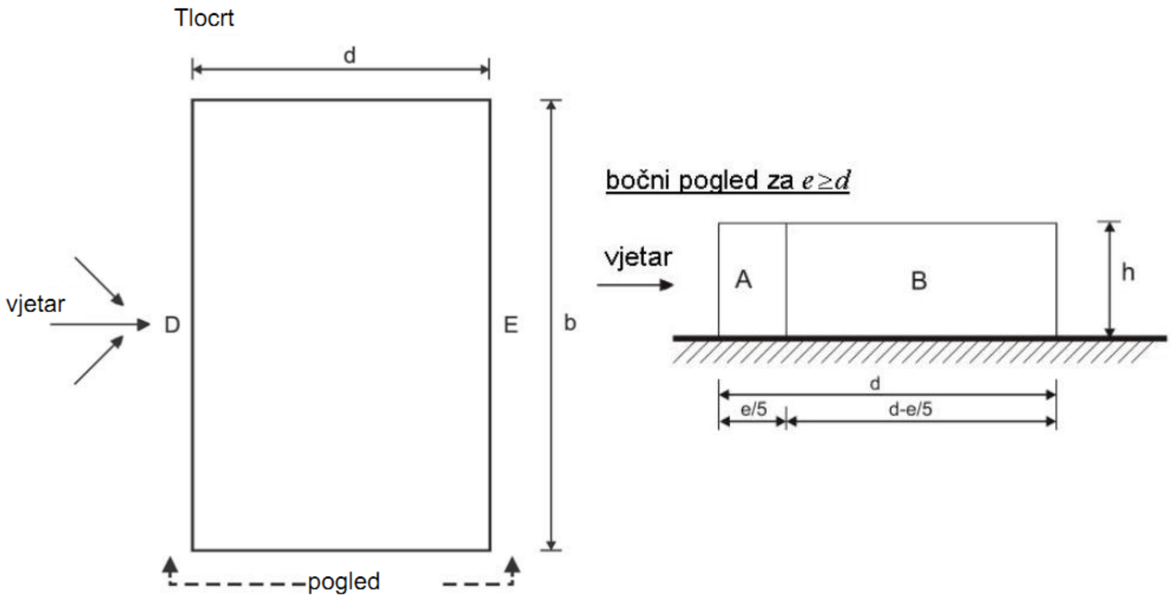
$h \leq b$ → z_e=h=19,08 m

Koeficijent tlaka na vertikalne stijene

e = min (b ; 2h) = min (75,25 ; 38,16) = 38,16m

d = 27,35 m → $e > d$

h / d = 19,08 / 27,35 = 0,675



Slika 3.3.5. Koeficijenti vanjskog tlaka za vertikalne zidove građevina pravokutnog tlocrta

Površina (A) = (e/5) · h = (38,16/5) · 19,08 = 136,16 m^2 > 10 m^2

→ $c_{pe} = c_{pe,10}$ = -1,2

Površina (B) = (d-e/5) · h = (27,35 - 38,16/5) · 19,08 = 368,45 m^2 > 10 m^2

→ $c_{pe} = c_{pe,10}$ = -0,8

Površina (D) = b · h = 27,35· 19,08 = 504,61 m^2

→ $c_{pe} = c_{pe,10}$ = +0,8

Površina (E) = b · h = 27,35 · 19,08 = 504,61 m^2

→ $c_{pe} = c_{pe,10}$ = -0,5

Koeficijent izloženosti

Teren IV kategorije – područja s najmanje 15% površine pokrivene građevinama čija prosječna visina premašuje 15 m

c_e(19,08) = 1,5

q_p (ze) = c_e(z) · q_b = 1,5 · 0,391 = 0,587 kN/m^2

Djelovanje vjetra na vertikalne površine

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

w_e^A = 0,587 · (-1,2) = -0,704 kN/m^2

w_e^B = 0,587 · (-0,8) = -0,469 kN/m^2

$w_e^D = 0{,}587 \cdot (+0{,}8) = +0{,}469\ kN/m^2$

$w_e^E = 0{,}587 \cdot (-0{,}5) = -0{,}293\ kN/m^2$

Vanjski tlak na ravni krov -5°< α < 5°

Referentna visina:

$$z_e = f_c\left(\frac{h}{b}\right)$$

gdje je:

h = 19,08 m

b = 75,25 m (širina površine na koju puše vjetar)

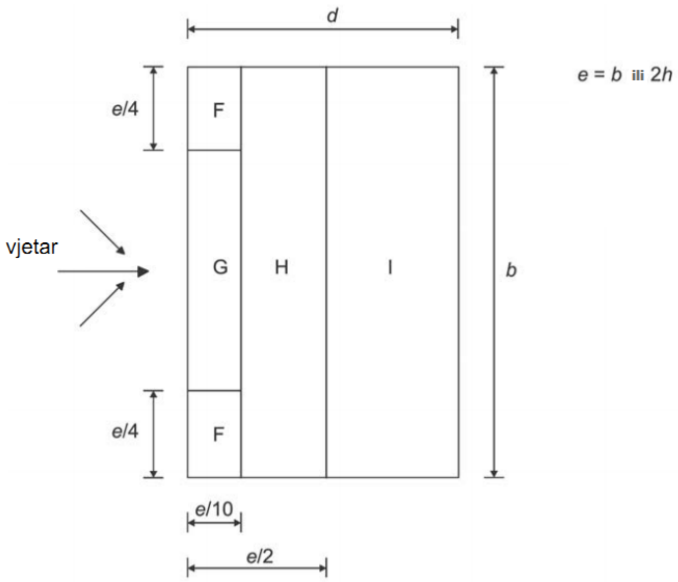
$h \leq b$ → z_e = h = 19,08 m

Koeficijent tlaka na vertikalne stijene

e = min (b ; 2h) = min (75,25 ; 38,16) = 38,16 m

d = 27,35 m → $e > d$

h / d = 19,08 / 27,35 = 0,675



Slika 3.3.6. Koeficijenti vanjskog tlaka za ravne krovove

Površina (F) = (e/4) · (e/10) = (38,16/4) · (38,16/10) = 34,04 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10} = -1{,}8$

Površina (G) = (b - 2·0,25e) · 0,1e = (75,25 – 2·0,25·38,16) · 0,1 · 38,16= 209,59 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10} = -1{,}2$

Površina (H) = b · (0,5e – 0,1e) = 75,25· (0,5 · 38,16– 0,1 · 38,16) =

1110,69 m^2 > 10 m^2

→ $c_{pe} = c_{pe,10} = -0,7$

Površina (I) = b · (d - 0,5e) = 75,25 · (37,35 – 0,5 · 38,16 = 1422,23 m^2 > 10 m^2

→ $c_{pe} = c_{pe,10} = \pm 0,2$

<u>Koeficijent izloženosti</u>

Teren IV kategorije – područja s najmanje 15% površine pokrivene građevinama čija prosječna visina premašuje 15 m

$c_e(19,08) = 1,5$

q_p (ze) = $c_e(z) \cdot q_b$ = 1,5 · 0,391 = 0,587 kN/m^2

<u>Djelovanje vjetra na ravne krovove</u>

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

w_e^F = 0,587 · (-1,8) = -1,060 kN/m^2

w_e^G = 0,587 · (-1,2) = -0,707 kN/m^2

w_e^H = 0,587 · (-0,7) = -0,412 kN/m^2

w_e^I = 0,587 · (0,2) = +0,118 kN/m^2

w_e^{II} = 0,587 · (-0,2) = -0,118 kN/m^2

Unutarnji tlak

Djelovanje vjetra na sve površine c_{pi} = + 0,2

w_i = 0,587 · (0,2) = 0,118 kN/m^2

Tlak na površinu je algebarski zbroj unutarnjeg i vanjskog tlaka:

$w_k^A = w_e^A - w_i$ = -0,704 - 0,118 = -0,822 kN/m^2

$w_k^B = w_e^B - w_i$ = -0,469 - 0,118 = -0,587 kN/m^2

$w_k^D = w_e^D - w_i$ = +0,469 - 0,118 = +0,351 kN/m^2

$w_k^E = w_e^E - w_i$ = -0,293 - 0,118 = -0,411 kN/m^2

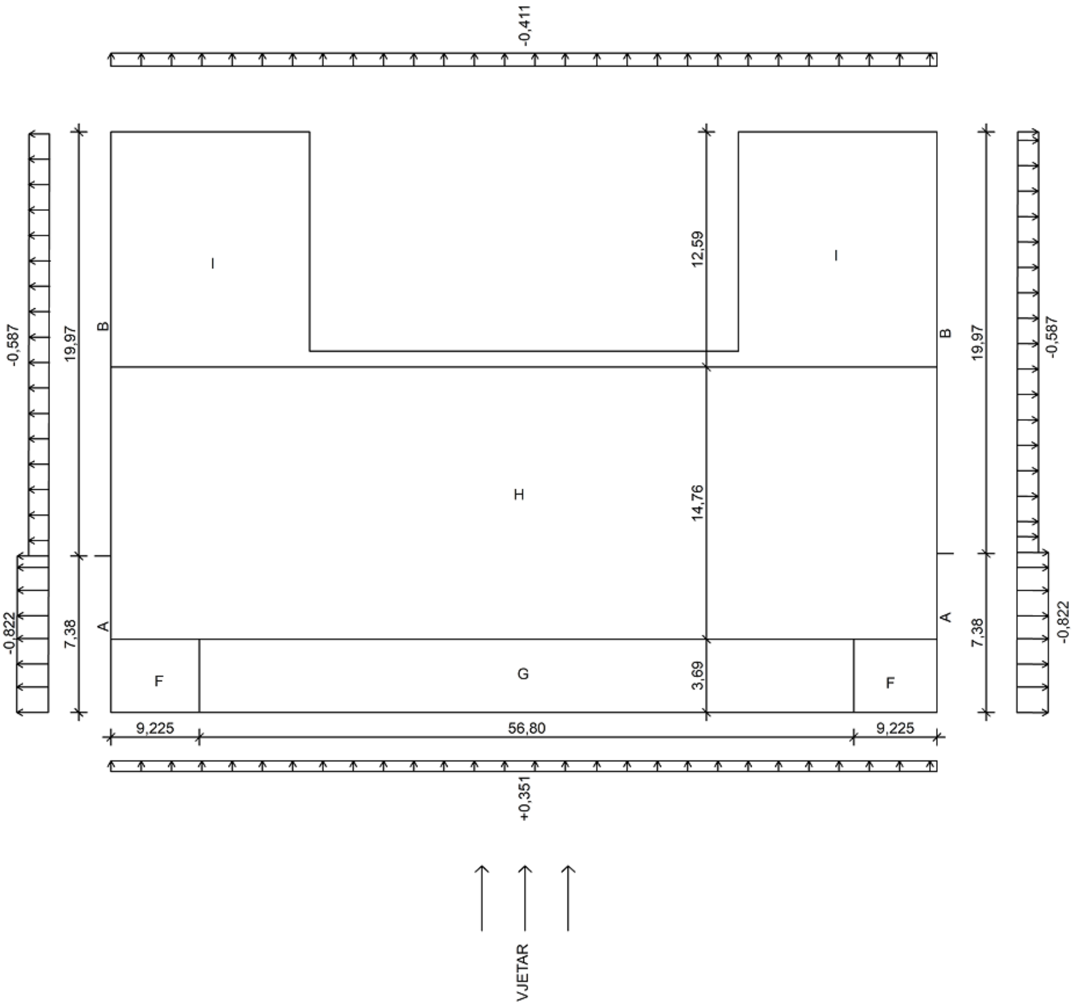
$w_k^F = w_e^F - w_i$ = -1,060 - 0,118 = -1,178 kN/m^2

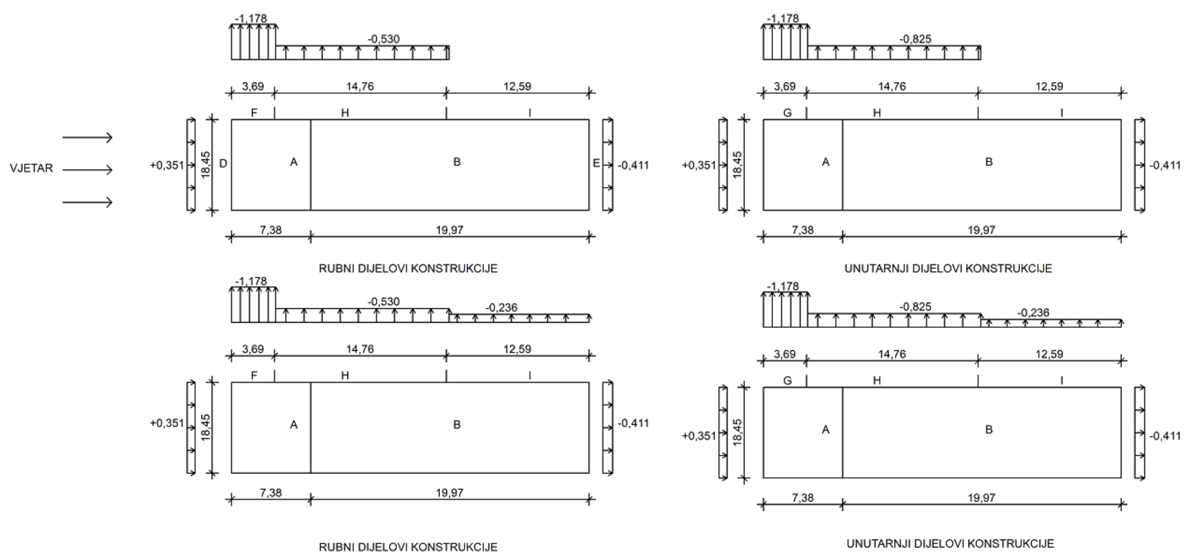
$w_k^G = w_e^G - w_i$ = -0,707 - 0,118 = -0,825 kN/m^2

$w_k^H = w_e^H - w_i$ = -0,412 - 0,118 = -0,530 kN/m^2

$w_{k1}^I = w_e^I - w_i$ = +0,118 - 0,118 = 0,000 kN/m^2

$w_{k2}^I = w_e^I - w_i$ = -0,118 - 0,118 = -0,236 kN/m^2


-0,411
-0,587
19,97
B
I
12,59
H
14,76
-0,822
7,38
A
F
G
3,69
9,225
56,80
+0,351
VJETAR


-1,178
-0,530
-0,825
-0,236
3,69
14,76
12,59
F
H
I
G
VJETAR
+0,351
18,45
D
A
B
E
-0,411
7,38
19,97
RUBNI DIJELOVI KONSTRUKCIJE
UNUTARNJI DIJELOVI KONSTRUKCIJE

Slika 3.3.7. Opterećenje vjetrom [kN/m^2]: Slučaj 1 – transverzalni tlak, c_{pi} = + 0,2

3.3.6. **Slučaj 2 – vjetar puše na uzdužnu stranu objekta, cpi = - 0,3**

Vanjski tlak

Isti kao i u slučaju 1.

Unutarnji tlak

Djelovanje vjetra na sve površine $c_{pi} = -0,3$

w_i = 0,587 · (-0,3) = -0,178 kN/m^2

Tlak na površinu je algebarski zbroj unutarnjeg i vanjskog tlaka:

$w_k^A = w_e^A - w_i$ = -0,704 – (-0,178) = -0,526 kN/m^2

$w_k^B = w_e^B - w_i$ = -0,469 – (-0,178) = -0,291 kN/m^2

$w_k^D = w_e^D - w_i$ = +0,587 – (-0,178) = +0,409 kN/m^2

$w_k^E = w_e^E - w_i$ = -0,293 – (-0,178) = -0,115 kN/m^2

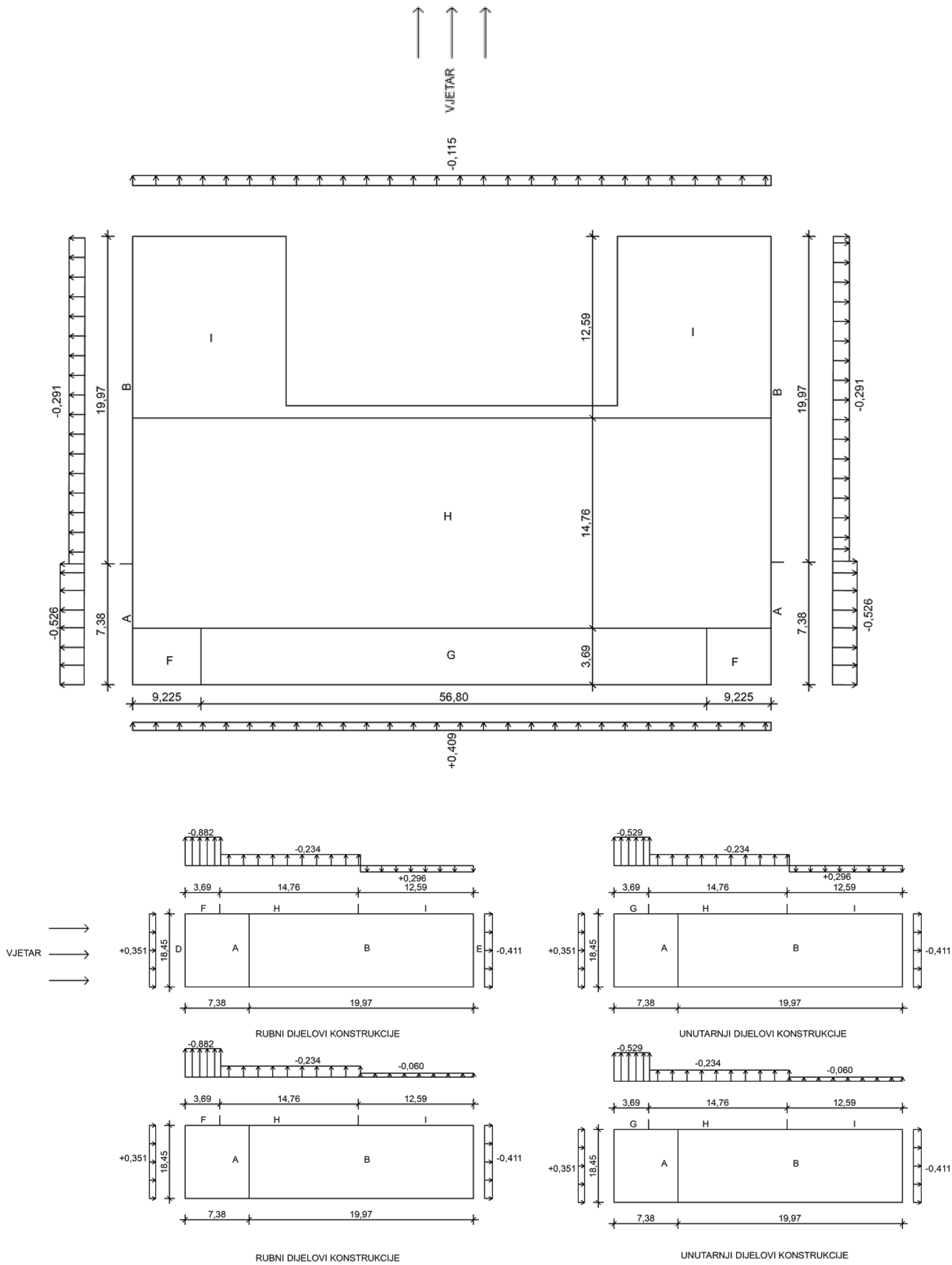
$w_k^F = w_e^F - w_i$ = -1,060– (-0,178) = -0,882 kN/m^2

$w_k^G = w_e^G - w_i$ = -0,707 – (-0,178) = -0,529 kN/m^2

$w_k^H = w_e^H - w_i$ = -0,412 – (-0,178) = -0,234 kN/m^2

$w_{k1}^I = w_e^I - w_i$ = +0,118 – (-0,178) = +0,296 kN/m^2

$w_{k2}^I = w_e^{II} - w_i$ = -0,118 – (-0,178) = -0,060 kN/m^2



Slika 3.3.8. Opterećenje vjetrom [kN/m^2]: Slučaj 2 – transverzalni tlak, c_{pi} = - 0,3

3.3.7. **Slučaj 3 – vjetar puše na poprečnu stranu objekta cpi = +0,2**

Vanjski tlak

Vanjski tlak na vertikalne stijene

Referentna visina:

$$z_e = f_c\left(\frac{h}{b}\right)$$

gdje je:

h = 19,08 m

b = 27,35 m (širina površine na koju puše vjetar)

$h \leq b$ → z_e = h = 19,08 m

Koeficijent tlaka na vertikalne stijene

e = min (b ; 2h) = min (27,35; 38,16) = 27,35 m

d = 75,25 m → $e < d$

h / d = 19,08 / 75,25 = 0,245

Površina (A) = (A) = (e/5) · h = (27,35/5) · 19,08 = 100,920 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10} = -1,2$

Površina (B) = (4/5) · e · h = (4/5) · 27,35 · 19,08 =403,686 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10} = -0,8$

Površina (C) = (d-e) · h = (75,25 – 27,35) · 19,08 = 885,603 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10} = -0,5$

Površina (D) = b · h = 27,35 · 19,08 = 504,608 m^2
→ $c_{pe} = c_{pe,10} = +0,7$

Površina (E) = b · h = 27,35 · 19,08 = 504,608 m^2
→ $c_{pe} = c_{pe,10} = -0,3$

Koeficijent izloženosti

Teren IV kategorije – područja s najmanje 15% površine pokrivene građevinama čija prosječna visina premašuje 15 m

$c_e(19,08) = 1,5$

q_p (ze) = $c_e(z) \cdot q_b$ = 1,5 · 0,391 = 0,587 kN/m^2

Djelovanje vjetra na vertikalne površine

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

w_e^A = 0,587 · (-1,2) = -0,704 kN/m^2

w_e^B = 0,587 · (-0,8) = -0,469 kN/m^2

w_e^C = 0,587 · (-0,5) = -0,294 kN/m^2

w_e^D = 0,587 · (+0,8) = +0,469 kN/m^2

w_e^E = 0,587 · (-0,5) = -0,294 kN/m^2

Vanjski tlak na krovnu plohu

Referentna visina:

$$z_e = f_c\left(\frac{h}{b}\right)$$

gdje je:

h = 19,08 m

b = 27,35 m (širina površine na koju puše vjetar)

$h \le b$ → z_e = h = 19,08 m

Koeficijent tlaka na vertikalne stijene

e = min (b ; 2h) = min (27,35 ; 38,16) = 27,35 m

d = 75,25 m → $e < d$

h / d = 19,08 / 75,25 = 0,245

Površina (F) = (e/4) · (e/10) = (27,35/4) · (27,35/10) = 18,701 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10}$ = -1,8

Površina (G) = (b - 2·0,25e) · 0,1e = (27,35 – 2·0,25·27,35) · 0,1 · 27,35 =
37,401 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10}$ = -1,2

Površina (H) = b · (0,5e – 0,1e) = 27,35 · (0,5 · 27,35 – 0,1 · 27,35) =
299,209 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10}$ = -0,7

Površina (I) = b · (d - 0,5e) = 27,35 · (75,25 – 0,5 · 27,35) = 1684,08 m^2 > 10 m^2
→ $c_{pe} = c_{pe,10}$ = ±0,2

Koeficijent izloženosti

Teren IV kategorije – područja s najmanje 15% površine pokrivene građevinama čija prosječna visina premašuje 15 m

c_e(19,08) = 1,5

q_p (ze) = c_e(z) · q_b = 1,5 · 0,391 = 0,587 kN/m^2

Djelovanje vjetra na ravne krovove

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

w_e^F = 0,587 · (-1,8) = -1,060 kN/m^2

w_e^G = 0,587 · (-1,2) = -0,707 kN/m^2

w_e^H = 0,587 · (-0,7) = -0,412 kN/m^2

w_e^I = 0,587 · (0,2) = +0,118 kN/m^2

w_e^I = 0,587 · (-0,2) = -0,118 kN/m^2

Unutarnji tlak

Pritisak vjetra

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

Referentna visina

z_i = 19,08 m

Koeficijent unutrašnjeg tlaka vjetra c_{pi}

$c_{\text{pi}} = +0,2$ kad vjetar izaziva tlak iznutra ili

Djelovanje vjetra na sve unutrašnje površine $c_{\text{pi}} = +0,2$

w_i = 0,587 · (+0,2) = 0,118 kN/m^2

$w_k^A = w_e^A - w_i$ = -0,704 – (+0,118) = -0,822 kN/m^2

$w_k^B = w_e^B - w_i$ = -0,469 – (+0,118) = -0,589 kN/m^2

$w_k^C = w_e^C - w_i$ = -0,294 – (+0,118) = -0,412 kN/m^2

$w_k^D = w_e^D - w_i$ = +0,469 – (+0,118) = +0,351 kN/m^2

$w_k^E = w_e^E - w_i$ = -0,294 – (+0,118) = -0,412 kN/m^2

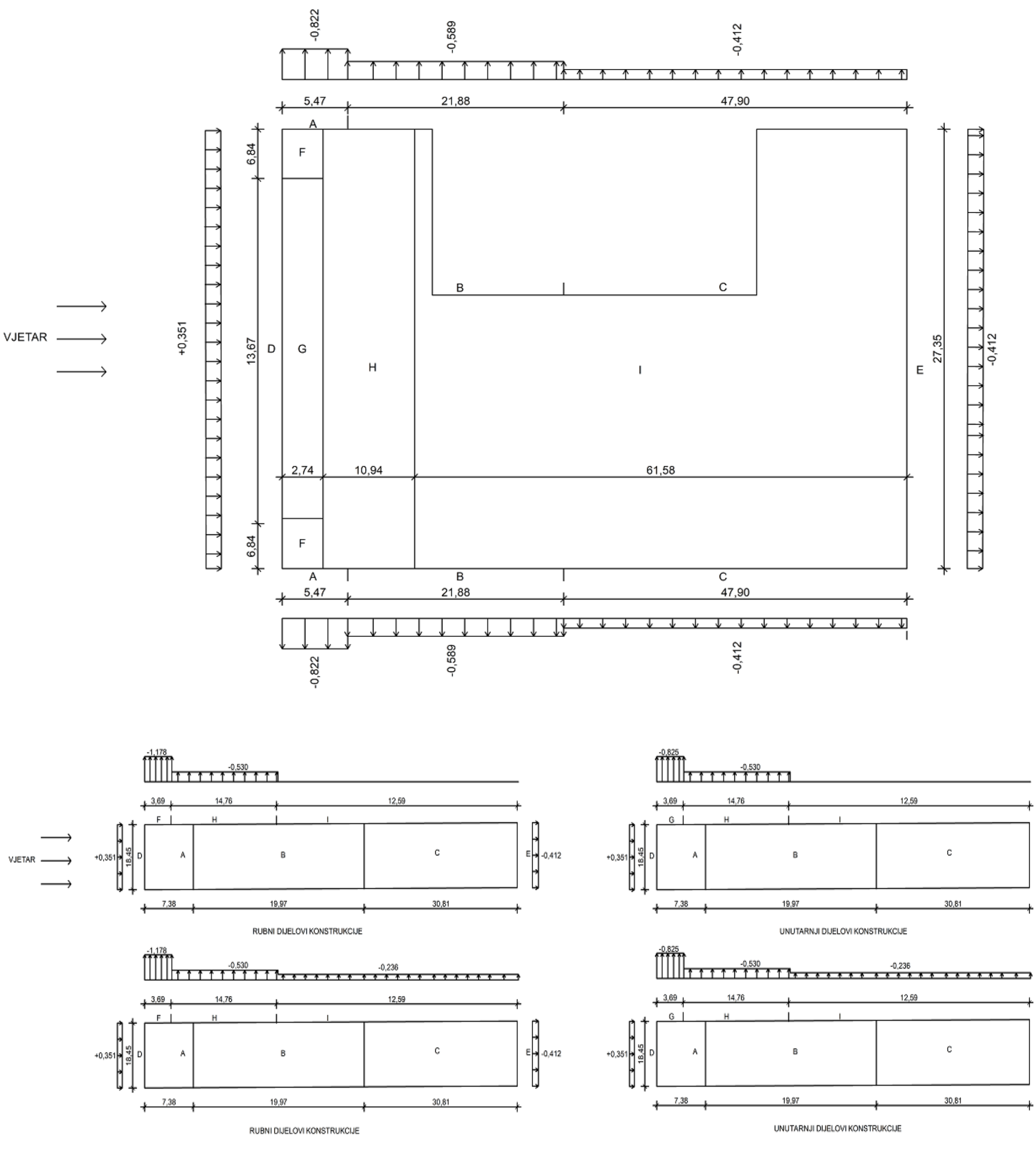
$w_k^F = w_e^F - w_i$ = -1,060 – (+0,118) = -1,178 kN/m^2

$w_k^G = w_e^G - w_i$ = -0,707 – (+0,118) = -0,825 kN/m^2

$w_k^H = w_e^H - w_i$ = -0,412 – (+0,118) = -0,530 kN/m^2

$w_{k1}^I = w_e^I - w_i$ = +0,118 – (+0,118) = 0,000 kN/m^2

$w_{k2}^I = w_e^{II} - w_i$ = -0,118 – (+0,118) = -0,236 kN/m^2



Slika 3.3.9. Opterećenje vjetrom [kN/m^2]: Slučaj 3 – longitudinalni tlak, c_{pi} = + 0,2

3.3.8. Slučaj 4 – vjetar puše na poprečnu stranu objekta, cpi = - 0,3

Vanjski i unutrašnji tlak

Isti kao i u slučaju 2.

Djelovanje vjetra na sve površine $c_{pi} = -0,3$

$w_i = 0,587 \cdot (-0,3) = -0,178$ kN/m²

Tlak na površinu je algebarski zbroj unutarnjeg i vanjskog tlaka:

$w_k^A = w_e^A - w_i = -0,704 - (-0,178) = -0,526$ kN/m²

$w_k^B = w_e^B - w_i = -0,469 - (-0,178) = -0,291$ kN/m²

$w_k^C = w_e^C - w_i = -0,294 - (-0,178) = -0,116$ kN/m²

$w_k^D = w_e^D - w_i = +0,469 - (-0,178) = +0,647$ kN/m²

$w_k^E = w_e^E - w_i = -0,294 - (-0,178) = -0,116$ kN/m²

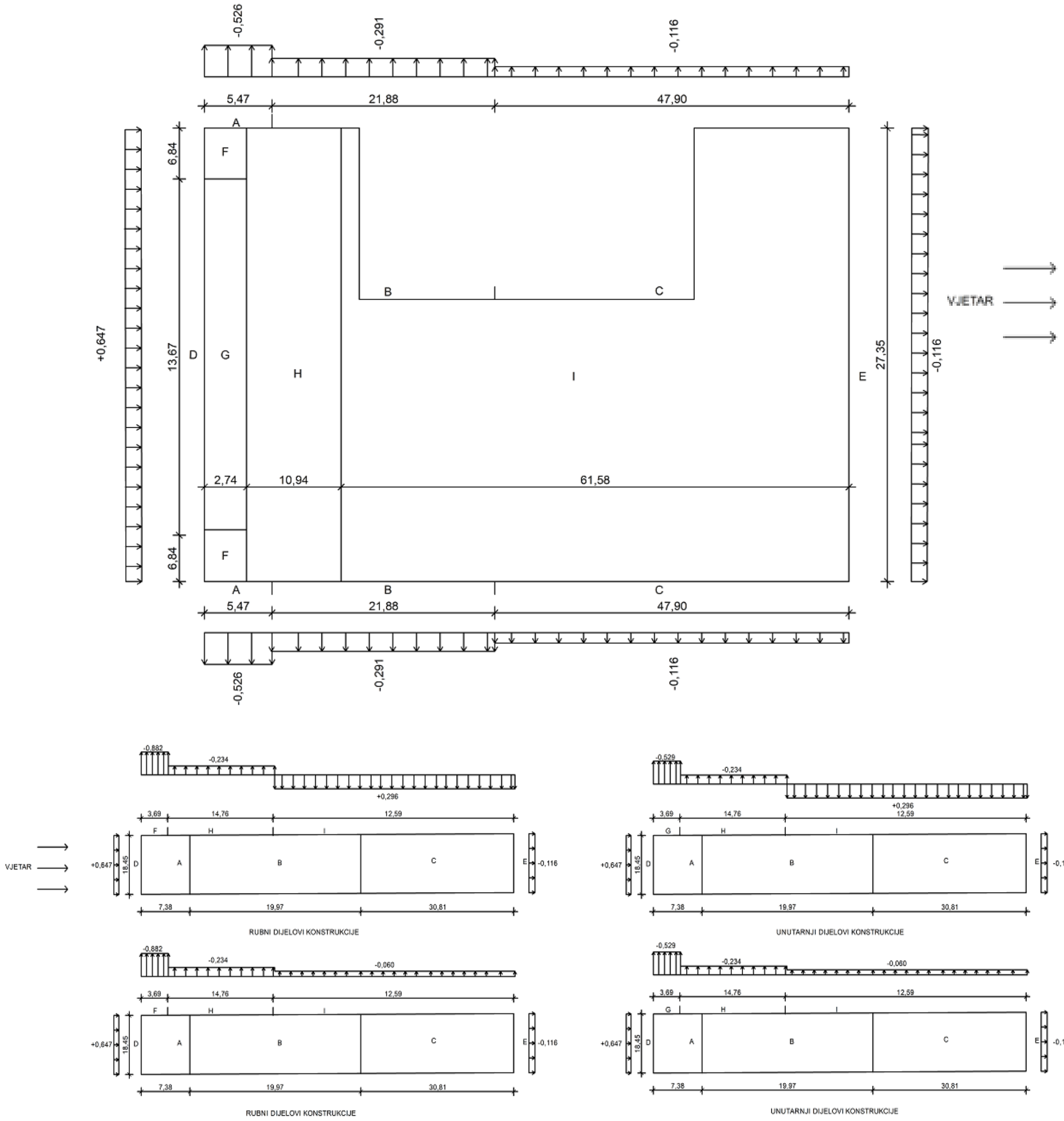
$w_k^F = w_e^F - w_i = -1,060 - (-0,178) = -0,882$ kN/m²

$w_k^G = w_e^G - w_i = -0,707 - (-0,178) = -0,529$ kN/m²

$w_k^H = w_e^H - w_i = -0,412 - (-0,178) = -0,234$ kN/m²

$w_{k1}^I = w_e^I - w_i = +0,118 - (-0,178) = +0,296$ kN/m²

$w_{k2}^I = w_e^{II} - w_i = -0,118 - (-0,178) = -0,060$ kN/m²



Slika 3.3.10. Opterećenje vjetrom [kN/m^2]: Slučaj 4 – longitudinalni tlak, c_{pi} = - 0,3

3.3.9. **Potres**

Prema HRN EN 1998-1 [4]

Slika 3.3.11. Prikaz povratnih perioda i ubrzanja tla za odabranu lokaciju

- Razred tla (pretpostavka): C
- Razred važnosti zgrade: II $\gamma_I = 1,0$

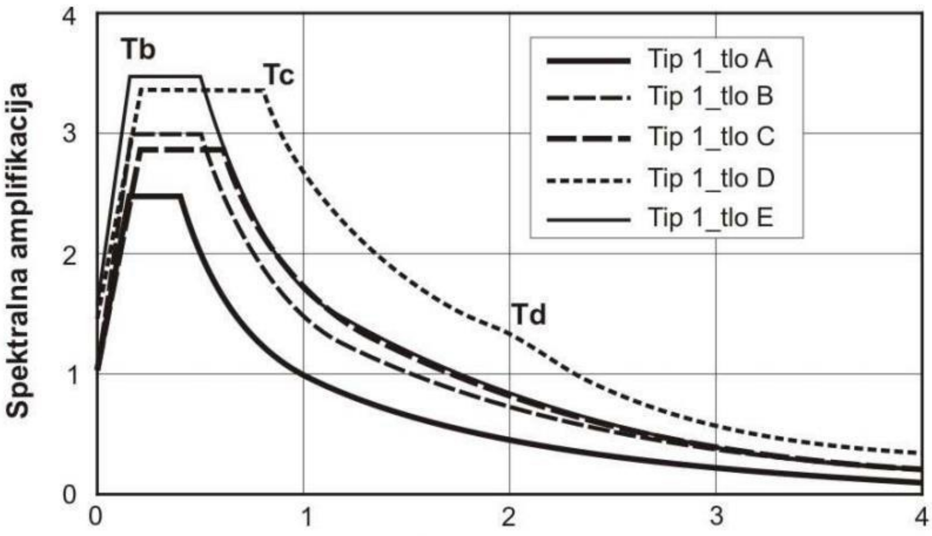
Vrijednosti parametara kojima se opisuje horizontalni elastični spektar odziva za potres Tipa 1:

Razred tla	S	b	T_B	T_C	T_D
A	1,00	0,2	0,15	0,40	2,0
B	1,20	0,2	0,15	0,50	2,0
C	1,15	0,2	0,20	0,60	2,0
D	1,35	0,2	0,20	0,80	2,0
E	1,40	0,2	0,15	0,50	2,0

Projektni spektar za elastični proračun

Kako bi se izbjegao nelinearni proračun konstrukcije, kapacitet gubljenja energije konstrukcije uzima se u obzir koristeći linearan proračun konstrukcije zasnovan na reduciranom elastičnom spektru odziva ubrzanja tla. Redukcija se vrši uvođenjem faktora ponašanja *q*.

$0 \leq T \leq T_B$	$S_d(T) = \alpha_g \times S \times [2/3 + T/T_B \times (2{,}5/q - 2/3)]$
$T_B \leq T \leq T_C$	$S_d(T) = \alpha_g \times S \times 2{,}5/q$
$T_C \leq T \leq T_D$	$S_d(T) = \alpha_g \times S \times 2{,}5/q \times [T_C/T] \geq \beta \times \alpha_g$
$T_D < T$	$S_d(T) = \alpha_g \times S \times 2{,}5/q \times [T_C \times T_D/T^2] \geq \beta \times \alpha_g$



Slika 3.3.12. Elastični spektar odziva Tipa 1

Faktor ponašanja

Način proračuna i razred duktilnosti	***q***	**Primjeri konstrukcija**
Mala sposobnost trošenja energije – DCL	1,5	Konzole; grede; dvozglobni ili trozglobni lukovi; rešetke spojene spajalima
Umjerena sposobnost trošenja energije – DCM	2	Lijepljeni zidni paneli s lijepljenim dijafragmama spojeni čavlima i vijcima; rešetke spojene trnovima i vijcima; mješovite konstrukcije od drvenih okvira (koji preuzimaju horizontalne sile) i nenosive ispune
	2,5	Statički neodređeni portalni okviri spojeni trnovima i vijcima (vidjeti točku 8.1.3(3)P)
Velika sposobnost trošenja energije – DCH	3	Zidni paneli spojeni čavlima s lijepljenim dijafragmama spojenim čavlima i vijcima s čavlanim spojevima
	4	Statički neodređeni portalni okviri spojeni trnovima i vijcima (vidjeti točku 8.1.3(3)P)
	5	Zidni paneli spojeni čavlima s dijafragmama spojenim čavlima, spojeni međusobno čavlima i vijcima

Slika 3.3.13. Odabrani faktor ponašanja za drvene konstrukcije prema HRN EN 1998-1

Vertikalna komponenta seizmičkog djelovanja

Vertikalna komponenta potresnog djelovanja prikazuje se elastičnim spektrom odziva.

$0 \leq T \leq T_B$	$S_{ve}(T) = \alpha_{vg} \times [1 + T/T_B \times (\eta \times 3{,}0 - 1)]$
$T_B \leq T \leq T_C$	$S_{ve}(T) = \alpha_{vg} \times S \times \eta \times 3{,}0$
$T_C \leq T \leq T_D$	$S_{ve}(T) = \alpha_{vg} \times \eta \times 3{,}0 \times [T_C/T]$
$T_D < T$	$S_{ve}(T) = \alpha_{vg} \times \eta \times 3{,}0 \times [T_C \times T_D/T^2]$

Vrijednosti parametara kojima se opisuje vertikalni elastični spektar odziva za potres Tipa 1:

α_{vg}/α_g	S	T_B (s)	T_C (s)	T_D (s)
0,90	1,0	0,05	0,15	1,0

Uvjet za uzimanje u obzir vertikalne komponente potresnog djelovanja:

$\alpha_{vg} > 0{,}25g$

$\alpha_{vg} = 0{,}9\ \alpha_g = 0{,}9 \times 0{,}24g = 0{,}22g < 0{,}25g$

UVJET NIJE ISPUNJEN – NIJE POTREBNO UZIMATI U OBZIR VERTIKALNU KOMPONENTU SEIZMIČKOG DJELOVANJA.

3.4. Globalni statički proračun konstrukcije (P+5)

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MODEL

CONTENTS

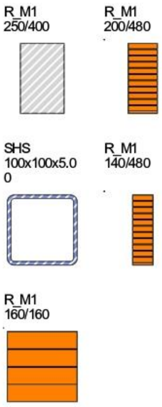
1 Basic Objects

1.1 MATERIALS

Legend
% Stiffness modification

Material No.	Material Name	Material Type	Analysis Model	Options
6	Stora Enso (40 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%
7	C 35/40 beton	Concrete	Isotropic | Linear Elastic	
8	GL32h | Isotropic | Linear Elastic	Timber	Isotropic | Linear Elastic	%
9	S355 | Isotropic | Linear Elastic	Steel	Isotropic | Linear Elastic	
10	Stora Enso (30 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%
11	Stora Enso (20 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%

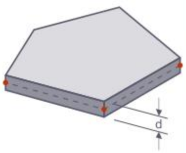
1.2 SECTIONS



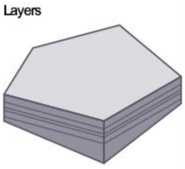
Section No.	Material No.	Section Type	Manufacturing Type	I_t [cm⁴] / A [cm²]	I_y [cm⁴] / A_y [cm²]	I_z [cm⁴] / A_z [cm²]	Overall Dimensions b [mm]	h [mm]
1	R_M1 250/400 | 7 - C 35/40 beton							
	7	Parametric - Massive I		127345.16	133333.33	52083.33	250.0	400.0
				1000.00	833.33	833.33		
2	R_M1 200/480 | 8 - GL32h							
	8	Parametric - Massive I		94484.39	184320.00	32000.00	200.0	480.0
				960.00	800.00	800.00		
3	SHS 100x100x5.00 | 9 - S355							
	9	Standardized - Steel	Cold formed	440.51	271.02	271.02	100.0	100.0
				18.35	8.05	8.05		
4	R_M1 140/480 | 8 - GL32h							
	8	Parametric - Massive I		35841.51	129024.00	10976.00	140.0	480.0
				672.00	560.00	560.00		
5	R_M1 160/160 | 8 - GL32h							
	8	Parametric - Massive I		9229.65	5461.33	5461.33	160.0	160.0
				256.00	213.33	213.33		

1.3 THICKNESSES

Uniform



Layers



Thick. No.	Type	Assigned to Surface No.	Material	Symbol	Thickness Value	Unit	Nodes	Direction
2	CLT-200							
	Layers	18-21,23-34,42-45,49-52,57,262-264,268-270,293,302,303,306,313,362,366,674-679						
3	CLT-140							
	Layers	14,16,17,22,35,38,46,47,54-56,60-62,67,68,70-77,81,84,86,87,90,93,96,99,105,106,108,109,111,112,114,115,117,118,120,121,123-126,130,131,133-135,141,179-181,185,186,191-193,195,197,198,200,201,204,206,207,209,210,212,213,215,216,218,219,222,225,226,228-230,233,237,250,253,255,258,265-267,272,274,278-284,286-290,294,298,300,301,304,305,316,318,320,324,327,329-335,341,347,348,357,358,417-422,424-427,432-461,464-497,506-512,515,518,519,521-524,526-539,543-547,549-563,567-572,603-609,613-621,628,631-637,657,658,665,672,673,680-689,695-726,730-744,784-790,793-801,803,804,806-813						
4	BETON-ZIDOVI							
	Uniform	1,	7	d	200.0	mm		

1.3

THICKNESSES

Thick. No.	Type	Assigned to Surface No.	Material	Symbol	Thickness Value	Unit	Nodes	Direction
		2,4-8,10,12,13,15,36,37,39-41,53,58,59,78-80,82,137,140,239,242,244,246,259,271,276,277,285,307-311,314,399,412,416,428-431,462,463,500-505,514,516,517,525,540-542,564,566,588,611,612,622,623,642,654,660,664,666-668,690-694,727-729,759,760						
5	CLT-240-PLOČA							
	Layers	3, 9,11,48,63-66,69,83,85,91,92,94,95,97,98,100-104,107,110,113,116,119,122,127-129,132,136,138,139,142-178,182-184,187-190,194,196,199,202,203,205,208,211,214,217,220,221,223,224,227,231,232,234-236,238,240,241,243,245,247-249,251,252,254,256,257,260,261,273,275,291,292,295-297,299,312,315,317,319,321-323,325,326,328,336-340,342-346,349-356,359-361,363-365,367-398,400-402,404-411,413-415,423,498,499,513,520,548,565,573-587,589-602,610,624-627,629,630,638-641,643-653,655,656,659,661-663,669-671,745-758,761-783,791,792,802,805						

1.3.1

THICKNESSES - LAYER INFO

Thick. No.	Total Thickness d [mm]	Total Weight g [N/m²]	Direction of Main Thickness	Comment
2	200.0	1000.0	90.00	
3	140.0	700.0	0.00	
5	240.0	1200.0	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]
2	1	Directly	6	40.0	90.00	9	5000.0	200.0
	2	Directly	6	40.0	0.00	9	5000.0	200.0
	3	Directly	6	40.0	90.00	9	5000.0	200.0
	4	Directly	6	40.0	0.00	9	5000.0	200.0
	5	Directly	6	40.0	90.00	9	5000.0	200.0
3	1	Directly	10	30.0	0.00	9	5000.0	150.0
	2	Directly	10	30.0	90.00	9	5000.0	150.0
	3	Directly	11	20.0	0.00	9	5000.0	100.0
	4	Directly	10	30.0	90.00	9	5000.0	150.0
	5	Directly	10	30.0	0.00	9	5000.0	150.0
5	1	Directly	10	30.0	0.00	9	5000.0	150.0
	2	Directly	6	40.0	90.00	9	5000.0	200.0
	3	Directly	10	30.0	0.00	9	5000.0	150.0
	4	Directly	6	40.0	90.00	9	5000.0	200.0
	5	Directly	10	30.0	0.00	9	5000.0	150.0
	6	Directly	6	40.0	90.00	9	5000.0	200.0
	7	Directly	10	30.0	0.00	9	5000.0	150.0

1.3.3

THICKNESSES - OPTIONS FOR CLT

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

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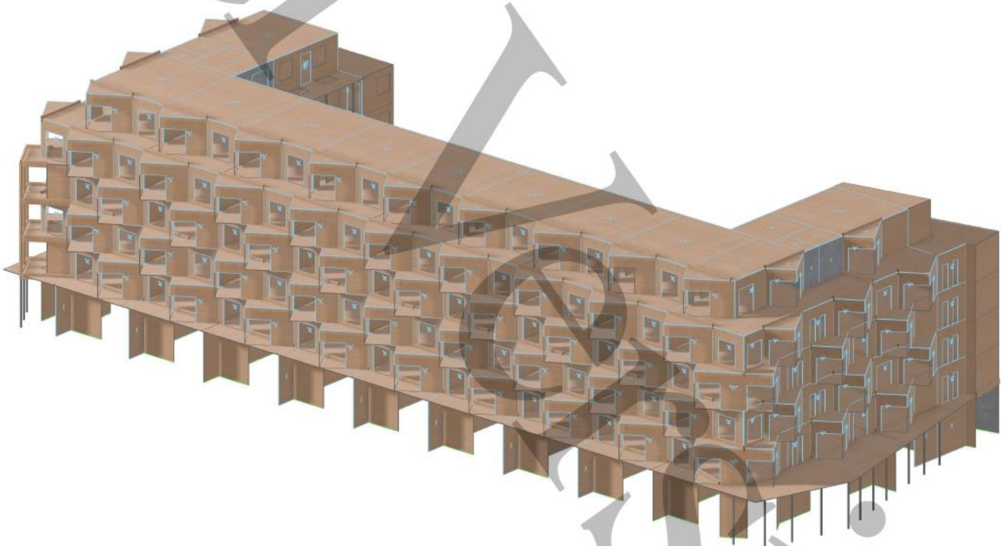
1.5 MODEL, IN AXONOMETRIC DIRECTION

In Axonometric Direction



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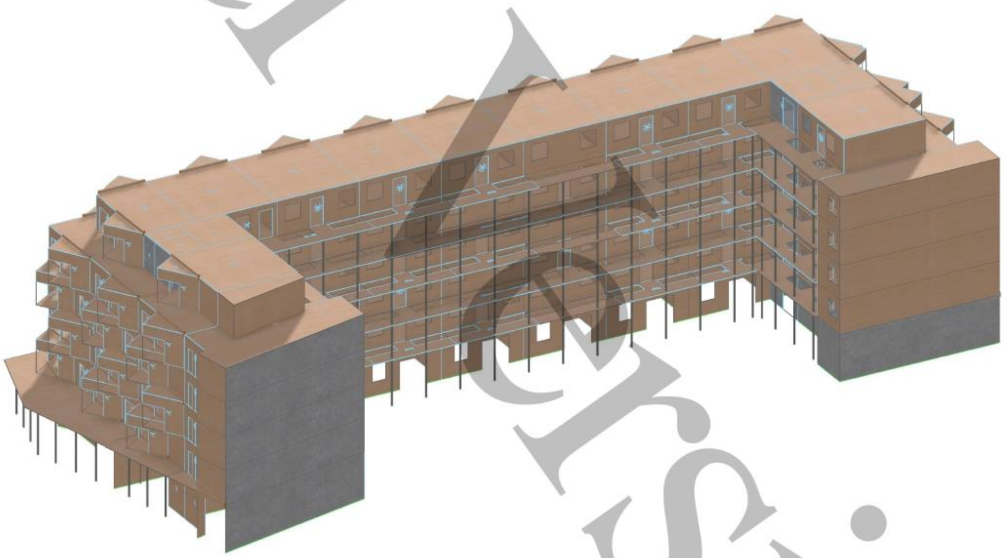
MODEL

1.6 MODEL, IN AXONOMETRIC DIRECTION

In Axonometric Direction



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2 Load Cases & Combinations

2.1 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 | 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	Gq Dodatno stalno				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			
	Action category	Gq Permanent/Imposed			
	Load duration	Permanent			
	Self-weight mode for geotechnical analysis	Normal			
3	QI A Uporabno				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | 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			
4	Qs Snijeg				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | Timber | CEN | 2010-04			
	Static analysis settings	SA1 - Geometrically linear | Newton-Raphson			
	Action category	Qs Snow/Ice loads - H <= 1000 m			
	Load duration	Medium-term			
	Self-weight mode for geotechnical analysis	Normal			
9	AE Potres				
	Analysis type	Modal Analysis		☒	
	Associated standard	EN 1990 | Timber | CEN | 2010-04			
	Modal analysis settings	MOS1 - #20 | Lanczos			
	Import masses from	SE/M CO127			
	Action category	AE Seismic actions			
	Self-weight mode for geotechnical analysis	Normal			
10	AE Spektar				
	Analysis type	Response Spectrum Analysis		☒	Accidental torsion
	Associated standard	EN 1990 | 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			
11	Qw Vjetar pritiskajući				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | 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			
12	Qw Vjetar odižući				
	Analysis type	Static Analysis		☒	
	Associated standard	EN 1990 | 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			

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2.2 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		☐	
	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		☐	

2.3 MODAL ANALYSIS SETTINGS

Settings No.	Description	Symbol	Value	Unit
1	#20 | Lanczos			
	Number of modes method		User-Defined	
	Number of modes		20	
	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		No neglection	
2	f_{me} : 30.00 % | Root of characteristic polynomial			
	Number of modes method		Automatic, to reach effective modal mass factors	
	Effective modal mass factor	f_{me}	30.00	%
	Solution method		Root of characteristic polynomial	
	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		No neglection	

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2.4 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		☐	

2.5 COMBINATION WIZARDS

Wizard No.	Settings	Value
1	Load combinations | SA2 - Second-order (P-Δ) | Picard | 100 | 1	
	Assigned to	DS 1-4
	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 1-4
	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	Result combinations	
	Assigned to	DS 5
	Generate combinations	Result combinations (linear analysis)
	Consider imperfection case	☐
	Generate as permanent superposition	☒
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Assigned to	DS 5
	Generate combinations	Result combinations (linear analysis)
	Consider imperfection case	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐

2.5.1 COMBINATION WIZARDS - INITIAL STATE ITEMS

Wizard No.	Definition Type	Case Object
1	Load combinations | SA2 - Second-order (P-Δ) | Picard | 100 | 1	
2	Result combinations	

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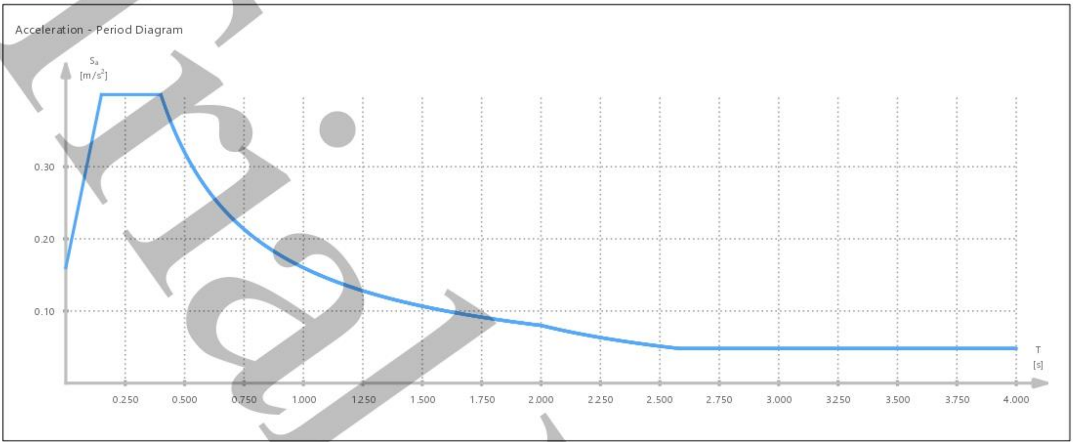
2.6 RESPONSE SPECTRA | DIAGRAM



3 Load Wizards

3.1 WIND PROFILES

Profile No.	Profile Type / Definition Type	Assigned To / Load Zone	Δz [m]	Level z [m]	Velocity v [m/s]	Turb. Intensity I [%]
1	According to Standard - EN 1991 | CEN | 2015-09					
	According to Standard - EN 1991 | CEN | 2015-09			0.000	33.65	17.21
				1.245	34.57	16.59
				2.491	37.46	14.88
				3.736	39.14	14.03
				4.981	40.33	13.49
				6.227	41.25	13.09
				7.472	42.00	12.79
				8.717	42.63	12.54
				9.963	43.17	12.33
				11.208	43.66	12.16
				12.453	44.09	12.00
				13.699	44.48	11.87
				14.944	44.83	11.75
				16.189	45.16	11.64
				17.435	45.46	11.54
				18.680	45.74	11.45

3.1.1 WIND PROFILE - PARAMETERS

Profile No.	Description	Symbol	Value	Unit
1	According to Standard - EN 1991 | CEN | 2015-09			
	Parameters			
	Terrain category		Category 0	
	Structure height	h	18.680	m
	Air density	ρ	1.25	kg/m³
	Wind velocity			
	Consider mean wind velocity		☐	
	Fundamental wind velocity	$v_{b,0}$	25.00	m/s
	Turbulence intensity			
	Uniform turbulence intensity		☐	
	Coefficients			
	Orography factor	c_o	1.00	–
	Directional factor	c_{dir}	1.00	–
	Seasonal factor	c_{season}	1.00	–
	Turbulence factor	k_I	1.00	–
	Terrain factor			

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3.1.1 **WIND PROFILE - PARAMETERS**

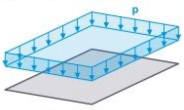
Profile No.	Description	Symbol	Value	Unit
	Manual definition of terrain factor		☐	
	Terrain factor	k_r	0.16	–
	Velocity pressure			
	Basic velocity pressure	q_b	0.39	kN/m²

4 Loads

4.1 LC2 - Dodatno stalno

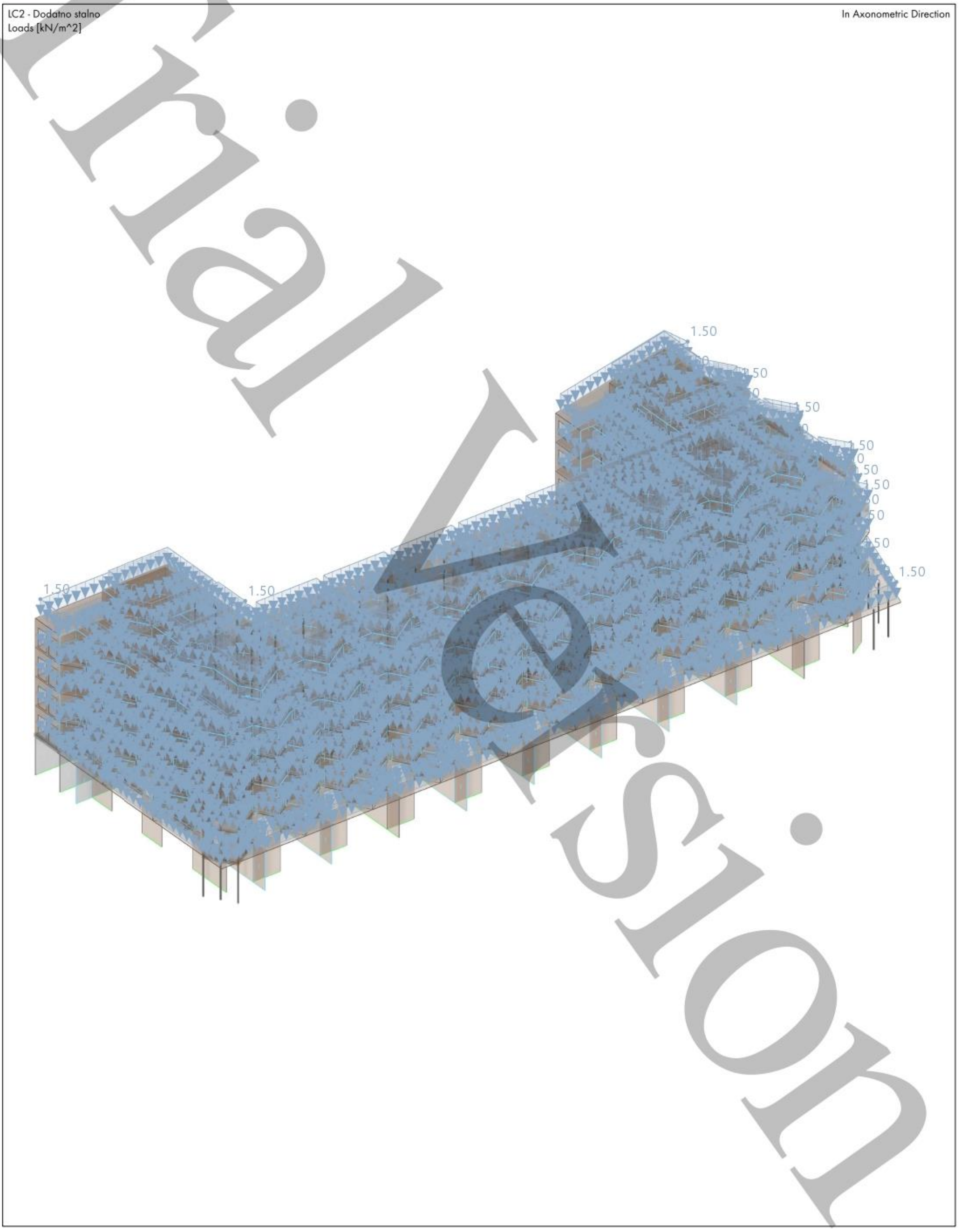
4.1.1 **SURFACE LOADS** **LC2: Dodatno stalno** Gq

Load Type 'Force' | Load Distribution 'Uniform'



Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Parameters Symbol	Value	Unit
1		Force	Uniform	1	Z_A	p	-1.50	kN/m²
2	3, 11,48,63,64,66,69,149,153,155,159,161,163,165,166,168,169,310,311,314,317,349-356,360,363,364,382-396,412,414,514,639,642,646-648,651,652,655,659,670,671,802	Force	Uniform	1	Z_A	p	1.50	kN/m²
3	83,85,91,92,94,95,97,98,100-104,107,110,113,116,119,122,127-129,132,136,138,139,142-148,150-152,154,156-158,160,162,164,167,170-178,182-184,187-190,194,196,199,202,203,205,208,211,214,217,220,221,223,224,227,231,232,234-236,238,240,241,243,245,247-249,251,252,254,256,257,260,261,273,275,291,292,295-297,299,312,315,319,321-323,325,326,328,336-340,342-346,359,361,365,367-381,397,398,400-402,404-411,413,415,423,498,499,513,520,548,565,573-587,589-602,610,624-627,629,630,638,641,643-645,649,650,653,656,661-663,669,745-758,761-783,791,792,805	Force	Uniform	1	Z_A	p	1.50	kN/m²

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



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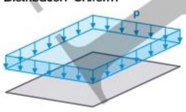
LOADS

4.2 LC3 - Uporabno

4.2.1 SURFACE LOADS

LC3: Uporabno QI A

Load Type 'Force' | Load Distribution 'Uniform'



Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Symbol	Parameters Value	Unit
1	387-390,392,394,396	Force	Uniform	1	Z_A	p	2.00	kN/m²
3	640	Force	Uniform	1	Z_A	p	4.00	kN/m²
4	9,652	Force	Uniform	1	Z_A	p	4.00	kN/m²
5	63	Force	Uniform	1	Z_A	p	4.00	kN/m²
6	375	Force	Uniform	1	Z_A	p	2.00	kN/m²
7	345,359,367,415,423,498,499,513,520,565,574,587,589-596,601,610,625,638	Force	Uniform	1	Z_A	p	4.00	kN/m²
8	164,170,173,177,183,187,194,202,208,217,223,227,231,236	Force	Uniform	1	Z_A	p	4.00	kN/m²
9	600	Force	Uniform	1	Z_A	p	4.00	kN/m²
10	662	Force	Uniform	1	Z_A	p	2.00	kN/m²
11	240,243,247,251,254,257,261,275,312,319,325,326,337-339,342	Force	Uniform	1	Z_A	p	4.00	kN/m²
12	3, 11,48,153,155,159,161,163,165,166,363,364,382-386,391,393,395,514	Force	Uniform	1	Z_A	p	4.00	kN/m²
13	761	Force	Uniform	1	Z_A	p	4.00	kN/m²
14	414	Force	Uniform	1	Z_A	p	4.00	kN/m²
15	772	Force	Uniform	1	Z_A	p	4.00	kN/m²
16	762	Force	Uniform	1	Z_A	p	4.00	kN/m²
17	64,66,69,149,168,169	Force	Uniform	1	Z_A	p	4.00	kN/m²
18	765,767-771	Force	Uniform	1	Z_A	p	4.00	kN/m²
19	763	Force	Uniform	1	Z_A	p	4.00	kN/m²
20	764	Force	Uniform	1	Z_A	p	4.00	kN/m²
21	381	Force	Uniform	1	Z_A	p	4.00	kN/m²
22	575,578	Force	Uniform	1	Z_A	p	4.00	kN/m²
23	370,373,376-380,408,409,411	Force	Uniform	1	Z_A	p	4.00	kN/m²
24	597,598	Force	Uniform	1	Z_A	p	4.00	kN/m²
25	626	Force	Uniform	1	Z_A	p	4.00	kN/m²
26	372	Force	Uniform	1	Z_A	p	2.00	kN/m²
27	627	Force	Uniform	1	Z_A	p	2.00	kN/m²
28	410	Force	Uniform	1	Z_A	p	4.00	kN/m²
31	83,97,101,102,104,107,113,116,122,127,129,132,138,139,143,145,146,148,150-152,158	Force	Uniform	1	Z_A	p	4.00	kN/m²
32	777-783	Force	Uniform	1	Z_A	p	4.00	kN/m²
34	745-758	Force	Uniform	1	Z_A	p	0.60	kN/m²
35	669	Force	Uniform	1	Z_A	p	0.60	kN/m²
36	776	Force	Uniform	1	Z_A	p	4.00	kN/m²
37	85,91,92,95	Force	Uniform	1	Z_A	p	4.00	kN/m²
38	94,98,100,103,110,119,128,136,142,147,154,157,160	Force	Uniform	1	Z_A	p	2.00	kN/m²
39	668	Force	Uniform	1	Z_A	p	4.00	kN/m²
40	162,167,171,174,176,182,188,190,199,205,214,221,224,232,235	Force	Uniform	1	Z_A	p	4.00	kN/m²
41	576,577,579-586,599	Force	Uniform	1	Z_A	p	4.00	kN/m²
42	144,172,175,178,184,189,196,203,211,220,234,573,602	Force	Uniform	1	Z_A	p	2.00	kN/m²
43	666	Force	Uniform	1	Z_A	p	4.00	kN/m²
44	249,252,256,260,273,291,315,322,328,340,624,656	Force	Uniform	1	Z_A	p	2.00	kN/m²
45	238	Force	Uniform	1	Z_A	p	2.00	kN/m²
46	792	Force	Uniform	1	Z_A	p	2.00	kN/m²
47	241,245,248	Force	Uniform	1	Z_A	p	2.00	kN/m²
48	292,295-297,299,32	Force	Uniform	1	Z_A	p	2.00	kN/m²

4.2.1 **SURFACE LOADS** **LC3: Uporabno** QI A

Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Parameters Symbol	Value	Unit
49	1,323 629,630,641,643-64 5,649,650	Force	Uniform	1	Z_A	p	2.00	kN/m²
50	336	Force	Uniform	1	Z_A	p	2.00	kN/m²
51	653	Force	Uniform	1	Z_A	p	2.00	kN/m²
52	661,663	Force	Uniform	1	Z_A	p	2.00	kN/m²
53		Force	Uniform	1	Z_A	p	2.00	kN/m²
54	343,344,346,365,36 8,369,397,398,400- 402,404-407,413,54 8,805	Force	Uniform	1	Z_A	p	2.00	kN/m²
55	371,374	Force	Uniform	1	Z_A	p	2.00	kN/m²
56	314,317,349-356,36 0,647,648,651,655,6 59,670,671	Force	Uniform	1	Z_A	p	2.00	kN/m²
57	412,639,642,646	Force	Uniform	1	Z_A	p	2.00	kN/m²
58	802	Force	Uniform	1	Z_A	p	2.00	kN/m²
59	310	Force	Uniform	1	Z_A	p	4.00	kN/m²
60	399	Force	Uniform	1	Z_A	p	4.00	kN/m²
61	667	Force	Uniform	1	Z_A	p	4.00	kN/m²
62	588	Force	Uniform	1	Z_A	p	4.00	kN/m²
63	660	Force	Uniform	1	Z_A	p	4.00	kN/m²
64	311	Force	Uniform	1	Z_A	p	4.00	kN/m²
65	664	Force	Uniform	1	Z_A	p	4.00	kN/m²
66	654	Force	Uniform	1	Z_A	p	4.00	kN/m²
67	156	Force	Uniform	1	Z_A	p	0.60	kN/m²
68	773-775	Force	Uniform	1	Z_A	p	4.00	kN/m²

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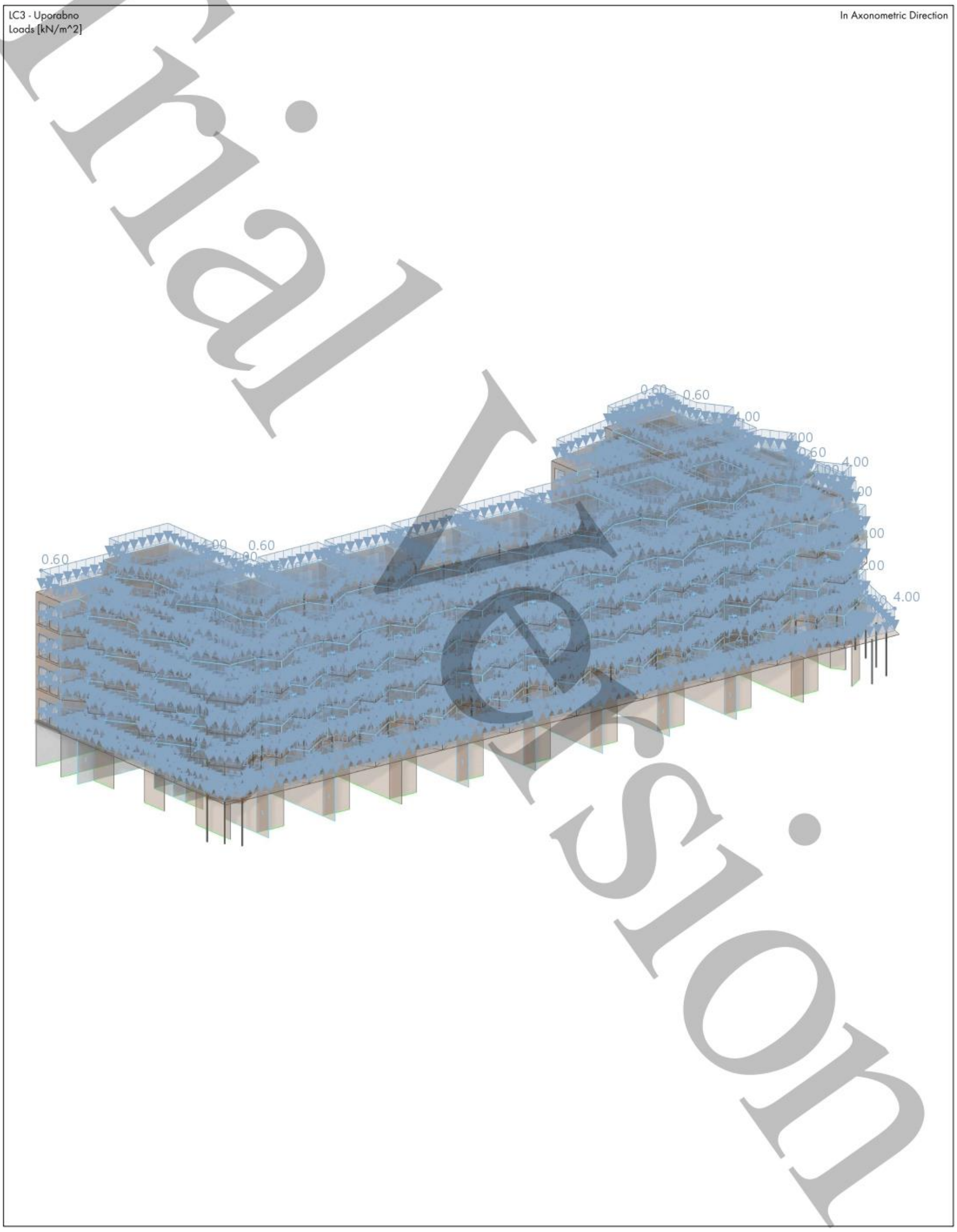
4.2.2 LC3: LOADING, IN AXONOMETRIC DIRECTION



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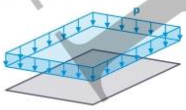
LOADS

4.3 LC4 - Snijeg

4.3.1 SURFACE LOADS

LC4: Snijeg Qs

Load Type 'Force' | Load Distribution 'Uniform'

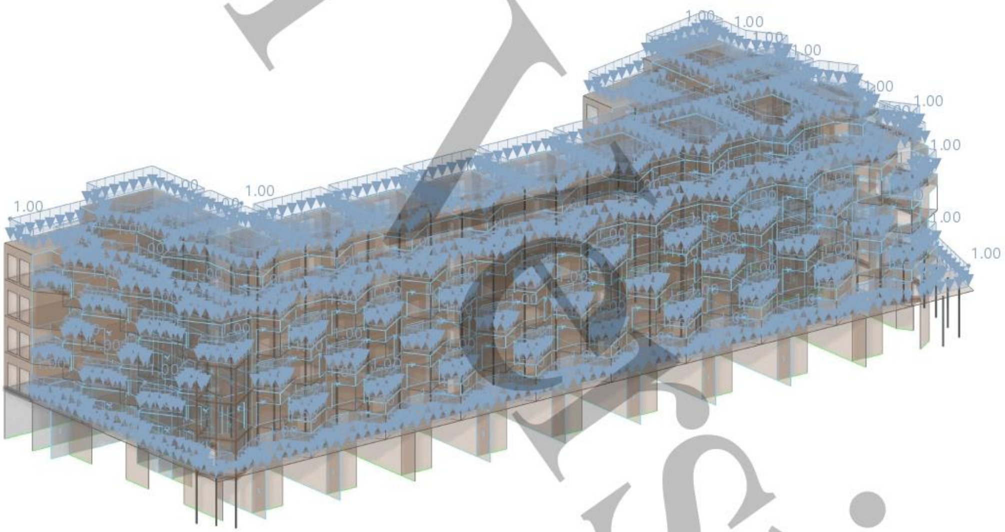


Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Symbol	Parameters Value	Unit
1	83,85,91,92,95,97,101,102,104,107,113,116,122,127,129,132,138,139,143,145,146,148,150-152,156,158,164,170,173,177,183,187,194,202,208,217,223,227,231,236,575,578,669,745-758,776-783	Force	Uniform	1	Z_A	p	1.00	kN/m²
2	3, 11,48,153,155,159,161,163,165,166,240,243,251,254,257,261,275,312,319,325,337-339,342,345,359,361,363,364,367,370,382-386,391,393,395,415,498,499,514,565,587,590,592,594,596,601,638	Force	Uniform	1	Z_A	p	1.00	kN/m²

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

LC4 - Snijeg
Loads [kN/m^2]

In Axonometric Direction



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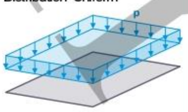
4.4 LC11 - Vjetar pritiskajući

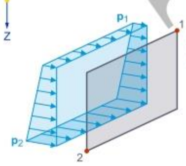
4.4.1 SURFACE LOADS

LC11: Vjetar pritiskajući Qw

Load Type 'Force' | Load Distribution 'Uniform'



Load Type 'Force' | Load Distribution 'Linear in Z'



Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Parameters Symbol	Parameters Value	Unit
1	85,91,92,95	Force	Uniform	1	Z_A	p	-0.53	kN/m²
2	83,97,669,745-747	Force	Uniform	1	Z_A	p	-0.23	kN/m²
3	101,102,104,107,113,116,122,127,129,132,138,139,143,145,146,148,150-152,156,158,748-758,776-783	Force	Uniform	1	Z_A	p	0.30	kN/m²
4	417	Force	Uniform	1	X_A	p	0.65	kN/m²
5	512	Force	Linear in Z	5	U_A	n_1	2287	
						p_1	0.65	kN/m²
						n_2	3257	
						p_2	0.65	kN/m²
6	469	Force	Linear in Z	5	U_A	n_1	2289	
						p_1	0.65	kN/m²
						n_2	1418	
						p_2	0.65	kN/m²
7	266	Force	Linear in Z	5	U_A	n_1	2289	
						p_1	0.65	kN/m²
						n_2	1418	
						p_2	0.65	kN/m²
8	67,71,186,192,419,422,471,473,658	Force	Linear in Z	5	U_A	n_1	2289	
						p_1	0.65	kN/m²
						n_2	1418	
						p_2	0.65	kN/m²
9	468	Force	Linear in Z	5	V_A	n_1	2289	
						p_1	0.65	kN/m²
						n_2	1418	
						p_2	0.65	kN/m²
10	68,70,185,191,420,421,470,472,657	Force	Linear in Z	5	V_A	n_1	2289	
						p_1	0.65	kN/m²
						n_2	1418	
						p_2	0.65	kN/m²
11	14,60,72,179,267,274,280,347,348,465,515,568,569,606,607	Force	Uniform	1	X_P	p	0.65	kN/m²
12	49,51,135,264,290,298,316,341,366,461,530,533,534,544,561-563,608,609,637,725,732,737	Force	Uniform	1	X_P	p	0.12	kN/m²
13	511	Force	Linear in Z	5	V_A	n_1	1606	
						p_1	0.12	kN/m²
						n_2	2436	
						p_2	0.12	kN/m²
14	130,133,222,225,228,265,457,459,491,492,494	Force	Linear in Z	5	V_A	n_1	1606	
						p_1	0.12	kN/m²
						n_2	2436	
						p_2	0.12	kN/m²
15	497	Force	Linear in Z	5	U_A	n_1	2655	
						p_1	0.12	kN/m²
						n_2	2663	
						p_2	0.12	kN/m²
16	131,134,226,233,357,358,458,460,493,570,571	Force	Linear in Z	5	U_A	n_1	2655	
						p_1	0.12	kN/m²
						n_2	2663	
						p_2	0.12	kN/m²

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4.4.1 **SURFACE LOADS** — **LC11: Vjetar pritiskajući** Qw

Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Symbol	Parameters Value	Unit
17	3, 11,153,155,159,161, 163,165,166,363,36 4,382-386,391,393, 395	Force	Uniform	1	Z_A	p	0.30	kN/m²
18	262,268,269	Force	Uniform	1	X_A	p	0.65	kN/m²
19	425	Force	Linear in Z	5	V_P	n_1	2305	
						p_1	0.53	kN/m²
						n_2	3046	
						p_2	0.53	kN/m²
20	74	Force	Linear in Z	5	V_P	n_1	2309	
						p_1	0.53	kN/m²
						n_2	1758	
						p_2	0.53	kN/m²
21	76,106,109,112,195, 198,201,204,426,44 2,444,446,475,477,4 79,480	Force	Linear in Z	5	V_P	n_1	2309	
						p_1	0.23	kN/m²
						n_2	1758	
						p_2	0.23	kN/m²
22	115,118,121,124,21 0,216,219,448,450,4 52,454,482,484,486, 488,490,799,801	Force	Linear in Z	5	V_P	n_1	2309	
						p_1	0.23	kN/m²
						n_2	1758	
						p_2	0.23	kN/m²
23	427	Force	Linear in Z	5	U_P	n_1	2315	
						p_1	-0.23	kN/m²
						n_2	3102	
						p_2	-0.23	kN/m²
24	193,474	Force	Linear in Z	5	U_P	n_1	2315	
						p_1	-0.53	kN/m²
						n_2	3102	
						p_2	-0.53	kN/m²
25	77,105,108,197,200, 427,441,443,476,47 8,700,703	Force	Linear in Z	5	U_P	n_1	2315	
						p_1	-0.23	kN/m²
						n_2	3102	
						p_2	-0.23	kN/m²
26	111,114,117,120,123 ,126,206,209,212,21 5,218,445,447,451,4 53,481,483,485,487, 489,603,604,706,70 9,712,715,718,721	Force	Linear in Z	5	U_P	n_1	2315	
						p_1	-0.12	kN/m²
						n_2	3102	
						p_2	-0.12	kN/m²
27	697	Force	Linear in Z	5	U_P	n_1	2315	
						p_1	-0.53	kN/m²
						n_2	3102	
						p_2	-0.53	kN/m²
28	698	Force	Linear in Z	5	V_P	n_1	2315	
						p_1	0.53	kN/m²
						n_2	3102	
						p_2	0.53	kN/m²
29	81,701,704,707,710, 713,716,722	Force	Linear in Z	5	V_P	n_1	2315	
						p_1	0.23	kN/m²
						n_2	3102	
						p_2	0.23	kN/m²
30	699	Force	Uniform	1	Y_A	p	0.29	kN/m²
31	125,281-284,286-28	Force	Uniform	1	Y_A	p	0.29	kN/m²

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SURFACE LOADS

LC11: Vjetar pritiskajući Qw

Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Symbol	Parameters Value	Unit
	9,324,327,329-335,455,510,521-524,526-529,549,551-558,702,705,708,711,714,717,720							
32	4,61,180,418,466,682	Force	Uniform	1	Y_A	p	-0.53	kN/m²
33	17,690,691,793	Force	Uniform	1	X_A	p	0.65	kN/m²
34	313,620,621,672-674	Force	Uniform	1	Y_A	p	-0.29	kN/m²
35	689,695,726,743,744,804	Force	Uniform	1	Y_A	p	-0.29	kN/m²
36	207,272,318,506,543,547,550,572,615-619,628,675-681,685,696,719,733,738-742	Force	Uniform	1	Y_A	p	-0.12	kN/m²
37	53,62,276,277,516,517	Force	Uniform	1	Y_A	p	-0.12	kN/m²
38	21,27-32,34,44	Force	Uniform	1	Y_A	p	0.29	kN/m²
39	2,5,8,78,93,181,278,428,438,467,518,566,567,605,622,686,693	Force	Uniform	1	X_A	p	0.12	kN/m²
40		Force	Uniform	1	X_A	p	-0.65	kN/m²
41	39,57,75,99,270,300,305,307,416,440,536,539,540,611,613,729,735	Force	Uniform	1	X_A	p	0.65	kN/m²

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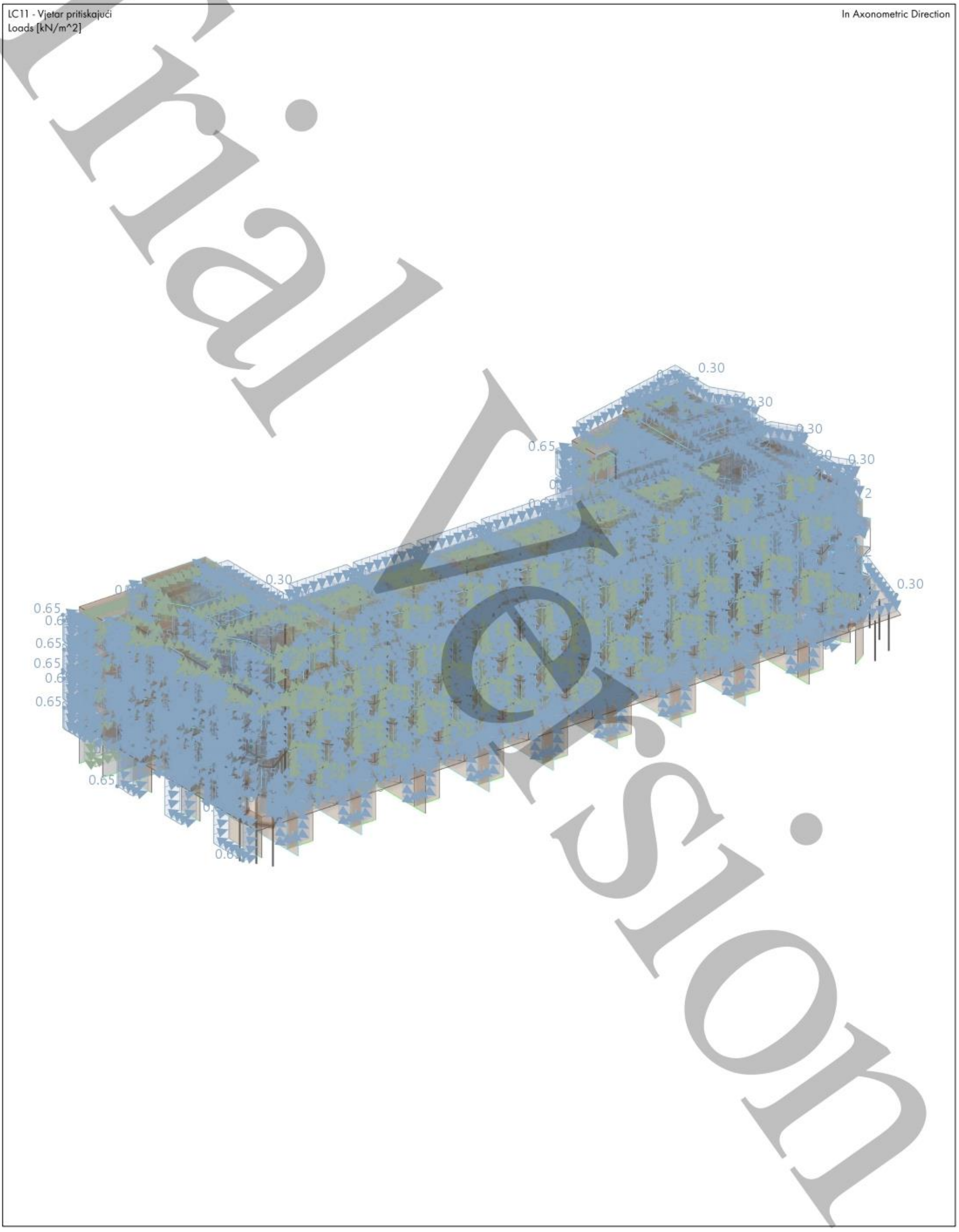
4.4.2 LC11: LOADING, IN AXONOMETRIC DIRECTION



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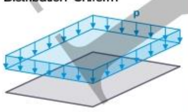
4.5 LC12 - Vjetar odižući

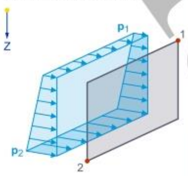
4.5.1 SURFACE LOADS

LC12: Vjetar odižući Qw

Load Type 'Force' | Load Distribution 'Uniform'



Load Type 'Force' | Load Distribution 'Linear in Z'



Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Symbol	Value	Unit
1	92,97,102,107,116,127,132,139,146,158,223,231,232,578	Force	Uniform	1	Z_A	p	-0.82	kN/m²
2	95,156,669,745-758,776-783	Force	Uniform	1	Z_A	p	-0.53	kN/m²
3	475	Force	Uniform	5	V_P	p	-0.35	kN/m²
4	74,76,81,106,109,112,115,118,121,124,195,198,210,213,216,219,265,425,426,442,444,446,448,450,452,454,477,479,480,482,484,486,488,490,511,698,701,704,707,710,713,716,722,796,799	Force	Uniform	5	V_P	p	-0.35	kN/m²
6	77,105,108,111,114,117,120,123,126,193,197,200,206,209,212,215,218,427,441,443,445,447,449,451,453,456,474,476,478,481,483,485,487,489,603,604,700,703,706,709,712,715,718,721	Force	Uniform	5	U_P	p	0.35	kN/m²
7	125,258,281-284,286-289,324,327,329-334,455,510,521-524,526-529,549,551-558,699,702,705,708,711,714,717,720,797	Force	Uniform	1	Y_A	p	-0.35	kN/m²
8	207,272,318,506,543,547,550,572,615-621,628,672,673,680,681,685,689,695,696,719,726,733,738-744,804	Force	Uniform	1	Y_A	p	-0.41	kN/m²
9	313,674-679	Force	Uniform	1	Y_A	p	-0.41	kN/m²
10	469	Force	Linear in Z	5	U_P	n_1	2574	
						p_1	0.59	kN/m²
						n_2	2580	
						p_2	0.59	kN/m²
11	67,186,266,419,471,512,658,684,688	Force	Linear in Z	5	U_P	n_1	2574	
						p_1	0.59	kN/m²
						n_2	2580	
						p_2	0.59	kN/m²
12	71,192,422,473,697	Force	Linear in Z	5	U_P	n_1	2574	
						p_1	0.82	kN/m²
						n_2	2580	
						p_2	0.82	kN/m²
13	472	Force	Linear in Z	5	V_P	n_1	2574	
						p_1	0.82	kN/m²
						n_2	2580	
						p_2	0.82	kN/m²
14	191,424	Force	Linear in Z	5	V_P	n_1	2574	
						p_1	0.82	kN/m²
						n_2	2580	
						p_2	0.82	kN/m²
15	68,70,185,420,421,468,470,657,683,687	Force	Linear in Z	5	V_P	n_1	2574	
						p_1	0.53	kN/m²
						n_2	2580	
						p_2	0.53	kN/m²
16	14,17,60,72,179,267	Force	Uniform	1	X_A	p	0.59	kN/m²

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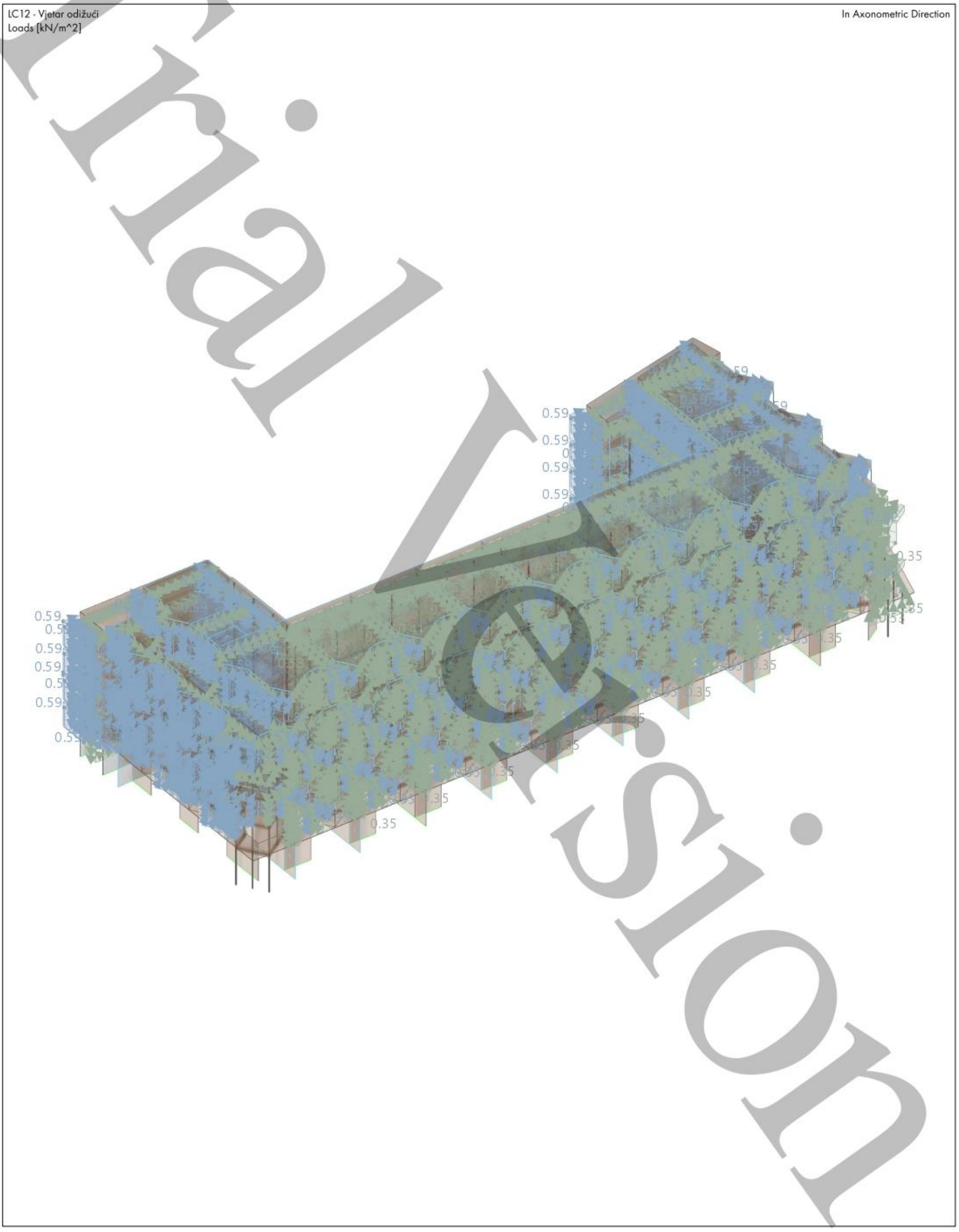
4.5.1 **SURFACE LOADS** **LC12: Vjetar odižući** Qw

Load No.	Surfaces No.	Load Type	Load Distribution	Coord. System	Load Direction	Symbol	Parameters Value	Unit
	,274,280,347,348,417,465,515,568,569,606,607,690,691,793							
17	130,133,225,228,457,459,492,494,730	Force	Linear in Z	5	V_P	n_1	2438	
						p_1	0.59	kN/m²
						n_2	3180	
						p_2	0.59	kN/m²
18	222,491,723	Force	Linear in Z	5	V_P	n_1	2438	
						p_1	0.82	kN/m²
						n_2	3180	
						p_2	0.82	kN/m²
19	570	Force	Linear in Z	5	U_P	n_1	2438	
						p_1	0.82	kN/m²
						n_2	3180	
						p_2	0.82	kN/m²
20	357,358,571,724	Force	Linear in Z	5	U_P	n_1	2438	
						p_1	0.82	kN/m²
						n_2	3180	
						p_2	0.82	kN/m²
21	131,134,226,233,460,493,497,731	Force	Linear in Z	5	U_P	n_1	2438	
						p_1	0.59	kN/m²
						n_2	3180	
						p_2	0.59	kN/m²
22	49,51,135,230,264,290,298,316,341,461,496,530,531,533,534,544,561-563,608,609,637,725,727,732,737,803	Force	Uniform	1	X_P	p	0.59	kN/m²
23	363,364	Force	Uniform	1	Z_P	p	-0.53	kN/m²
24	4, 53,61,62,180,276,277,418,466,516,517,682	Force	Uniform	1	Y_P	p	-0.41	kN/m²
25	39,57,75,99,270,300,305,307,416,440,536,539,540,611,613,729,735,736	Force	Uniform	1	X_A	p	0.59	kN/m²
26		Force	Uniform	1	X_A	p	-0.59	kN/m²
27	2, 5,8,78,93,181,278,428,438,467,518,566,567,605,622,686,693	Force	Uniform	1	X_A	p	0.59	kN/m²

4.5.2 **LC12: LOADING, IN AXONOMETRIC DIRECTION**



5 Dynamic Loads

5.1 RESPONSE SPECTRA

RS No.	Definition Type	Comment
1	According to Standard - EN 1998-1 | CEN | 2013-05	
2	According to Standard - EN 1998-1 | CEN | 2013-05	

5.1.1 RESPONSE SPECTRA - PARAMETERS

RS No.	Parameter	Symbol	Value	Unit	Reference
1	According to Standard - EN 1998-1 | CEN | 2013-05				
	Type of spectrum				
	Spectrum shape		Design Spectrum		
	Spectrum direction		Horizontal		
	Spectrum type		1		
	Ground type		A		
	Earthquake action				
	Reference peak ground acceleration	a_{gR}	0.24	m/s²	
	Importance class		II		
	Importance factor | Class II	γ_I	1.000	--	4.2.5(5)P
	Design ground acceleration | Horizontal	a_g	0.24	m/s²	
	Factors				
	Behavior factor	q	1.500	--	
	Limit value	β	0.200	--	
	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	
2	According to Standard - EN 1998-1 | CEN | 2013-05				
	Type of spectrum				
	Spectrum shape		Design Spectrum		
	Spectrum direction		Horizontal		
	Spectrum type		1		
	Ground type		A		
	Earthquake action				
	Reference peak ground acceleration	a_{gR}	0.24	m/s²	
	Importance class		II		
	Importance factor | Class II	γ_I	1.000	--	4.2.5(5)P
	Design ground acceleration | Horizontal	a_g	0.24	m/s²	
	Factors				
	Behavior factor	q	1.500	--	
	Limit value	β	0.200	--	
	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 Static Analysis Results

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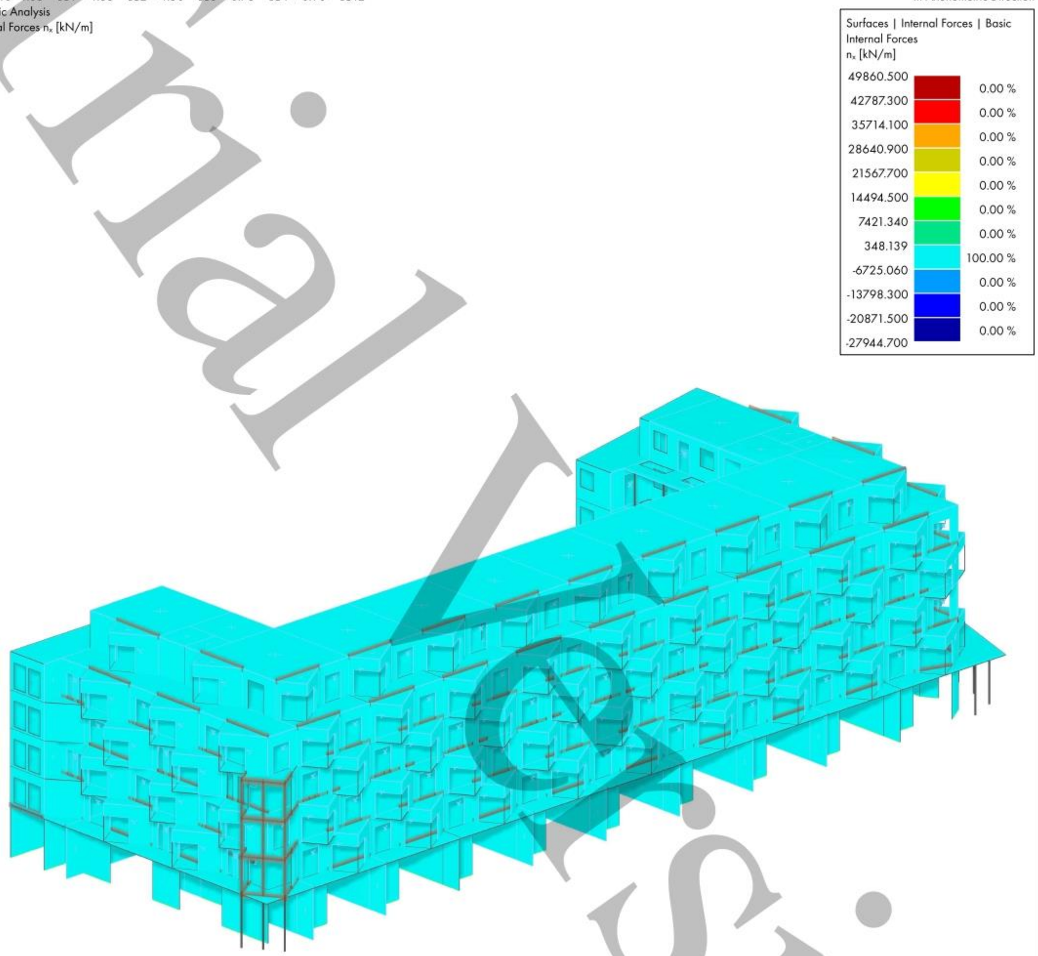
MODEL

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

CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 0.75 * LC4 + 0.90 * LC12
Static Analysis
Axial Forces n_x [kN/m]

In Axonometric Direction



max n_x : 49860.500 | min n_x : -27944.700 kN/m

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MODEL

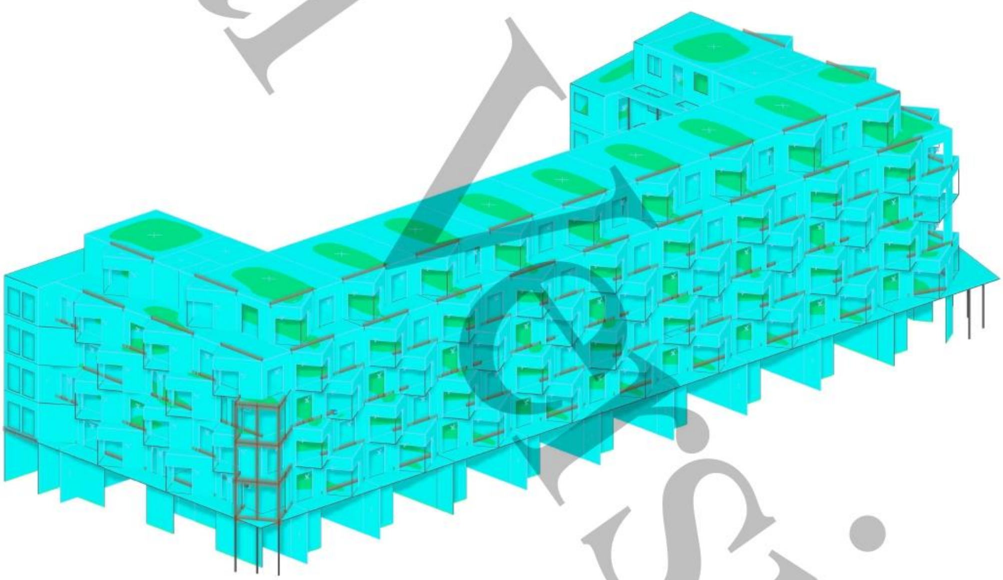
6.2 **CO10: BASIC INTERNAL FORCES M_x, IN AXONOMETRIC DIRECTION** **Static Analysis**

CO10 - 1.35 * LC1 + 1.35 * LC2 + 1.50 * LC3 + 0.75 * LC4 + 0.90 * LC12
Static Analysis
Moments m_x [kNm/m]

In Axonometric Direction

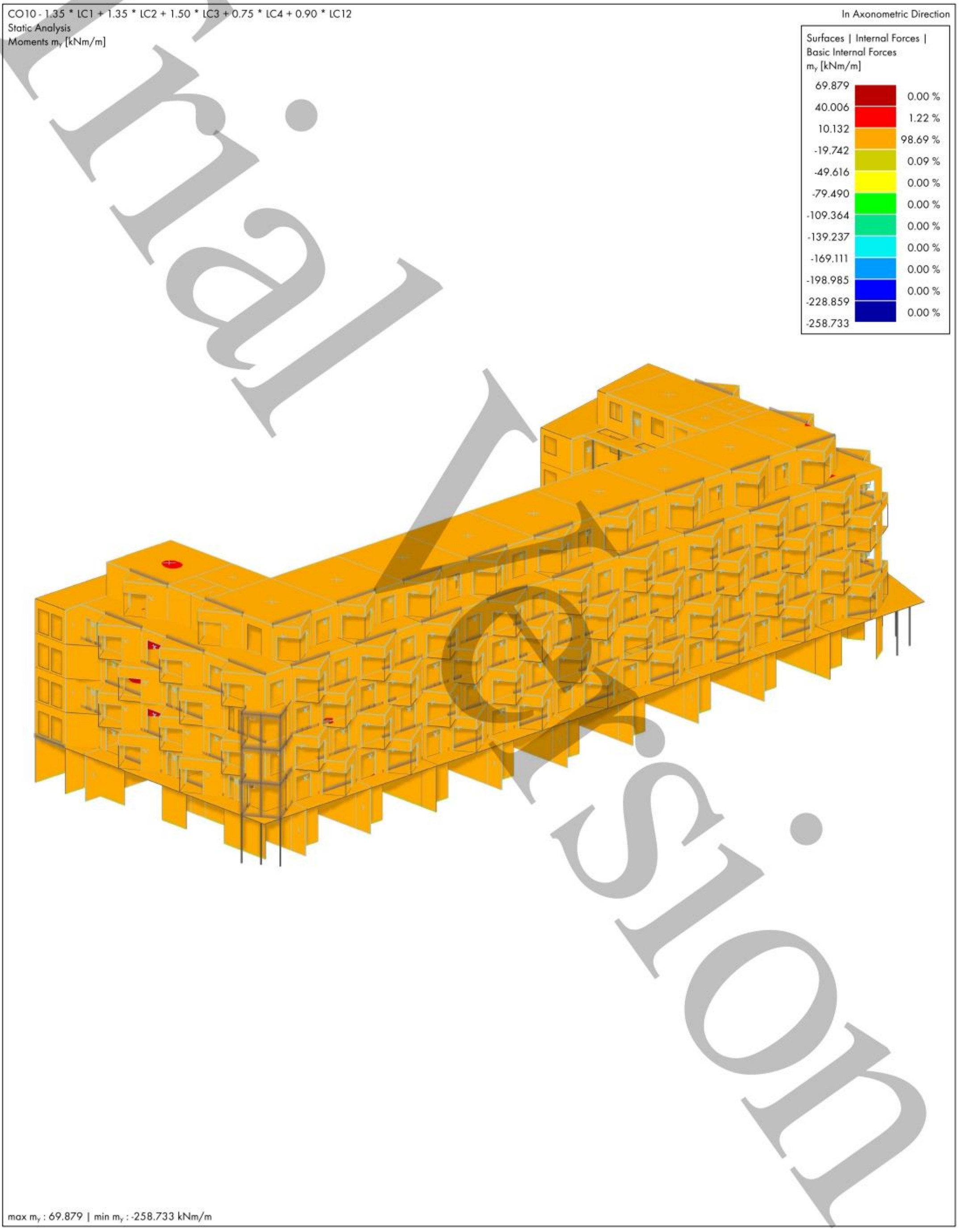
Surfaces | Internal Forces | Basic Internal Forces
m_x [kNm/m]

242.382	
208.561	0.00 %
174.740	0.00 %
140.919	0.00 %
107.099	0.00 %
73.278	0.00 %
39.457	0.00 %
5.636	13.45 %
-28.185	86.47 %
-62.006	0.08 %
-95.827	0.00 %
-129.648	0.00 %
	0.00 %



max m_x : 242.382 | min m_x : -129.648 kNm/m

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



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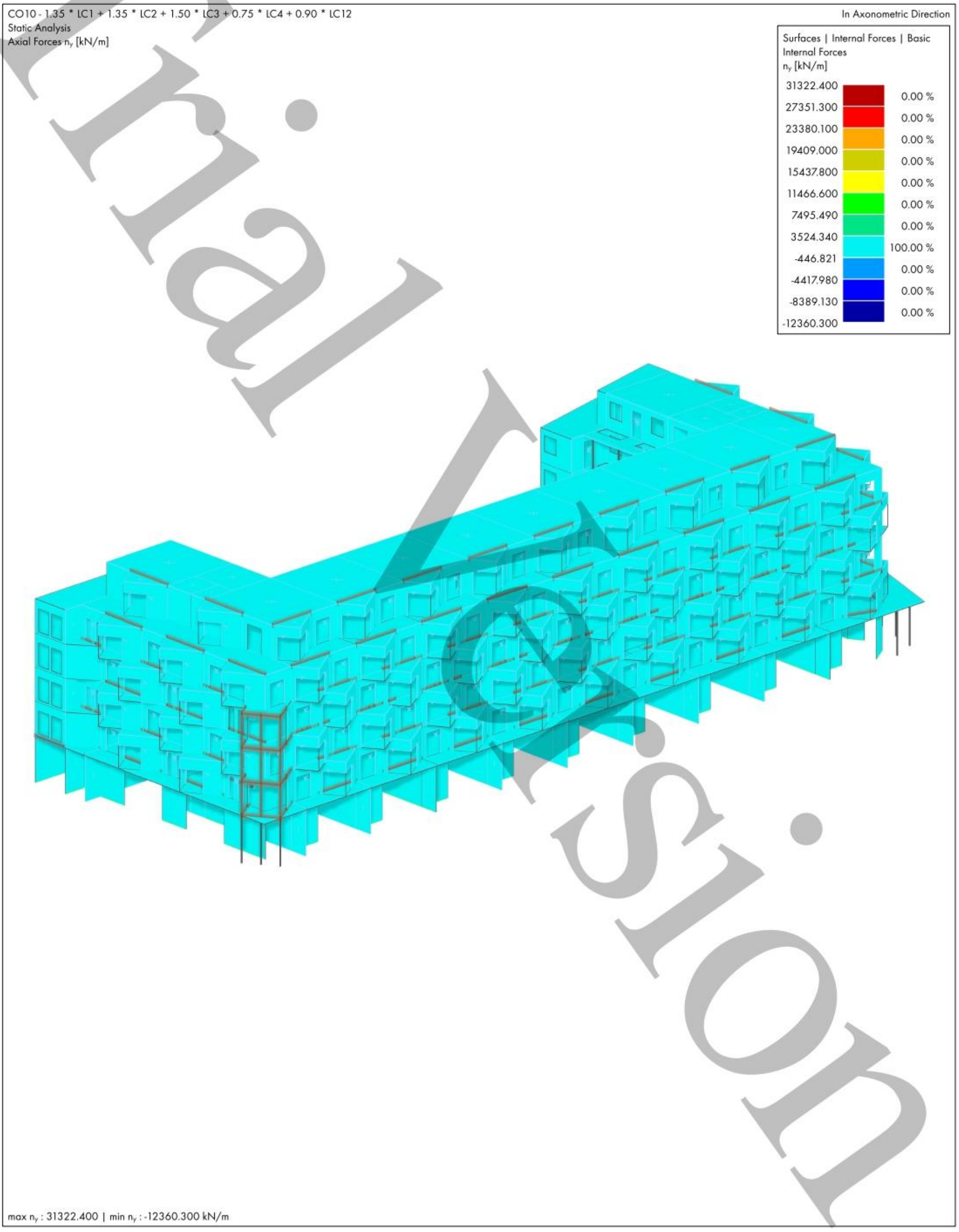
MODEL

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



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MODEL

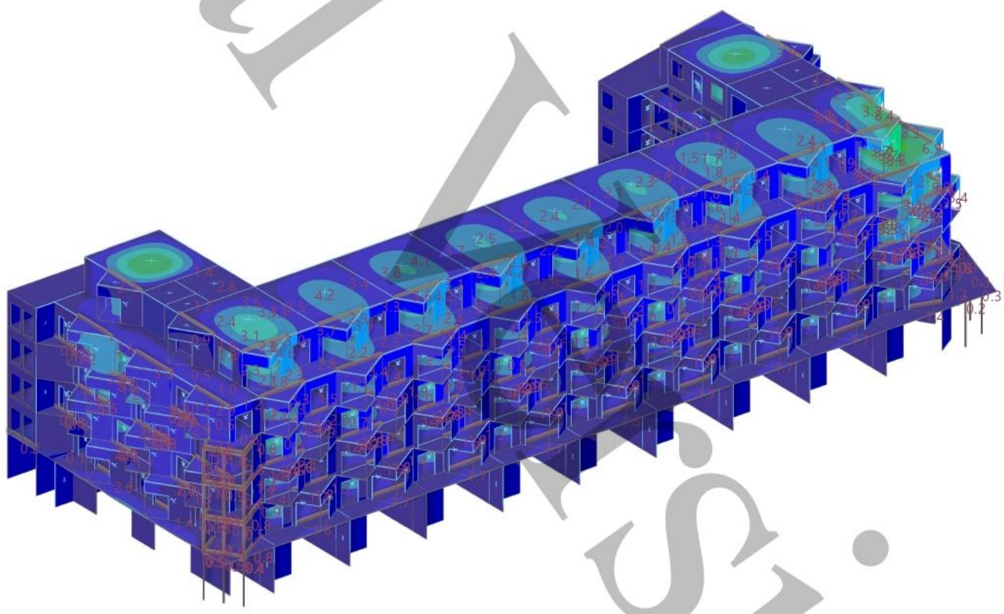
6.5 CO80: GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION

Static Analysis

CO80 - LC1 + LC2 + 0.70 * LC3 + 0.50 * LC4 + LC12
Static Analysis
Displacements |u| [mm]

In Axonometric Direction

Global Deformations |u| [mm]	
19.4	
17.6	0.00 %
15.9	0.01 %
14.1	0.03 %
12.3	0.03 %
10.6	0.26 %
8.8	0.64 %
7.1	1.24 %
5.3	3.97 %
3.5	11.24 %
1.8	24.46 %
0.0	58.11 %



max |u| : 19.4 | min |u| : 0.0 mm

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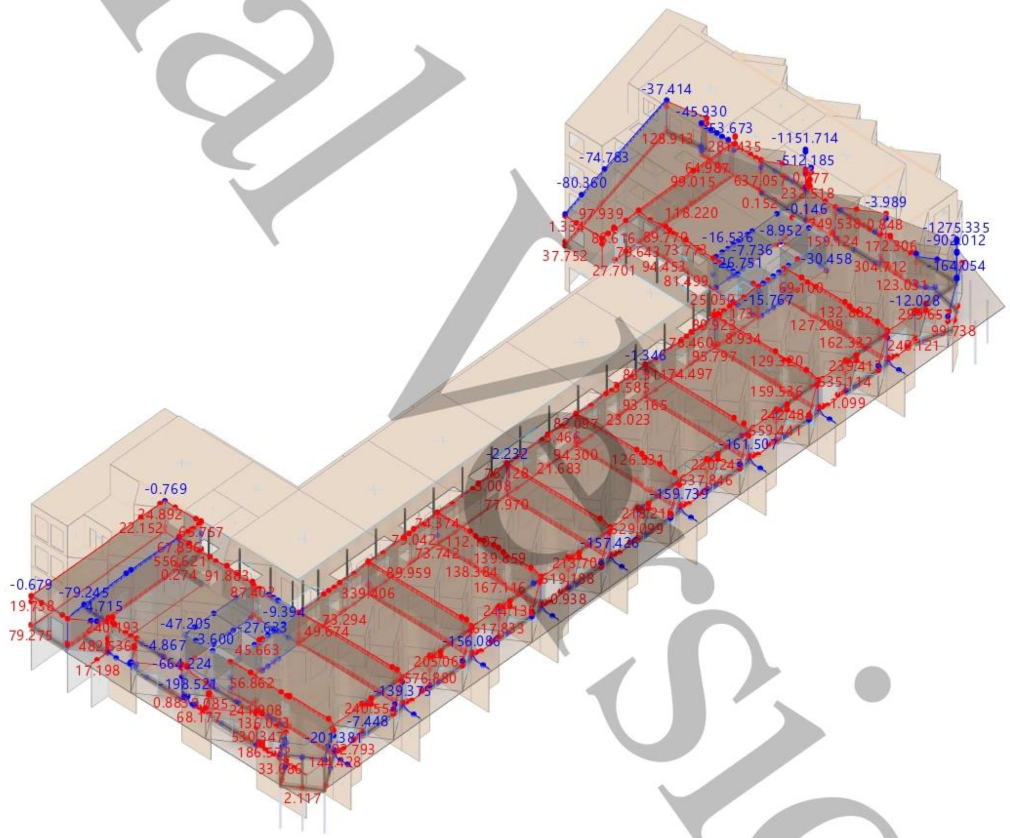
MODEL

6.6 RC4: ENVELOPE VALUES - MAX AND MIN VALUES, FORCES V_z, IN AXONOMETRIC DIRECTION

Static Analysis

Visibility mode
RC4 - LC1/p + LC2/p + 0.30 * LC3/p + LC10/p
Static Analysis
Forces v_z [kN/m]

In Axonometric Direction



max v_z : 749.538 | min v_z : -1275.340 kN/m

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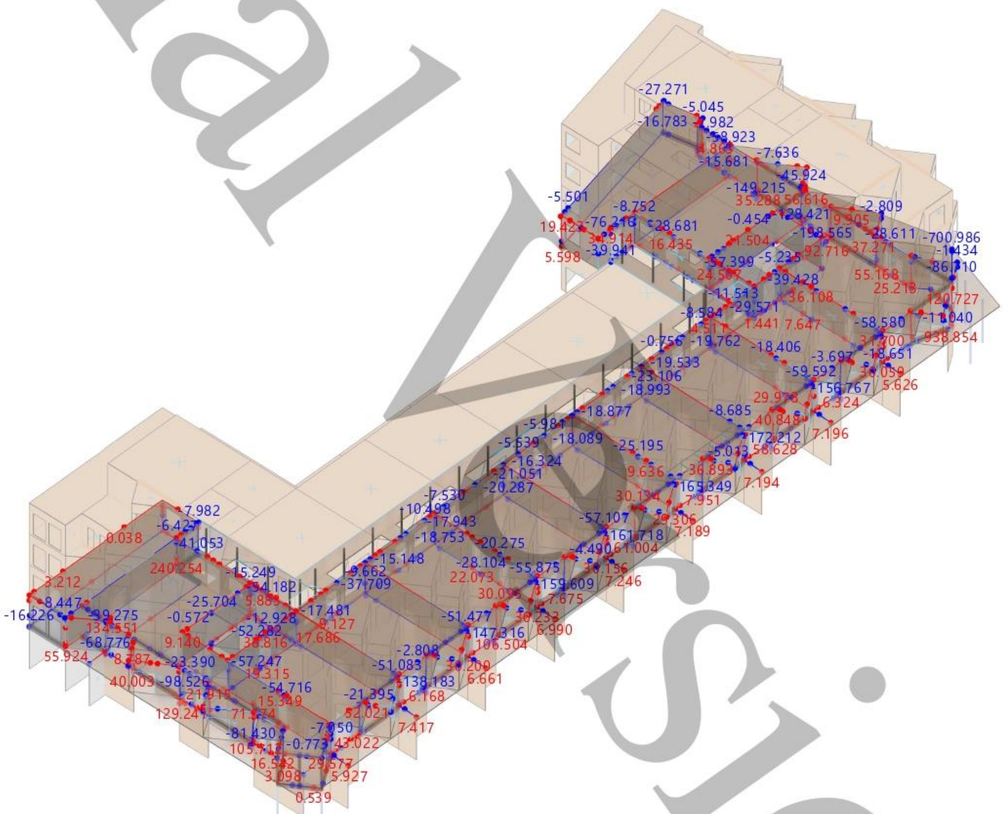
MODEL

6.7 **RC4: ENVELOPE VALUES - MAX AND MIN VALUES, FORCES N, IN AXONOMETRIC DIRECTION** **Static Analysis**

Visibility mode
RC4 - LC1/p + LC2/p + 0.30 * LC3/p + LC10/p
Static Analysis
Forces n [kN/m]

In Axonometric Direction



max n : 938.854 | min n : -700.987 kN/m

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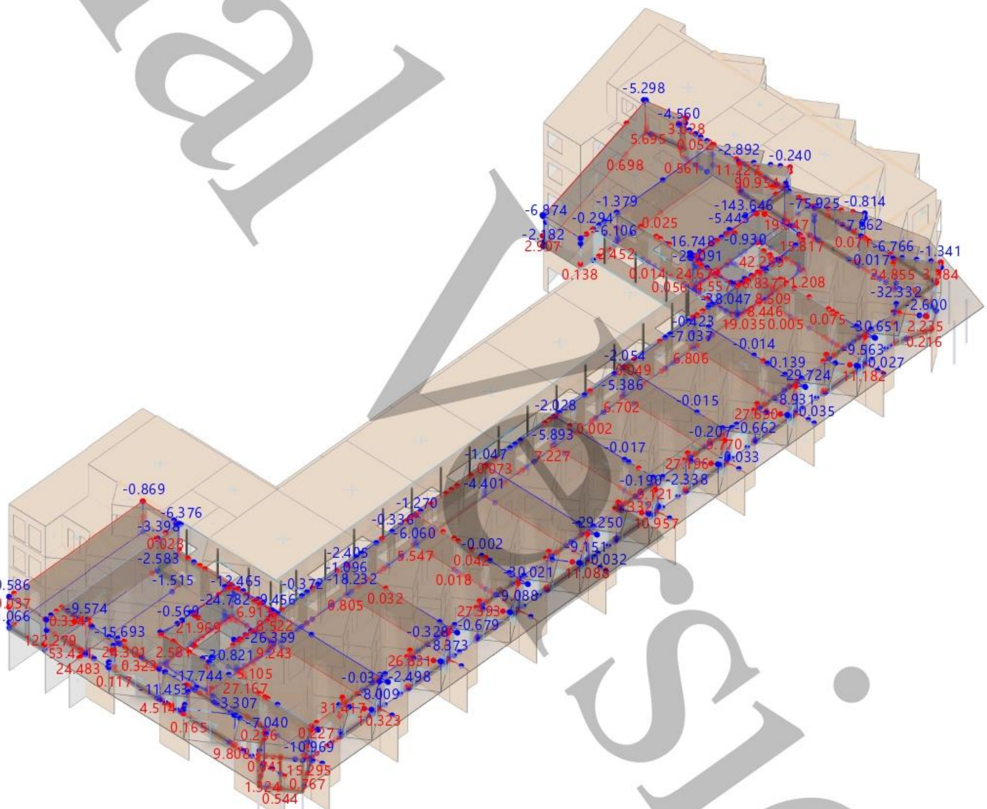
MODEL

6.8 RC4: ENVELOPE VALUES - MAX AND MIN VALUES, FORCES V_y, IN AXONOMETRIC DIRECTION — Static Analysis

Visibility mode
RC4 - LC1/p + LC2/p + 0.30 * LC3/p + LC10/p
Static Analysis
Forces v_y [kN/m]

In Axonometric Direction



max v_y : 122.279 | min v_y : -143.646 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]
	AE LC9 - Potres			
1	989.615	31.458	5.007	0.200
2	1196.244	34.587	5.505	0.182
3	1401.971	37.443	5.959	0.168
4	1612.895	40.161	6.392	0.156
5	1631.275	40.389	6.428	0.156
6	1995.460	44.671	7.110	0.141
7	2136.357	46.221	7.356	0.136
8	2196.768	46.870	7.460	0.134
9	2209.125	47.001	7.480	0.134
10	2216.327	47.078	7.493	0.133
11	2376.699	48.751	7.759	0.129
12	2872.780	53.598	8.530	0.117
13	2940.677	54.228	8.631	0.116
14	2979.164	54.582	8.687	0.115
15	2989.215	54.674	8.702	0.115
16	3013.283	54.893	8.737	0.114
17	3079.868	55.497	8.833	0.113
18	3101.487	55.691	8.863	0.113
19	3111.952	55.785	8.878	0.113
20	3115.814	55.819	8.884	0.113

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] $m_{e\varphi X}$	$m_{e\varphi Y}$	$m_{e\varphi Z}$
	AE LC9 - Potres						
1	519387.3	707.8	1493310.0	1096.8	19337300.00	111325.00	1.68e+08
2	451201.7	731660.0	90554.2	148.8	1633450.00	5392100.00	5.71e+08
3	349717.2	740738.0	74261.1	190.5	1596830.00	12857500.00	2.99e+08
4	15.0	7.1	10.1	0.0	2768.82	3796.16	712.45
5	15.0	5.8	6.7	0.1	1577.86	2044.66	1773.52
6	763.2	0.0	100.3	3670.2	16.24	174960.00	18302.10
7	807.2	23.3	164.6	4175.6	287.35	1109.09	14440.60
8	996.0	3.7	81.6	1502.9	97.31	30938.00	12495.60
9	929.2	0.0	1.4	15.7	5.47	8188.49	252.70
10	831.0	0.0	1.9	367.9	23.58	9155.78	268.39
11	214711.5	5943.6	69614.0	28.9	715641.00	198551.00	15559100.00
12	11236.9	3.9	2.2	167.8	5881.81	90921.90	206.43
13	6839.4	2.1	290.1	24086.4	902697.00	21472400.00	198001.00
14	4133.0	34.8	361.2	29505.0	700241.00	24873500.00	190070.00
15	4502.5	0.4	5.2	106.2	2173.37	89269.80	3923.52
16	11793.6	597.5	606.4	16023.4	1068290.00	17473900.00	300791.00
17	8424.7	0.0	26.5	6727.4	256884.00	5507710.00	13850.80
18	4707.8	2.9	29.8	53.9	2503.85	51193.50	9777.14
19	13961.4	2.3	65.5	354.1	21102.00	542697.00	56458.10
20	4089.0	0.1	0.0	726.5	28057.90	629708.00	4.35
Σ	1609062.4	1479730.0	1729500.0	88948.2	26275900.00	89520900.00	1.05e+09
Σ_M		2450400.0	2450400.0	2450400.0	2.09e+08	1.52e+09	1.61e+09
%		60.39 %	70.58 %	3.63 %	12.57 %	5.87 %	65.62 %

Mode No.	Transl. Eff. Modal Mass Factor [–] f_{meX}	f_{meY}	f_{meZ}	Rotat. Eff. Modal Mass Factor [–] $f_{m\varphi X}$	$f_{m\varphi Y}$	$f_{m\varphi Z}$
1	0.000	0.609	0.000	0.093	0.000	0.105
2	0.299	0.037	0.000	0.008	0.004	0.356
3	0.302	0.030	0.000	0.008	0.008	0.186
4	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.001	0.000	0.000	0.000
7	0.000	0.000	0.002	0.000	0.000	0.000
8	0.000	0.000	0.001	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000
11	0.002	0.028	0.000	0.003	0.000	0.010
12	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.010	0.004	0.014	0.000
14	0.000	0.000	0.012	0.003	0.016	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.007	0.005	0.011	0.000
17	0.000	0.000	0.003	0.001	0.004	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000
Σ	0.604	0.706	0.036	0.126	0.059	0.656
Σ_M						
%						

7.3 EFFECTIVE MODAL MASSES - EQUIVALENT MASS PER UNIT LENGTH — Modal Analysis

Mode No.	Modal Mass M_i [kg]
	AE LC9 - Potres
1	519387.3
2	451201.7
3	349717.2
4	15.0
5	15.0
6	763.2
7	807.2
8	996.0
9	929.2
10	831.0
11	214711.5
12	11236.9
13	6839.4
14	4133.0
15	4502.5

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

Mode No.	Modal Mass M_i [kg]
16	11793.6
17	8424.7
18	4707.8
19	13961.4
20	4089.0
Σ	1609062.4
Σ_M	
%	

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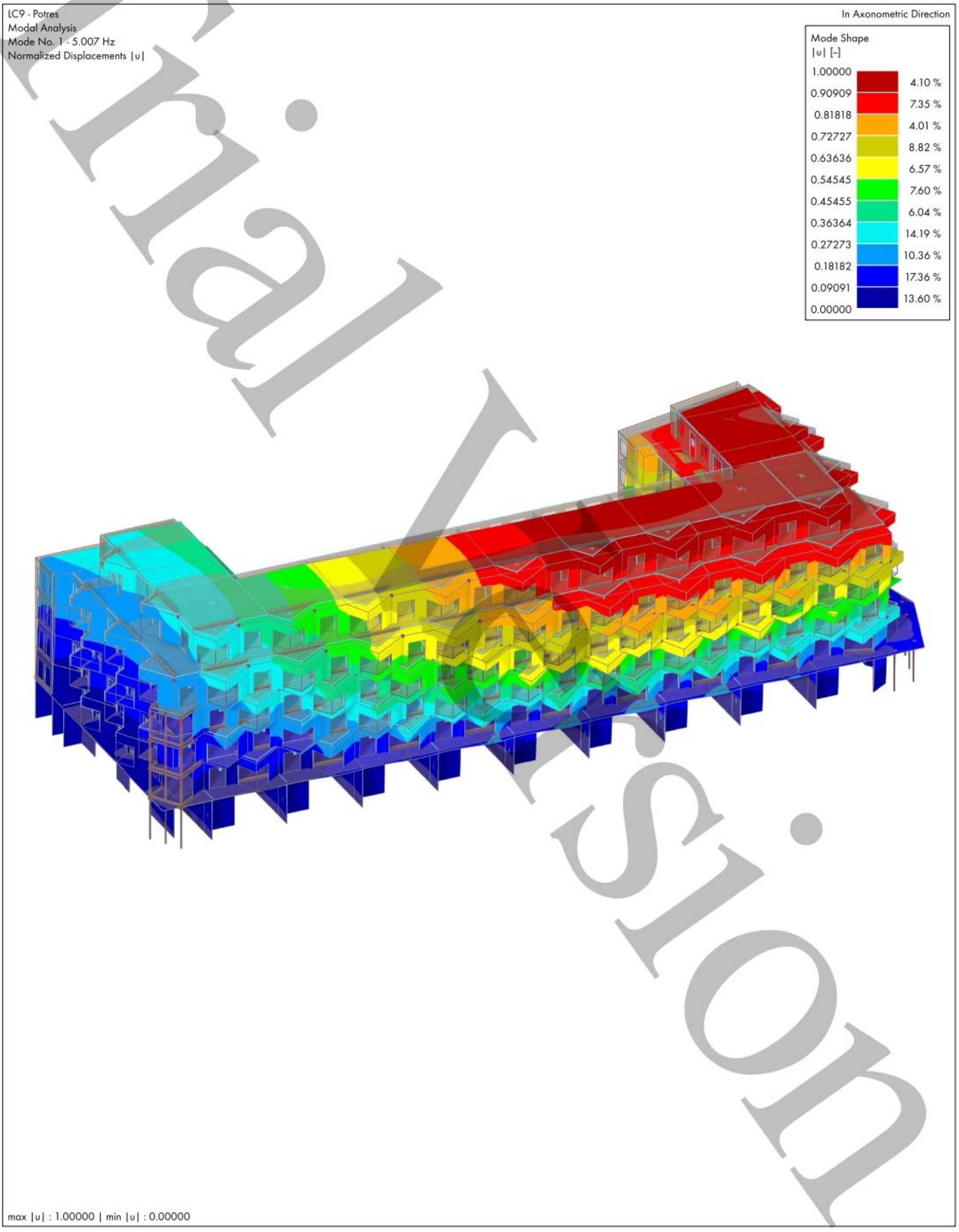
MODEL

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



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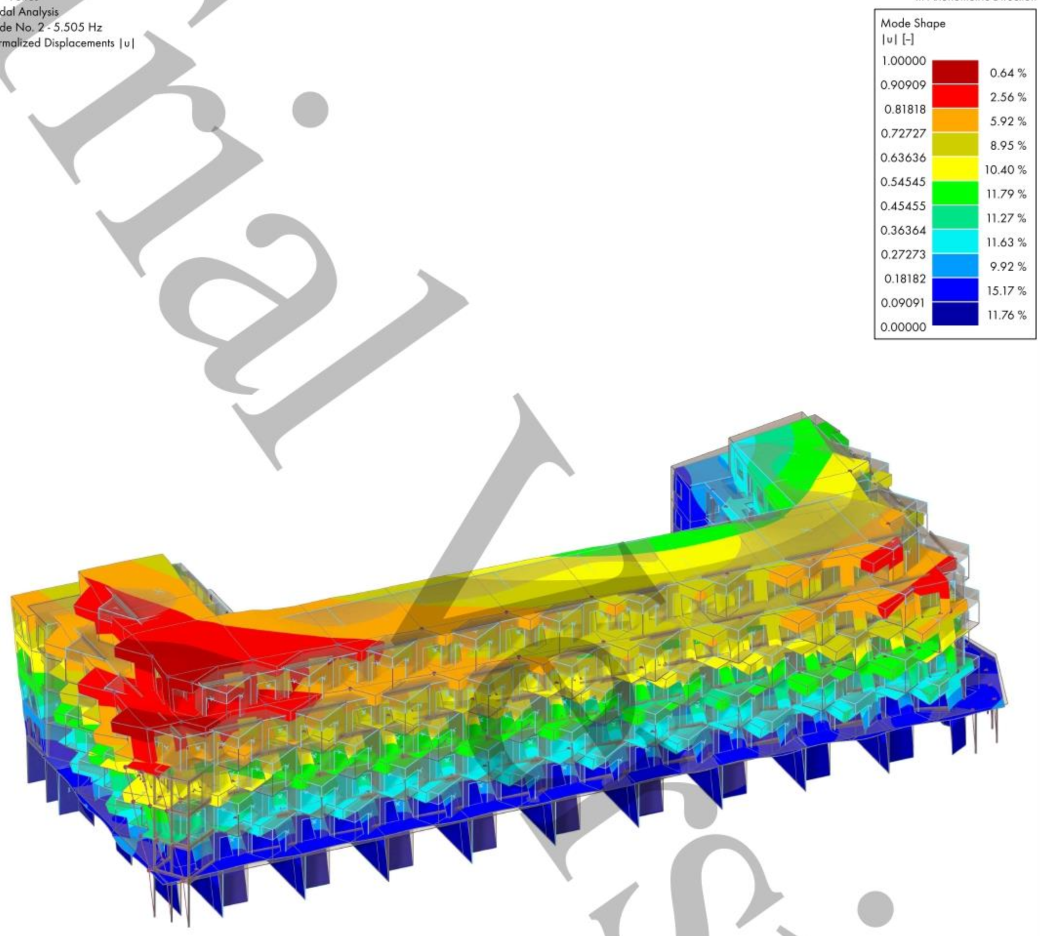
MODEL

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

LC9 - Potres
Modal Analysis
Mode No. 2 - 5.505 Hz
Normalized Displacements |u|

In Axonometric Direction



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

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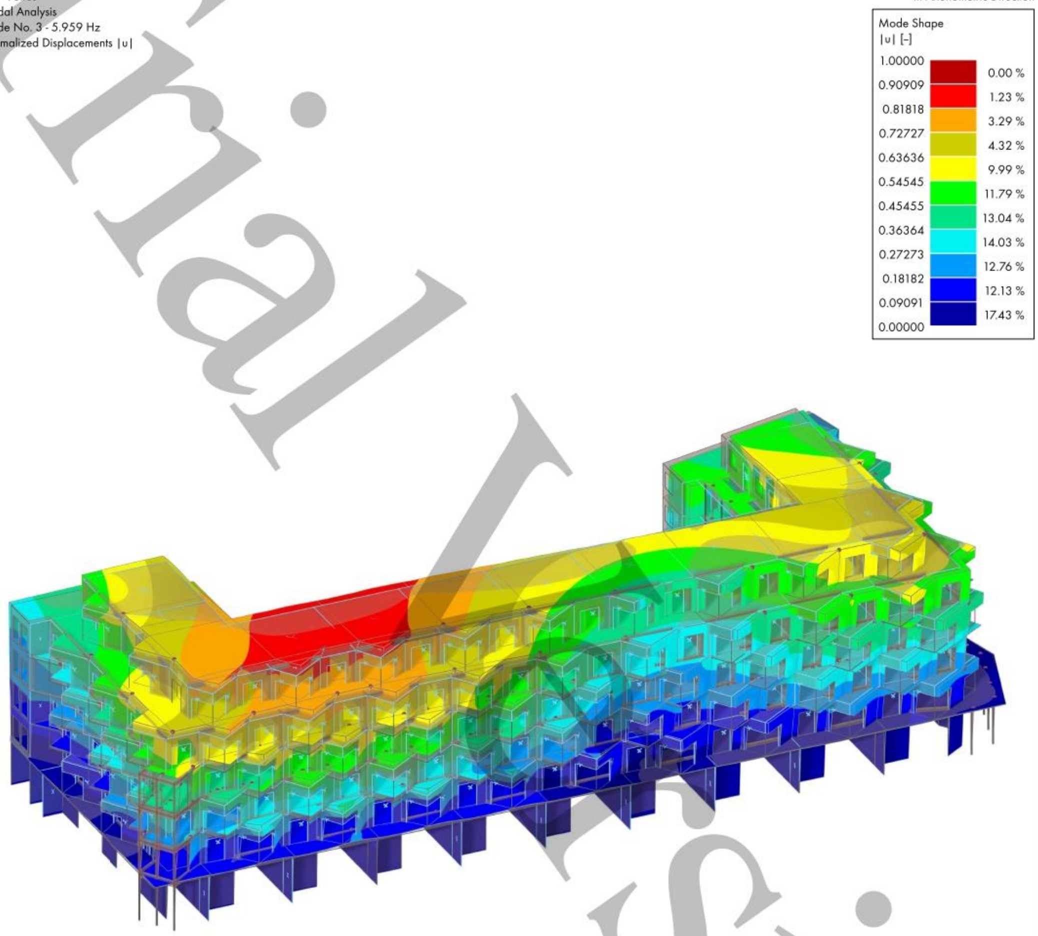
MODEL

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

LC9 - Potres
Modal Analysis
Mode No. 3 - 5.959 Hz
Normalized Displacements |u|

In Axonometric Direction



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

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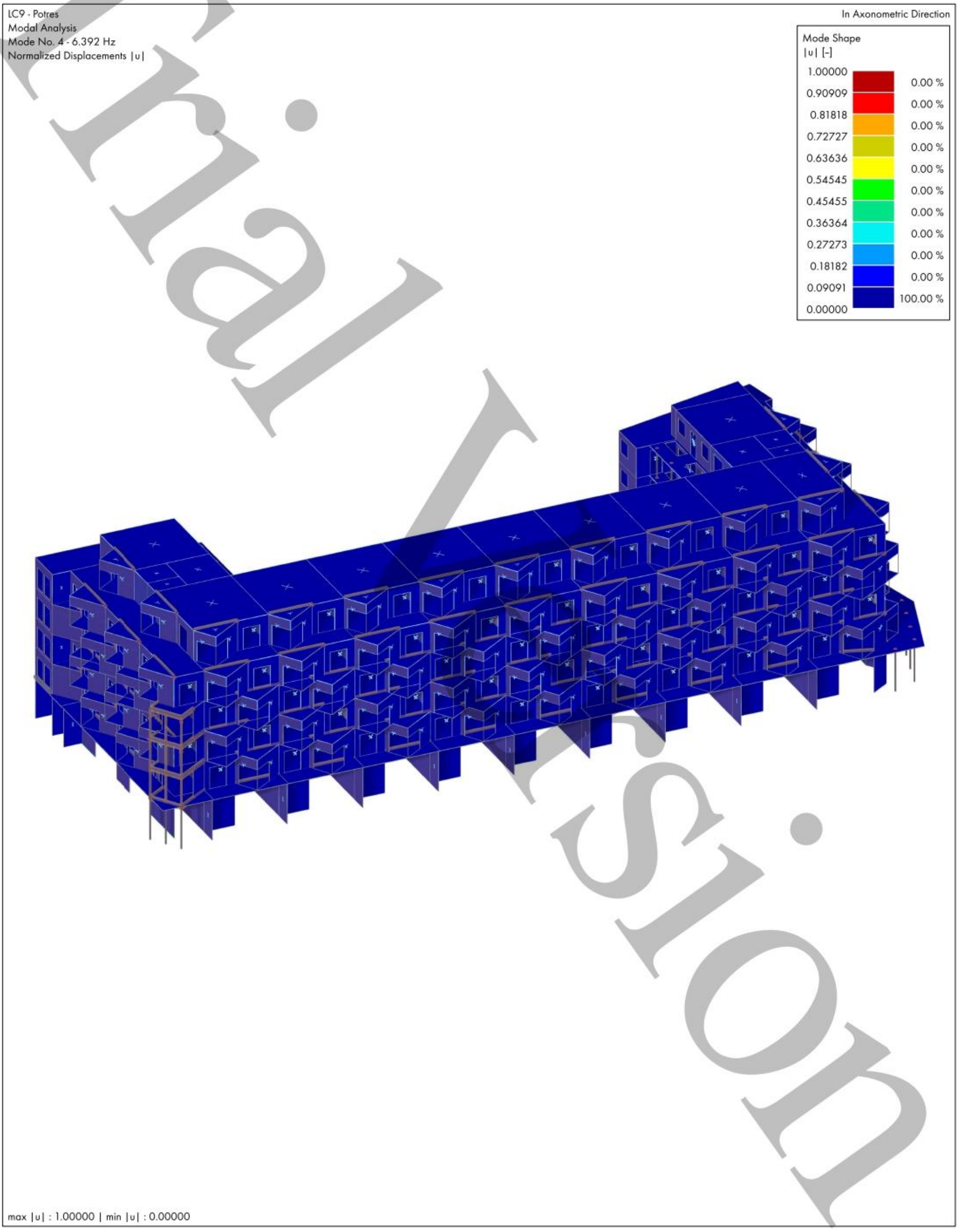
7.7 **LC9: MODE SHAPE |U|, IN AXONOMETRIC DIRECTION** **Modal Analysis**



3.5. **Dimenzioniranje – Dlubal RFEM**

3.5.1.1. Dimenzioniranje elemenata (grede i stupovi - GL32h)

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MODEL

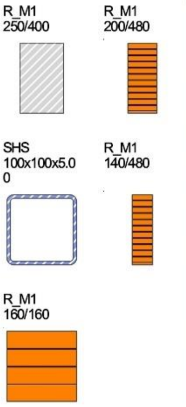
1 Basic Objects

1.1 MATERIALS

Legend
% Stiffness modification

Material No.	Material Name	Material Type	Analysis Model	Options
6	Stora Enso (40 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%
7	C 35/40 beton	Concrete	Isotropic | Linear Elastic	
8	GL32h | Isotropic | Linear Elastic	Timber	Isotropic | Linear Elastic	%
9	S355 | Isotropic | Linear Elastic	Steel	Isotropic | Linear Elastic	
10	Stora Enso (30 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%
11	Stora Enso (20 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%

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 250/400 | 7 - C 35/40 beton							
	7	Parametric - Massive I		127345.16	133333.33	52083.33	250.0	400.0
				1000.00	833.33	833.33		
2	R_M1 200/480 | 8 - GL32h							
	8	Parametric - Massive I		94484.39	184320.00	32000.00	200.0	480.0
				960.00	800.00	800.00		
3	SHS 100x100x5.00 | 9 - S355							
	9	Standardized - Steel	Cold formed	440.51	271.02	271.02	100.0	100.0
				18.35	8.05	8.05		
4	R_M1 140/480 | 8 - GL32h							
	8	Parametric - Massive I		35841.51	129024.00	10976.00	140.0	480.0
				672.00	560.00	560.00		
5	R_M1 160/160 | 8 - GL32h							
	8	Parametric - Massive I		9229.65	5461.33	5461.33	160.0	160.0
				256.00	213.33	213.33		

1.2.1 SECTIONS - INFORMATION

Legend
Thin-walled model
Warping stiffness deactivated

Section No.	Principal Axes α [deg]	Warping I_ω [cm⁶]	Combination Type	Corrugated S. W. b [mm]	Worn out w_v [%]	T. Reduction [–]	Options	Comment
1	R_M1 250/400 | 7 - C 35/40 beton							
	0.00						Warping stiffness deactivated	
2	R_M1 200/480 | 8 - GL32h							
	0.00						Warping stiffness deactivated	
3	SHS 100x100x5.00 | 9 - S355							
	0.00						Warping stiffness deactivated, Thin-walled model	
4	R_M1 140/480 | 8 - GL32h							
	0.00						Warping stiffness deactivated	
5	R_M1 160/160 | 8 - GL32h							
	0.00						Warping stiffness deactivated	

2 Timber Design

2.1 ULTIMATE CONFIGURATIONS

Config. No.	Name	Assigned to: Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
1	Default	All	All	3, 9,11,14,16-35 ,38,42-52,54- 57,60-77,81,8	All		

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2.1 ULTIMATE CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
				3-87,90-136,1 38,139,141-2 38,240,241,2 43,245,247-2 58,260-270,2 72-275,278-2 84,286-306,3 12,313,315-3 98,400-402,4 04-411,413-4 15,417-427,4 32-461,464-4 99,506-513,5 15,518-524,5 26-539,543-5 63,565,567-5 87,589-610,6 13-621,624-6 41,643-653,6 55-659,661-6 63,665,669-6 89,695-726,7 30-758,761-8 13			

2.1.1 ULTIMATE CONFIGURATIONS - SETTINGS - MEMBERS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	General			
	☒ Perform stability design			
	Limit Values for Special Cases			
	Tension ($\sigma_{t,0,d}$ / $f_{t,0,d}$)	$\eta_{\sigma t,lim}$	0.001	--
	Compression ($\sigma_{c,0,d}$ / $f_{c,0,d}$)	$\eta_{\sigma c,lim}$	0.001	--
	Shear ($\tau_{xy,d}$ / $f_{v,d}$)	$\eta_{\tau xy,lim}$	0.001	--
	Shear ($\tau_{xz,d}$ / $f_{v,d}$)	$\eta_{\tau xz,lim}$	0.001	--
	Torsion ($\tau_{tor,d}$ / $f_{v,d}$)	$\eta_{\tau tor,lim}$	0.010	--
	Bending ($\sigma_{m,y,d}$ / $f_{m,d}$)	$\eta_{\sigma m,y,lim}$	0.001	--
	Bending ($\sigma_{m,z,d}$ / $f_{m,d}$)	$\eta_{\sigma m,z,lim}$	0.001	--
	Curved and Saddle Members			
	☒ Perpendicular tension design of curved members			
	☒ Perpendicular tension design of saddle members			
	Cut-to-Grain Angle Limit			
	Allow further design if angle does not exceed limit	$\lvert\alpha\rvert \leq$	24.00	deg
	System Strength Acc. to 6.6			
	☐ Consider system strength factor			
	Settings for Stability Design			
	Stiffness Reduction			
	☐ Reduction of stiffness with coefficient 1/(1+k_{def}) acc. to DIN EN 1995-1-1			
	Position of Positive Transverse Load Application			
	Vertical position			
	◉ On section edge (destabilizing effect)			
	○ At shear point			
	○ At center point			
	○ On section edge (stabilizing effect)			
	☐ Reduction of effective length by 0.5h acc. to Tab. 6.1 (stabilizing effect)			

2.2 SERVICEABILITY CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
1	Default	All	All	3, 9,11,14,16-35 ,38,42-52,54- 57,60-77,81,8 3-87,90-136,1 38,139,141-2	All		

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2.2 SERVICEABILITY CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
				38,240,241,2 43,245,247-2 58,260-270,2 72-275,278-2 84,286-306,3 12,313,315-3 98,400-402,4 04-411,413-4 15,417-427,4 32-461,464-4 99,506-513,5 15,518-524,5 26-539,543-5 63,565,567-5 87,589-610,6 13-621,624-6 41,643-653,6 55-659,661-6 63,665,669-6 89,695-726,7 30-758,761-8 13			

2.2.1 SERVICEABILITY CONFIGURATIONS - SETTINGS - MEMBERS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Serviceability Limits to Be Checked			
	☒ Characteristic			
	☒ Quasi-permanent 1			
	☒ Quasi-permanent 2			
	Serviceability Limits (Deflections) Acc. to 7.2			
	Beam limits			
	Characteristic	L /	300	--
	Quasi-permanent 1	L /	250	--
	Quasi-permanent 2	L /	150	--
	Cantilever limits			
	Characteristic	L_c /	150	--
	Quasi-permanent 1	L_c /	125	--
	Quasi-permanent 2	L_c /	75	--
	Vibration Design			
	Vibration design	$w_{inst,lim}$	10.0	mm

2.3 FIRE RESISTANCE CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
1	Default	All	All	3, 9,11,14,16-35 ,38,42-52,54- 57,60-77,81,8 3-87,90-136,1 38,139,141-2 38,240,241,2 43,245,247-2 58,260-270,2 72-275,278-2 84,286-306,3 12,313,315-3 98,400-402,4 04-411,413-4 15,417-427,4 32-461,464-4 99,506-513,5 15,518-524,5 26-539,543-5 63,565,567-5 87,589-610,6 13-621,624-6 41,643-653,6 55-659,661-6	All		

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2.3 FIRE RESISTANCE CONFIGURATIONS

Config. No.	Name	Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
				63,665,669-689,695-726,730-758,761-813			

2.3.1 FIRE RESISTANCE CONFIGURATIONS - SETTINGS - MEMBERS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Fire Design Settings			
	Required time of fire resistance	t	90	min
	Fire exposure (not for circular sections)			
	☒ Top (-z)			
	☒ Left (-y)			
	☒ Right (+y)			
	☒ Bottom (+z)			

2.4 Results

2.4.1 DESIGN RATIOS ON MEMBERS BY SECTION

Timber Design

Section No.	Member No.	Location x [m]	Stress Point No.	Design Situation	Loading No.	Design Check Ratio η [--]	Design Check Type	Description
	R_M1 200/480 | 8 - GL32h							
2	119	0.671		DS5	RC1	0.000	SP0100.00	Section Proof | Negligible internal forces
	121	0.818	1	DS1	CO6	0.007	SP1100.00	Section Proof | Tension along grain acc. to 6.1.2
		2.454	1	DS1	CO6	0.011	SP1200.00	Section Proof | Compression along grain acc. to 6.1.4
	312	0.044	4	DS1	CO6	0.383	SP2100.00	Section Proof | Shear due to torsion acc. to 6.1.8
	120	0.546	4	DS1	CO6	0.347	SP3100.00	Section Proof | Shear in z-axis acc. to 6.1.7 | Rectangular section
	546	0.000	5	DS1	CO6	0.016	SP3200.00	Section Proof | Shear in y-axis acc. to 6.1.7 | Rectangular section
	114	1.526	1	DS1	CO6	0.146	SP4100.00	Section Proof | Bending about y-axis acc. to 6.1.6
	117	3.356	1	DS5	RC4	0.002	SP4200.00	Section Proof | Bending about z-axis acc. to 6.1.6
	120	0.000	3	DS1	CO6	0.111	SP4300.00	Section Proof | Biaxial bending acc. to 6.1.6
	116	2.158	7	DS1	CO4	0.167	SP5100.00	Section Proof | Bending about y-axis and tensile axial force acc. to 6.2.3
	117	3.356	3	DS5	RC4	0.003	SP5200.00	Section Proof | Bending about z-axis and tensile axial force acc. to 6.2.3
	116	3.776	7	DS1	CO4	0.077	SP5300.00	Section Proof | Biaxial bending and tensile axial force acc. to 6.2.3
	108	1.918	1	DS1	CO6	0.117	SP6100.00	Section Proof | Bending about y-axis and compressive axial force acc. to 6.2.4
	113	0.000	3	DS1	CO6	0.004	SP6200.00	Section Proof | Bending about z-axis and compressive axial force acc. to 6.2.4
	114	0.509	3	DS1	CO6	0.080	SP6300.00	Section Proof | Biaxial bending and compressive axial force acc. to 6.2.4
	113	0.000	1	DS5	RC2	0.002	ST1300.00	Stability | Axial compression with buckling about both axes acc. to 6.3.2
	109	1.918	1	DS1	CO6	0.118	ST1600.01	Stability | Bending about y-axis and compression with buckling about both axes acc. to 6.3.2
	113	0.000	3	DS1	CO6	0.009	ST1600.02	Stability | Bending about z-axis and compression with buckling about both axes acc. to 6.3.2
	114	0.509	3	DS1	CO6	0.082	ST1600.03	Stability | Biaxial bending and compression with buckling about both axes acc. to 6.3.2
	116	2.158	1	DS1	CO4	0.164	ST2100.00	Stability | Flexural member without compression force | Bending about y-axis acc. to 6.3.3
	111	1.918	1	DS1	CO6	0.016	ST3100.00	Stability | Bending about y-axis and compression acc. to 6.3.3
	102	0.000		DS2	CO43	0.000	SE0100.01	Serviceability | Negligible deflection | Combination of actions 'Characteristic'
				DS3	CO85	0.000	SE0100.02	Serviceability | Negligible deflection | Combination of actions 'Quasi-permanent 1'
	116	2.158		DS2	CO56	0.119	SE1200.01	Serviceability | Combination of actions 'Characteristic' | z-direction acc. to 7.2
				DS3	CO98	0.141	SE1200.02	Serviceability | Combination of actions 'Quasi-permanent 1' | z-direction acc. to 7.2
	R_M1 140/480 | 8 - GL32h							
4	229	3.390		DS1	CO27	0.000	SP0100.00	Section Proof | Negligible internal forces
	432	4.316	1	DS1	CO6	0.039	SP1100.00	Section Proof | Tension along grain acc. to 6.1.2
	433	0.000	1	DS1	CO6	0.043	SP1200.00	Section Proof | Compression along grain acc. to 6.1.4
	513	0.000	4	DS1	CO6	0.369	SP2100.00	Section Proof | Shear due to torsion acc. to 6.1.8
	220	0.000	4	DS1	CO6	0.963	SP3100.00	Section Proof | Shear in z-axis acc. to 6.1.7 | Rectangular section
	544	0.056	2	DS1	CO6	0.458	SP3200.00	Section Proof | Shear in y-axis acc. to 6.1.7 | Rectangular section
	160	0.000	1	DS1	CO3	0.232	SP4100.00	Section Proof | Bending about y-axis acc. to 6.1.6
	162	0.307	1	DS1	CO15	0.006	SP4200.00	Section Proof | Bending about z-axis acc. to 6.1.6
	161	0.070	3	DS1	CO6	0.329	SP4300.00	Section Proof | Biaxial bending acc. to 6.1.6
	432	3.836	1	DS1	CO9	0.278	SP5100.00	Section Proof | Bending about y-axis and tensile axial force acc. to 6.2.3
	527	1.753	3	DS1	CO14	0.020	SP5200.00	Section Proof | Bending about z-axis and tensile axial force acc. to 6.2.3

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2.4.1 DESIGN RATIOS ON MEMBERS BY SECTION

Timber Design

Section No.	Member No.	Location x [m]	Stress Point No.	Design Situation	Loading No.	Design Check Ratio η [--]	Design Check Type	Description
4	432	4.316	1	DS1	CO6	0.403 ✓	SP5300.00	Section Proof | Biaxial bending and tensile axial force acc. to 6.2.3
	201	0.226	1	DS1	CO6	0.203 ✓	SP6100.00	Section Proof | Bending about y-axis and compressive axial force acc. to 6.2.4
	544	0.000	3	DS1	CO20	0.026 ✓	SP6200.00	Section Proof | Bending about z-axis and compressive axial force acc. to 6.2.4
	433	0.000	9	DS1	CO18	0.484 ✓	SP6300.00	Section Proof | Biaxial bending and compressive axial force acc. to 6.2.4
	242	3.328	1	DS1	CO6	0.019 ✓	ST1300.00	Stability | Axial compression with buckling about both axes acc. to 6.3.2
	430	2.422	1	DS1	CO18	0.221 ✓	ST1600.01	Stability | Bending about y-axis and compression with buckling about both axes acc. to 6.3.2
		4.359	3	DS1	CO9	0.123 ✓	ST1600.02	Stability | Bending about z-axis and compression with buckling about both axes acc. to 6.3.2
	433	0.000	9	DS1	CO6	0.525 ✓	ST1600.03	Stability | Biaxial bending and compression with buckling about both axes acc. to 6.3.2
	432	4.316	7	DS1	CO6	0.363 ✓	ST2100.00	Stability | Flexural member without compression force | Bending about y-axis acc. to 6.3.3
	433	0.000	7	DS1	CO6	0.360 ✓	ST3100.00	Stability | Bending about y-axis and compression acc. to 6.3.3
	122	0.000		DS2	CO43	0.000 ✓	SE0100.01	Serviceability | Negligible deflection | Combination of actions 'Characteristic'
				DS3	CO85	0.000 ✓	SE0100.02	Serviceability | Negligible deflection | Combination of actions 'Quasi-permanent 1'
	429	2.606		DS2	CO51	0.004 ✓	SE1100.01	Serviceability | Combination of actions 'Characteristic' | y-direction acc. to 7.2
				DS3	CO93	0.005 ✓	SE1100.02	Serviceability | Combination of actions 'Quasi-permanent 1' | y-direction acc. to 7.2
	241	2.158 ½		DS2	CO51	0.196 ✓	SE1200.01	Serviceability | Combination of actions 'Characteristic' | z-direction acc. to 7.2
				DS3	CO93	0.220 ✓	SE1200.02	Serviceability | Combination of actions 'Quasi-permanent 1' | z-direction acc. to 7.2
	R_M1 160/160 | 8 - GL32h							
5	96	0.000	1	DS1	CO6	0.116 ✓	SP1200.00	Section Proof | Compression along grain acc. to 6.1.4
	217	1.251	4	DS1	CO6	0.032 ✓	SP3100.00	Section Proof | Shear in z-axis acc. to 6.1.7 | Rectangular section
	219	1.460 ½	2	DS1	CO6	0.031 ✓	SP3200.00	Section Proof | Shear in y-axis acc. to 6.1.7 | Rectangular section
	96	1.251	7	DS1	CO6	0.018 ✓	SP6100.00	Section Proof | Bending about y-axis and compressive axial force acc. to 6.2.4
	218	2.086	1	DS1	CO6	0.023 ✓	SP6200.00	Section Proof | Bending about z-axis and compressive axial force acc. to 6.2.4
	217	2.920	7	DS1	CO6	0.161 ✓	SP6300.00	Section Proof | Biaxial bending and compressive axial force acc. to 6.2.4
	97	2.336	1	DS1	CO7	0.100 ✓	ST1300.00	Stability | Axial compression with buckling about both axes acc. to 6.3.2
	96	1.251	7	DS1	CO6	0.163 ✓	ST1600.01	Stability | Bending about y-axis and compression with buckling about both axes acc. to 6.3.2
	97	2.336	1	DS1	CO6	0.144 ✓	ST1600.02	Stability | Bending about z-axis and compression with buckling about both axes acc. to 6.3.2
		0.000	7	DS1	CO6	0.285 ✓	ST1600.03	Stability | Biaxial bending and compression with buckling about both axes acc. to 6.3.2
	96	0.000		DS2	CO43	0.000 ✓	SE0100.01	Serviceability | Negligible deflection | Combination of actions 'Characteristic'
				DS3	CO85	0.000 ✓	SE0100.02	Serviceability | Negligible deflection | Combination of actions 'Quasi-permanent 1'
	97	1.168		DS2	CO52	0.040 ✓	SE1100.01	Serviceability | Combination of actions 'Characteristic' | y-direction acc. to 7.2
				DS3	CO94	0.044 ✓	SE1100.02	Serviceability | Combination of actions 'Quasi-permanent 1' | y-direction acc. to 7.2
				DS2	CO52	0.057 ✓	SE1200.01	Serviceability | Combination of actions 'Characteristic' | z-direction acc. to 7.2
				DS3	CO94	0.063 ✓	SE1200.02	Serviceability | Combination of actions 'Quasi-permanent 1' | z-direction acc. to 7.2

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2.5 **MEMBER NO. 96 | DS1 | CO6 | 1.251 M | LEFT SIDE | STRESS POINT NO. 7 | ST1600.01** **Timber Design**

Design Check ST1600.01 | EN 1995 | CEN | 2014-05

Stability
Bending about y-axis and compression with buckling about both axes acc. to 6.3.2

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

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

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{2.920\,\text{m}}{46.2\,\text{mm}} = 63.22$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{2.920\,\text{m}}{46.2\,\text{mm}} = 63.22$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}} = \frac{63.22}{\pi} \cdot \sqrt{\frac{32.000\,\text{N/mm}^2}{11800.0\,\text{N/mm}^2}} = 1.05$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{63.22}{\pi} \cdot \sqrt{\frac{32.000\,\text{N/mm}^2}{11800.0\,\text{N/mm}^2}} = 1.05$$ 6.3.2, Eq. 6.22

$\lambda_{rel,y} > 0.3$ or $\lambda_{rel,z} > 0.3$

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,y} - 0.3\right) + \left(\lambda_{rel,y}\right)^2\right) = 0.5 \cdot \left(1 + 0.10 \cdot (1.05 - 0.3) + (1.05)^2\right) = 1.09$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,z} - 0.3\right) + \left(\lambda_{rel,z}\right)^2\right) = 0.5 \cdot \left(1 + 0.10 \cdot (1.05 - 0.3) + (1.05)^2\right) = 1.09$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - \left(\lambda_{rel,y}\right)^2}} = \frac{1}{1.09 + \sqrt{(1.09)^2 - (1.05)^2}} = 0.73$$ 6.3.2, Eq. 6.25

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - \left(\lambda_{rel,z}\right)^2}} = \frac{1}{1.09 + \sqrt{(1.09)^2 - (1.05)^2}} = 0.73$$ 6.3.2, Eq. 6.26

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2.5 MEMBER NO. 96 | DS1 | CO6 | 1.251 M | LEFT SIDE | STRESS POINT NO. 7 | ST1600.01 — Timber Design

$$\eta_1 = \left| \frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right| = \left| \frac{-2.367\ \text{N/mm}^2}{0.73 \cdot 20.480\ \text{N/mm}^2} + \frac{-0.098\ \text{N/mm}^2}{20.480\ \text{N/mm}^2} \right| = 0.163$$ Eq. 6.23

$$\eta_2 = \left| \frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right| = \left| \frac{-2.367\ \text{N/mm}^2}{0.73 \cdot 20.480\ \text{N/mm}^2} + 0.70 \cdot \frac{-0.098\ \text{N/mm}^2}{20.480\ \text{N/mm}^2} \right| = 0.162$$ Eq. 6.24

$$\eta = \max(\eta_1, \eta_2) = \max(0.163, 0.162) = 0.163$$ 6.3.2

$$\eta = 0.163 \leq 1$$ ✔

$f_{c,0,d}$	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
λ_y	Slenderness ratio
$L_{cr,y}$	Equivalent member length
i_y	Radius of gyration
λ_z	Slenderness ratio
$L_{cr,z}$	Equivalent member length
i_z	Radius of gyration
$\lambda_{rel,y}$	Relative slenderness ratio
$E_{0,05,y}$	Modulus of elasticity
$\lambda_{rel,z}$	Relative slenderness ratio
$E_{0,05,z}$	Modulus of elasticity
k_y	Instability factor
β_c	Straightness factor
k_z	Instability factor
$k_{c,y}$	Instability factor
$k_{c,z}$	Instability factor
η_1	Design ratio 1
$\sigma_{c,0,d}$	Design compressive stress
$\sigma_{m,y,d}$	Design bending stress
η_2	Design ratio 2
k_m	Redistribution factor

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2.6 MEMBER NO. 220 | DS1 | CO6 | 0.000 M | STRESS POINT NO. 4 | SP3100 — Timber Design

Design Check SP3100 | EN 1995 | CEN | 2014-05

Section Proof
Shear in z-axis acc. to 6.1.7 | Rectangular section

2.4.1, Eq. 2.14

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M} = 0.80 \cdot \frac{3.500\ N/mm^2}{1.25} = 2.240\ N/mm^2$$

$$\tau_{xz,d} = \frac{\tau_{xz}}{k_{cr}} = \frac{1.446\ N/mm^2}{0.67} = 2.158\ N/mm^2$$

6.1.7, Eq. 6.13

$$\eta = \frac{|\tau_{xz,d}|}{f_{v,z,d}} = \frac{|2.158\ N/mm^2|}{2.240\ N/mm^2} = 0.963$$

$$\eta = 0.963 \leq 1 ✓$$

$f_{v,z,d}$	Design shear strength
k_{mod}	Modification factor
$f_{v,z,k}$	Characteristic shear strength
γ_M	Partial factor
$\tau_{xz,d}$	Design shear stress
τ_{xz}	Shear stress
k_{cr}	Crack influence factor

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2.7 MEMBER NO. 312 | DS1 | CO6 | 0.044 M | STRESS POINT NO. 4 | SP2100 — Timber Design

Design Check SP2100 | EN 1995 | CEN | 2014-05

Section Proof
Shear due to torsion acc. to 6.1.8

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M} = 0.80 \cdot \frac{3.500\,\text{N/mm}^2}{1.25} = 2.240\,\text{N/mm}^2$$ (2.4.1, Eq. 2.14)

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M} = 0.80 \cdot \frac{3.500\,\text{N/mm}^2}{1.25} = 2.240\,\text{N/mm}^2$$ (2.4.1, Eq. 2.14)

$$\eta = \frac{\tau_{tor,d}}{k_{shape} \cdot f_{v,d}} = \frac{0.960\,\text{N/mm}^2}{1.12 \cdot 2.240\,\text{N/mm}^2} = 0.383$$ (6.1.8, Eq. 6.14)

$$\eta = 0.383 \le 1$$ ✓

$f_{v,z,d}$	Design shear strength
k_{mod}	Modification factor
$f_{v,z,k}$	Characteristic shear strength
γ_M	Partial factor
$f_{v,y,d}$	Design shear strength
$f_{v,y,k}$	Characteristic shear strength
$\tau_{tor,d}$	Design torsional stress
k_{shape}	Torsion factor
$f_{v,d}$	Design shear strength

3.5.1.2. Dimenzioniranje CLT zidnih panela (d=20 cm i d=14 cm)

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MODEL

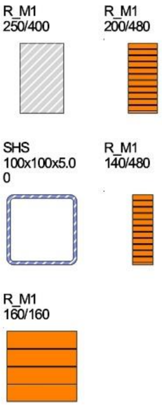
1 Basic Objects

1.1 MATERIALS

Legend
% Stiffness modification

Material No.	Material Name	Material Type	Analysis Model	Options
6	Stora Enso (40 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%
7	C 35/40 beton	Concrete	Isotropic | Linear Elastic	
8	GL32h | Isotropic | Linear Elastic	Timber	Isotropic | Linear Elastic	%
9	S355 | Isotropic | Linear Elastic	Steel	Isotropic | Linear Elastic	
10	Stora Enso (30 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%
11	Stora Enso (20 mm) | Orthotropic | Linear Elastic (Surfaces)	Timber	Orthotropic | Linear Elastic (Surfaces)	%

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 250/400 | 7 - C 35/40 beton							
	7	Parametric - Massive I		127345.16	133333.33	52083.33	250.0	400.0
				1000.00	833.33	833.33		
2	R_M1 200/480 | 8 - GL32h							
	8	Parametric - Massive I		94484.39	184320.00	32000.00	200.0	480.0
				960.00	800.00	800.00		
3	SHS 100x100x5.00 | 9 - S355							
	9	Standardized - Steel	Cold formed	440.51	271.02	271.02	100.0	100.0
				18.35	8.05	8.05		
4	R_M1 140/480 | 8 - GL32h							
	8	Parametric - Massive I		35841.51	129024.00	10976.00	140.0	480.0
				672.00	560.00	560.00		
5	R_M1 160/160 | 8 - GL32h							
	8	Parametric - Massive I		9229.65	5461.33	5461.33	160.0	160.0
				256.00	213.33	213.33		

1.2.1 SECTIONS - INFORMATION

Legend
⌶ Thin-walled model
⌶ Warping stiffness deactivated

Section No.	Principal Axes α [deg]	Warping I_ω [cm⁶]	Combination Type	Corrugated S. W. b [mm]	Worn out w_v [%]	T. Reduction [–]	Options	Comment
1	R_M1 250/400 | 7 - C 35/40 beton							
	0.00						⌶	
2	R_M1 200/480 | 8 - GL32h							
	0.00						⌶	
3	SHS 100x100x5.00 | 9 - S355							
	0.00						⌶ ⌶	
4	R_M1 140/480 | 8 - GL32h							
	0.00						⌶	
5	R_M1 160/160 | 8 - GL32h							
	0.00						⌶	

2 Timber Design

2.1 ULTIMATE CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
1	Default	All	All	3, 9,11,14,16-35 ,38,42-52,54- 57,60-77,81,8	All		

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2.1 ULTIMATE CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
				3-87,90-136,1 38,139,141-2 38,240,241,2 43,245,247-2 58,260-270,2 72-275,278-2 84,286-306,3 12,313,315-3 98,400-402,4 04-411,413-4 15,417-427,4 32-461,464-4 99,506-513,5 15,518-524,5 26-539,543-5 63,565,567-5 87,589-610,6 13-621,624-6 41,643-653,6 55-659,661-6 63,665,669-6 89,695-726,7 30-758,761-8 13			

2.1.1 ULTIMATE CONFIGURATIONS - SETTINGS - SURFACES

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Limit Values for Special Cases			
	Tension ($\sigma_{t,0,d}$ / $f_{t,0,d}$)	$\eta_{\sigma t,0,lim}$	0.001	--
	Tension perpendicular ($\sigma_{t,90,d}$ / $f_{t,90,d}$)	$\eta_{\sigma t,90,lim}$	0.001	--
	Compression ($\sigma_{c,0,d}$ / $f_{c,0,d}$)	$\eta_{\sigma c,0,lim}$	0.001	--
	Compression perpendicular ($\sigma_{c,90,d}$ / $f_{c,90,d}$)	$\eta_{\sigma c,90,lim}$	0.001	--
	Shear in yz-plane (τ_{yz} / $f_{v,yz,d}$)	$\eta_{\tau yz,lim}$	0.001	--
	Shear in xz-plane (τ_{xz} / $f_{v,xz,d}$)	$\eta_{\tau xz,lim}$	0.001	--
	Shear in xy-plane (τ_{xy} / $f_{v,xy,d}$)	$\eta_{\tau xy,lim}$	0.001	--
	Shear on net section (τ_{net} / $f_{v,net,d}$)	$\eta_{\tau net,lim}$	0.001	--
	Equivalent torsion (τ_{tor} / $f_{v,tor,d}$)	$\eta_{\tau tor,lim}$	0.001	--
	Bending ($\sigma_{b,0,d}$ / $f_{m,0,d}$)	$\eta_{\sigma b,0,lim}$	0.001	--
	Bending perpendicular ($\sigma_{b,90,d}$ / $f_{m,90,d}$)	$\eta_{\sigma b,90,lim}$	0.001	--
	System Strength			
	☐ Consider system strength factor			

2.2 SERVICEABILITY CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
1	Default	All	All	3, 9,11,14,16-35 ,38,42-52,54- 57,60-77,81,8 3-87,90-136,1 38,139,141-2 38,240,241,2 43,245,247-2 58,260-270,2 72-275,278-2 84,286-306,3 12,313,315-3 98,400-402,4 04-411,413-4 15,417-427,4 32-461,464-4 99,506-513,5 15,518-524,5 26-539,543-5 63,565,567-5 87,589-610,6 13-621,624-6 41,643-653,6 55-659,661-6 63,665,669-6	All		

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2.2 **SERVICEABILITY CONFIGURATIONS**

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
				89,695-726,7 30-758,761-8 13			

2.2.1 **SERVICEABILITY CONFIGURATIONS - SETTINGS - SURFACES**

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Serviceability Limits to Be Checked			
	☒ Characteristic			
	☒ Quasi-permanent 1			
	☒ Quasi-permanent 2			
	Serviceability Limits (Deflections) Acc. to 7.2			
	Limit for double-supported surface			
	Characteristic	L /	300	--
	Quasi-permanent 1	L /	250	--
	Quasi-permanent 2	L /	150	--
	Limit for cantilever surface			
	Characteristic	L_c /	150	--
	Quasi-permanent 1	L_c /	125	--
	Quasi-permanent 2	L_c /	75	--
	Vibration Design			
	Vibration design	w_{lim}	5.0	mm

2.3 **FIRE RESISTANCE CONFIGURATIONS**

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets	Shear Walls	Deep Beams
1	Default	All	All	3, 9,11,14,16-35 ,38,42-52,54- 57,60-77,81,8 3-87,90-136,1 38,139,141-2 38,240,241,2 43,245,247-2 58,260-270,2 72-275,278-2 84,286-306,3 12,313,315-3 98,400-402,4 04-411,413-4 15,417-427,4 32-461,464-4 99,506-513,5 15,518-524,5 26-539,543-5 63,565,567-5 87,589-610,6 13-621,624-6 41,643-653,6 55-659,661-6 63,665,669-6 89,695-726,7 30-758,761-8 13	All		

2.3.1 **FIRE RESISTANCE CONFIGURATIONS - SETTINGS - SURFACES**

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Fire Design Settings			
	Required time of fire resistance	t	90	min
	○ Wall			
	◉ Ceiling			
	○ Heat-proof adhesive of cross-laminated timber layers			
	◉ Non-heat-proof adhesive of cross-laminated timber layers			
	Coefficient increasing charring rate of inner layers	k_{β}	2.00	--

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2.3.1 **FIRE RESISTANCE CONFIGURATIONS - SETTINGS - SURFACES**

Config. No.	Description	Symbol	Value	Unit
	☐ User-defined coefficient of layer thickness with zero strength			
	Thickness to omit fire reduced layer		3.0	mm
	Fire exposure			
	☐ Top (-z)			
	☒ Bottom (+z)			
	☒ Consider non-heat-proof adhesive from bottom			
	☐ Initial fire protection from bottom (+z)			

2.4 Results

2.4.1 **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
	CLT-200											
2	676	56103	46.906	22.955	-3.651	DS1	CO1	1	Top	0.000 ✓	UL0100.00	Ultimate Limit State | Negligible stresses
		56074	45.536	22.955	-2.400	DS1	CO6	1	Top	0.071 ✓	UL1100.00	Ultimate Limit State | Tension along grain
		56094	47.696	22.955	-1.700	DS1	CO6	2	Top	0.246 ✓	UL1300.00	Ultimate Limit State | Compression along grain
		91	42.836	22.955	0.000	DS1	CO6	3	Top	0.164 ✓	UL3010.00	Ultimate Limit State | Shear in yz-plane
			42.836	22.955	0.000	DS1	CO6	2	Bottom	0.043 ✓	UL3020.00	Ultimate Limit State | Shear in xz-plane
			42.836	22.955	0.000	DS1	CO6	1	Top	0.166 ✓	UL3110.00	Ultimate Limit State | Shear in xy-plane | Failure mechanism 1
		56065	43.676	22.955	0.000	DS1	CO6	4	Top	0.009 ✓	UL3400.00	Ultimate Limit State | Shear in xz-plane and xy-plane
		95	50.036	22.955	0.000	DS1	CO6	2	Top	0.059 ✓	UL4100.00	Ultimate Limit State | Bending along grain
		56074	45.536	22.955	-2.400	DS1	CO10	1	Top	0.069 ✓	UL5100.00	Ultimate Limit State | Bending and tension along grain
		56094	47.696	22.955	-1.700	DS1	CO10	2	Top	0.234 ✓	UL6100.00	Ultimate Limit State | Bending and compression along grain
		91	42.836	22.955	0.000	DS2	CO43			0.000 ✓	SE0500.00	Serviceability | Negligible deflections
		56077	46.496	22.955	-1.920	DS2	CO80			0.049 ✓	SE5000.01	Serviceability | Combination of actions 'Characteristic' | Deflection in z-direction
			46.496	22.955	-1.920	DS3	CO122			0.042 ✓	SE5000.02	Serviceability | Combination of actions 'Quasi-permanent 1' | Deflection in z-direction
	CLT-140											
3	572	50014	48.412	22.955	-6.480	DS1	CO23	2	Middle	0.000 ✓	UL0100.00	Ultimate Limit State | Negligible stresses
		5759	42.836	22.955	-7.000	DS1	CO6	2	Top	0.101 ✓	UL1100.00	Ultimate Limit State | Tension along grain
		50016	43.197	22.955	-6.013	DS1	CO6	1	Top	0.204 ✓	UL1300.00	Ultimate Limit State | Compression along grain
		92	42.836	22.955	-4.080	DS1	CO6	2	Top	0.050 ✓	UL3010.00	Ultimate Limit State | Shear in yz-plane
			42.836	22.955	-4.080	DS1	CO6	3	Middle	0.015 ✓	UL3020.00	Ultimate Limit State | Shear in xz-plane
		1073	45.936	22.955	-4.080	DS1	CO6	5	Bottom	0.141 ✓	UL3110.00	Ultimate Limit State | Shear in xy-plane | Failure mechanism 1
			45.936	22.955	-4.080	DS1	CO6	5	Middle	0.016 ✓	UL3400.00	Ultimate Limit State | Shear in xz-plane and xy-plane
		15818	44.903	22.955	-4.080	DS1	CO4	1	Top	0.059 ✓	UL4100.00	Ultimate Limit State | Bending along grain
		5759	42.836	22.955	-7.000	DS1	CO6	2	Top	0.107 ✓	UL5100.00	Ultimate Limit State | Bending and tension along grain
		50005	47.945	22.955	-5.547	DS1	CO6	1	Top	0.231 ✓	UL6100.00	Ultimate Limit State | Bending and compression along grain
		92	42.836	22.955	-4.080	DS2	CO43			0.000 ✓	SE0500.00	Serviceability | Negligible deflections
		50007	48.412	22.955	-5.080	DS2	CO48			0.065 ✓	SE5000.01	Serviceability | Combination of actions 'Characteristic' | Deflection in z-direction
			48.412	22.955	-5.080	DS3	CO90			0.078 ✓	SE5000.02	Serviceability | Combination of actions 'Quasi-permanent 1' | Deflection in z-direction

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2.5 SURFACE NO. 572 | DS3 | CO90 | MESH NODE NO. 50007 | ELEMENT NO. 50988 | SE5000.02 Timber Design

Design Check SE5000.02 | EN 1995 | CEN | 2014-05

Serviceability
Combination of actions 'Quasi-permanent 1' | Deflection in z-direction

Design situation: Quasi-permanent 1
Surface type: Double-supported

$$w_{fin,limit,z} = \frac{l}{l/w_{fin,limit,z}} = \frac{3.101\,\text{m}}{250} = 12.4\,\text{mm}$$

$$\eta = \frac{|w_{fin,z}|}{w_{fin,limit,z}} = \frac{|1.0\,\text{mm}|}{12.4\,\text{mm}} = 0.078$$

$$\eta = 0.078 \leq 1$$ ✓

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

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2.6 SURFACE NO. 572 | DS1 | CO6 | MESH NODE NO. 50005 | ELEMENT NO. 50985 | UL6100 — Timber Design

Design Check UL6100 | EN 1995 | CEN | 2014-05

Ultimate Limit State
Bending and compression along grain

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.80 \cdot \frac{21.000\,N/mm^2}{1.20} = 14.000\,N/mm^2$$

$$f_{m,0,d} = k_{mod} \cdot \frac{f_{m,0,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,N/mm^2}{1.20} = 16.000\,N/mm^2$$

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} + \frac{|\sigma_{b,0,d}|}{f_{m,0,d}} = \frac{|-2.680\,N/mm^2|}{14.000\,N/mm^2} + \frac{|-0.632\,N/mm^2|}{16.000\,N/mm^2} = 0.231$$

$$\eta = 0.231 \le 1$$ ✓

$f_{c,0,d}$	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

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2.7 SURFACE NO. 676 | DS1 | CO6 | MESH NODE NO. 56094 | ELEMENT NO. 58579 | UL1300 — Timber Design

Design Check UL1300 | EN 1995 | CEN | 2014-05

Ultimate Limit State
Compression along grain

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.80 \cdot \frac{21.000\,N/mm^2}{1.20} = 14.000\,N/mm^2$$

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} = \frac{|-3.448\,N/mm^2|}{14.000\,N/mm^2} = 0.246$$

$$\eta = 0.246 \leq 1 \checkmark$$

$f_{c,0,d}$	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

3.5.1.3. Dimenzioniranje elemenata (S355) – čelični stupovi

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STEEL

1 Steel Design

1.1 SECTIONS

Legend
Thin-walled model
Warping stiffness deactivated

Section No.	Name	Material	To Design	Section Type	Use Other Section for Design	Section Classification	Options
1	R_M1 250/400	7	☒	Parametric - Massive I	--	Class 3	
2	R_M1 200/480	8	☒	Parametric - Massive I	--	Class 3	
3	SHS 100x100x5.00	9	☒	Standardized - Steel	--	Automatically	
4	R_M1 140/480	8	☒	Parametric - Massive I	--	Class 3	
5	R_M1 160/160	8	☒	Parametric - Massive I	--	Class 3	

1.2 ULTIMATE CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Shear Walls	Deep beams
1	Default	All	All	All	All

1.2.1 ULTIMATE CONFIGURATIONS - SETTINGS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	General			
	☒ Perform stability design			
	Limit Values for Special Cases			
	Tension ($N_{t,Ed}$ / $N_{t,Rd}$)	η_{Nt}	0.001	--
	Compression ($N_{c,Ed}$ / $N_{pl,Rd}$)	η_{Nc}	0.001	--
	Shear ($V_{y,Ed}$ / $V_{pl,y,Rd}$)	η_{Vy}	0.001	--
	Shear ($V_{z,Ed}$ / $V_{pl,z,Rd}$)	η_{Vz}	0.001	--
	Shear stress due to torsion ($\tau_{t,Ed}$ / τ_{Rd})	$\eta_{\tau t}$	0.010	--
	Bending about major axis ($M_{y,Ed}$ / $M_{pl,y,Rd}$)	η_{My}	0.001	--
	Bending about minor axis ($M_{z,Ed}$ / $M_{pl,z,Rd}$)	η_{Mz}	0.001	--
	Thin-Walled Analysis			
	Maximum number of iterations	n_{max}	3	
	Maximum difference between iterations	δ_{max}	1.00	%
	☐ Neglect bending moments due to the shift of the centroid			
	☐ Consider effective widths according to EN 1993-1-5, Annex E			
	Options			
	Elastic design			
	☐ Elastic design (also for class 1 and class 2 sections)			
	☐ Use verification acc. to equation 6.1 for elastic design			
	Plastic design			
	☐ Use linear interaction acc. to 6.2.1(7) for section check for M+N			
	Design of Cold-Formed Sections Acc. to EN 1993-1-3			
	☒ Perform design of cold-formed sections			
	Forming factor k acc. to 3.2.2(3)		Roll forming (k = 7)	
	☐ Use elastic design acc. to 6.1.6			
	☐ Consider web as stiffened acc. to Tab. 6.1			
	☒ Determine local transverse resistance of web acc. to 6.1.7			
	Limiting inclination of principal axes acc. to 6.2.4(2)	α_{lim}	0.00	deg
	Design of Shear Buckling Acc. to EN 1993-1-5			
	☒ Perform design of shear buckling			
	Stability Analyses with Second-Order Internal Forces			
	☐ Use γ_{M1} for determination of the section resistance			
	Settings for Stability Design			
	Calculation Method			
	Equivalent member method (effective lengths)			
	Structure Type acc. to Table B.3			
	☐ Sway y-y (C_{my} = 0.9)			
	☐ Sway z-z (C_{mz} = 0.9)			
	2D - General method (4 degrees of freedom)			
	☒ Enable also for non-I-sections			
	☐ Extension methods			
	Include Second-Order Effects Acc. to 5.2.2(4) by Increasing Bending Moment About			
	☐ Major y-axis			
	☐ Minor z-axis			

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1.2.1 **ULTIMATE CONFIGURATIONS - SETTINGS**

Config. No.	Description	Symbol	Value	Unit
	Position of Positive Transverse Load Application			
	Vertical position			
	◉ On profile edge (destabilizing effect)			
	○ At shear point			
	○ At center point			
	○ On profile edge (stabilizing effect)			
	Parameters for Lateral-Torsional Buckling			
	6.3.2.3 Determine lateral-torsional buckling curves for 6.3.2 and 6.3.3			
	○ Always according to Eq. 6.56 General case (conservative)			
	◉ If possible, according to Eq. 6.57, otherwise according to Eq. 6.56			
	☒ Use factor f for modification of χ_{LT} acc. to 6.3.2.3(2)			
	6.3.3(4) Parameters k_{yy}, k_{yz}, k_{zy}, k_{zz}			
	Determine interaction factors for 6.3.3(4) according to			
	○ Method 1 acc. to Annex A			
	◉ Method 2 acc. to Annex B			
	Lateral-Torsional Buckling of Hollow Sections			
	☒ Perform design for non-circular doubly symmetric hollow sections			
	Stability Design of Cold-Formed Sections Acc. to EN 1993-1-3			
	☒ Design of bending with axial force acc. to 6.2.5(2) or 6.3			

1.3 **SERVICEABILITY CONFIGURATIONS**

Config. No.	Name	Assigned to Members	Member Sets	Shear Walls	Deep beams
1	Default	All	All	All	All

1.3.1 **SERVICEABILITY CONFIGURATIONS - SETTINGS**

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Serviceability Limits (Deflections) Acc. to 7.2			
	Beam limits - action combination (Table A 1.4 of EN 1990)			
	Characteristic	L /	300	–
	Frequent	L /	200	–
	Quasi-permanent	L /	200	–
	Cantilever limits - action combination (Table A 1.4 of EN 1990)			
	Characteristic	L_c /	150	–
	Frequent	L_c /	100	–
	Quasi-permanent	L_c /	100	–
	Vibration Design			
	Vibration design	$w_{inst,lim}$	5.0	mm
	Limitation of Web Breathing			
	☐ Design as steel bridge structure acc. to EN 1993-2, 7.4			

1.4 **FIRE RESISTANCE CONFIGURATIONS**

Config. No.	Name	Assigned to Members	Member Sets	Shear Walls	Deep beams
1	Default	All	All	All	All

1.4.1 **FIRE RESISTANCE CONFIGURATIONS - SETTINGS**

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Definition of Temperature			
	Define final temperature		Analytically	
	Fire design settings			
	Required time of fire resistance	$t_{fi,req}$	45	min
	Fire exposure		All Sides	
	Time interval of analysis	Δt	5.000	s
	Fire protection			
	☐ Set fire protection parameters			

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1.4.1 **FIRE RESISTANCE CONFIGURATIONS - SETTINGS**

Config. No.	Description	Symbol	Value	Unit
	Temperature curve for determination of temperature of gases			
	Temperature curve			
	◉ Standard temperature-time curve			
	○ External fire curve			
	○ Hydrocarbon curve			
	Coefficient of heat transfer by convection	α_c	25	$W \cdot m^{-2} \cdot K^{-1}$
	Thermal actions for temperature analysis			
	Configuration factor	φ	1.000	–
	☐ Galvanized surface of carbon steel member			
	Surface emissivity of carbon steel member	ε_m	0.700	–
	Surface emissivity of stainless steel member	ε_m	0.400	–
	Emissivity of fire	ε_f	1.000	–

1.5 Results

1.5.1 **DESIGN RATIOS ON MEMBERS BY SECTION** — **Steel Design**

Section No.	Member No.	Location x [m]	Stress Point No.	Design Situation	Loading No.	Design Check Ratio η [–]	Type	Description
	SHS 100x100x5.00 | 9 - S355							
3	26	0.000		DS1	CO1	0.000 ✓	SP0100.00	Section Proof | Negligible internal forces
		4.080		DS1	CO1	0.001 ✓	SP1100.00	Section Proof | Tension acc. to EN 1993-1-1, 6.2.3
	33	0.000		DS1	CO9	0.267 ✓	SP1200.00	Section Proof | Compression acc. to EN 1993-1-1, 6.2.4
	335	0.000		DS1	CO14	0.005 ✓	SP4100.03	Section Proof | Bending about y-axis acc. to EN 1993-1-1, 6.2.5 | Plastic design
				DS1	CO6	0.003 ✓	SP5100.03	Section Proof | Bending about z-axis acc. to EN 1993-1-1, 6.2.5 | Plastic design
				DS1	CO14	0.000 ✓	SP6500.01	Section Proof | Biaxial bending, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
				DS1	CO30	0.003 ✓	SP6500.02	Section Proof | Bending about y-axis, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
				DS5	RC4	0.018 ✓	SP6500.03	Section Proof | Bending about z-axis, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	26	4.080		DS5	RC1	0.000 ✓	SP6500.04	Section Proof | Biaxial bending and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	33	0.000		DS1	CO9	0.756 ✓	ST1100.00	Stability | Flexural buckling about principal y-axis acc. to EN 1993-1-1, 6.3.1
				DS1	CO9	0.756 ✓	ST1300.00	Stability | Flexural buckling about principal z-axis acc. to EN 1993-1-1, 6.3.1
	335	0.000		DS1	CO9	0.075 ✓	ST3100.00	Stability | Bending and buckling about principal axes acc. to EN 1993-1-1, 6.3.3
	22	0.000		DS2	CO43	0.000 ✓	SE0100.00	Serviceability | Negligible deflections
	335	1.251		DS2	CO76	0.005 ✓	SE1100.00	Serviceability | Deflections in z-direction
				DS2	CO48	0.005 ✓	SE1200.00	Serviceability | Deflections in y-direction

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MODEL

1.6 **MEMBER NO. 33 | DS1 | CO9 | 0.000 M | SP1200** **Steel Design**

Design Check SP1200 | EN 1993 | CEN | 2015-06

Section Proof
Compression acc. to EN 1993-1-1, 6.2.4

$$N_{c,Rd} = A \cdot \frac{f_y}{\gamma_{M0}} = 18.35\,\text{cm}^2 \cdot \frac{355.000\,\text{N/mm}^2}{1.00} = 651.51\,\text{kN}$$ Eq. 6.10

$$\eta_N = \frac{N_{c,Ed}}{N_{c,Rd}} = \frac{173.93\,\text{kN}}{651.51\,\text{kN}} = 0.267$$

$$\eta = \eta_N = 0.267$$ 6.2.4, Eq. 6.9

$$\eta = 0.267 \leq 1$$ ✓

$N_{c,Rd}$	Design axial force resistance
A	Sectional area
f_y	Yield strength
γ_{M0}	Partial factor
η_N	Design component for N
$N_{c,Ed}$	Design compression force

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MODEL

1.7 **MEMBER NO. 33 | DS1 | CO9 | 0.000 M | ST1300** **Steel Design**

Design Check ST1300 | EN 1993 | CEN | 2015-06

Stability
Flexural buckling about principal z-axis acc. to EN 1993-1-1, 6.3.1

$$N_{cr,z} = (\pi)^2 \cdot E \cdot \frac{I_z}{(L_{cr,z})^2} = (\pi)^2 \cdot 210000.000\,N/mm^2 \cdot \frac{271.02\,cm^4}{(4.080\,m)^2} = 337.44\,kN$$ 6.3.1.2(1)

$$\bar{\lambda}_z = \sqrt{\frac{A \cdot f_y}{N_{cr,z}}} = \sqrt{\frac{18.35\,cm^2 \cdot 355.000\,N/mm^2}{337.44\,kN}} = 1.390$$ 6.3.1.3(1)

$$\eta_{N_{cr,z}} = \gamma_{M1} \cdot \frac{N_{c,Ed}}{N_{cr,z}} = 1.00 \cdot \frac{173.93\,kN}{337.44\,kN} = 0.515$$ 6.3.1.2(4)

$$\Phi_z = 0.5 \cdot \left[1 + \alpha_z \cdot (\bar{\lambda}_z - 0.2) + (\bar{\lambda}_z)^2\right] = 0.5 \cdot \left[1 + 0.490 \cdot (1.390 - 0.2) + (1.390)^2\right] = 1.757$$ 6.3.1.2(1)

$$\chi_z = \frac{1}{\Phi_z + \sqrt{(\Phi_z)^2 - (\bar{\lambda}_z)^2}} = \frac{1}{1.757 + \sqrt{(1.757)^2 - (1.390)^2}} = 0.35$$ 6.3.1.2(1), Eq. 6.49

$$N_{b,z,Rd} = \chi_z \cdot A \cdot \frac{f_y}{\gamma_{M1}} = 0.35 \cdot 18.35\,cm^2 \cdot \frac{355.000\,N/mm^2}{1.00} = 230.07\,kN$$ 6.3.1.1(3)

$$\eta = \frac{N_{c,Ed}}{N_{b,z,Rd}} = \frac{173.93\,kN}{230.07\,kN} = 0.756$$ 6.3.1

$\eta = 0.756 \leq 1$ ✓

$N_{cr,z}$	Elastic critical force
E	Modulus of elasticity
I_z	Moment of inertia
$L_{cr,z}$	Buckling length
$\bar{\lambda}_z$	Non-dimensional slenderness
A	Sectional area
f_y	Yield strength
$\eta_{N_{cr,z}}$	Criterion N_{Ed} / $N_{cr,z}$
γ_{M1}	Partial factor
$N_{c,Ed}$	Design compression force
Φ_z	Value to determine reduction factor χ
α_z	Imperfection factor
χ_z	Reduction factor
$N_{b,z,Rd}$	Design buckling resistance of a compression member

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MODEL

1.8 **MEMBER NO. 33 | DS1 | CO9 | 0.000 M | ST1100** **Steel Design**

Design Check ST1100 | EN 1993 | CEN | 2015-06

Stability
Flexural buckling about principal y-axis acc. to EN 1993-1-1, 6.3.1

$$N_{cr,y} = (\pi)^2 \cdot E \cdot \frac{I_y}{(L_{cr,y})^2} = (\pi)^2 \cdot 210000.000\,N/mm^2 \cdot \frac{271.02\,cm^4}{(4.080\,m)^2} = 337.44\,kN$$ 6.3.1.2(1)

$$\bar{\lambda}_y = \sqrt{\frac{A \cdot f_y}{N_{cr,y}}} = \sqrt{\frac{18.35\,cm^2 \cdot 355.000\,N/mm^2}{337.44\,kN}} = 1.390$$ 6.3.1.3(1)

$$\eta_{N_{cr,y}} = \gamma_{M1} \cdot \frac{N_{c,Ed}}{N_{cr,y}} = 1.00 \cdot \frac{173.93\,kN}{337.44\,kN} = 0.515$$ 6.3.1.2(4)

$$\Phi_y = 0.5 \cdot \left[1 + \alpha_y \cdot (\bar{\lambda}_y - 0.2) + (\bar{\lambda}_y)^2\right] = 0.5 \cdot \left[1 + 0.490 \cdot (1.390 - 0.2) + (1.390)^2\right] = 1.757$$ 6.3.1.2(1)

$$\chi_y = \frac{1}{\Phi_y + \sqrt{(\Phi_y)^2 - (\bar{\lambda}_y)^2}} = \frac{1}{1.757 + \sqrt{(1.757)^2 - (1.390)^2}} = 0.35$$ 6.3.1.2(1), Eq. 6.49

$$N_{b,y,Rd} = \chi_y \cdot A \cdot \frac{f_y}{\gamma_{M1}} = 0.35 \cdot 18.35\,cm^2 \cdot \frac{355.000\,N/mm^2}{1.00} = 230.07\,kN$$ 6.3.1.1(3)

$$\eta = \frac{N_{c,Ed}}{N_{b,y,Rd}} = \frac{173.93\,kN}{230.07\,kN} = 0.756$$ 6.3.1

$$\eta = 0.756 \leq 1$$ ✓

$N_{cr,y}$	Elastic critical force
E	Modulus of elasticity
I_y	Moment of inertia
$L_{cr,y}$	Buckling length
$\bar{\lambda}_y$	Non-dimensional slenderness
A	Sectional area
f_y	Yield strength
$\eta_{N_{cr,y}}$	Criterion N_{Ed} / $N_{cr,y}$
γ_{M1}	Partial factor
$N_{c,Ed}$	Design compression force
Φ_y	Value to determine reduction factor χ
α_y	Imperfection factor
χ_y	Reduction factor for buckling
$N_{b,y,Rd}$	Design buckling resistance of a compression member

3.6. Dimenzioniranje CLT panela (d=22 cm) – Stora Enso

3.6.1. Dimenzioniranje međukatne konstrukcije – kontinuirana ploča preko 2 raspona

Diplomski rad
Međukatna ploča

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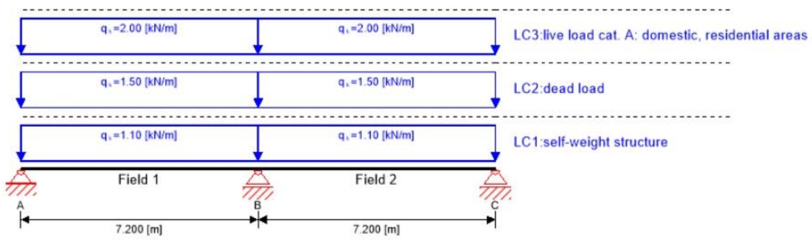
System

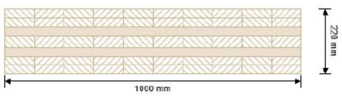


Global utilization ratio 99%

ULS	33%	ULS Fire	26%	SLS	56%	Vibration	99%	Support	10%

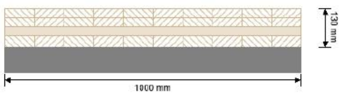
Product data

Section: CLT 220 L7s - 2



Layer	Thickness	Orientation	Material
1	30.0 mm	0°	C24 spruce ETA (2022)
2	30.0 mm	0°	C24 spruce ETA (2022)
3	30.0 mm	90°	C24 spruce ETA (2022)
4	40.0 mm	0°	C24 spruce ETA (2022)
5	30.0 mm	90°	C24 spruce ETA (2022)
6	30.0 mm	0°	C24 spruce ETA (2022)
7	30.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**220.0 mm**		

Section Fire: CLT 220 L7s - 2



Layer	Thickness	Orientation	Material
1	30.0 mm	0°	C24 spruce ETA (2022)
2	30.0 mm	0°	C24 spruce ETA (2022)
3	30.0 mm	90°	C24 spruce ETA (2022)
4	40.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**130.0 mm**		

Diplomski rad
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Section Fire: CLT 220 L7s - 2

Fire resistance class: R 90

Time **90 min**

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	82.0	89.0	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	1.10
2	1.10

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	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

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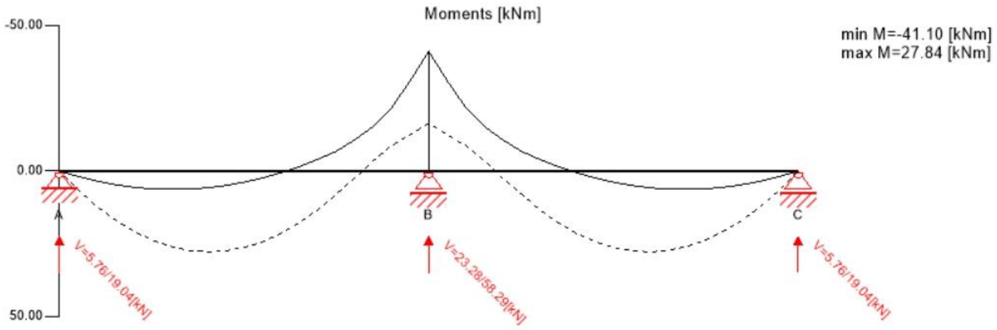
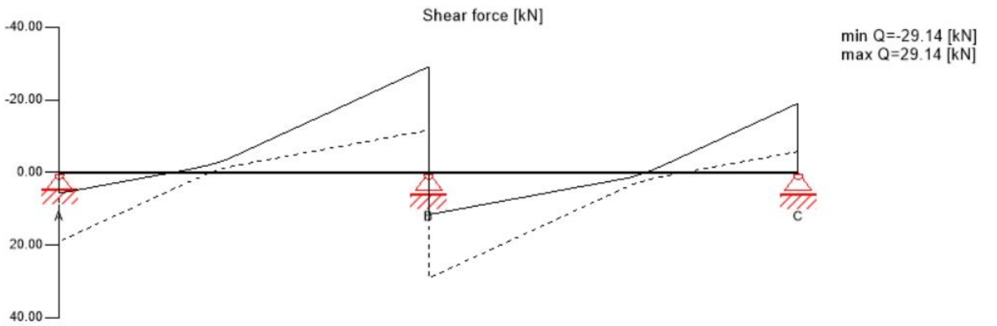
SLS Quasi-permanent Combination

	Combination rule
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	7.2	24.00	1.25	0.80	1.10	16.90	-41.10	5.59	33%	LCO2
2	0.0	24.00	1.25	0.80	1.10	16.90	-41.10	5.59	33%	LCO2

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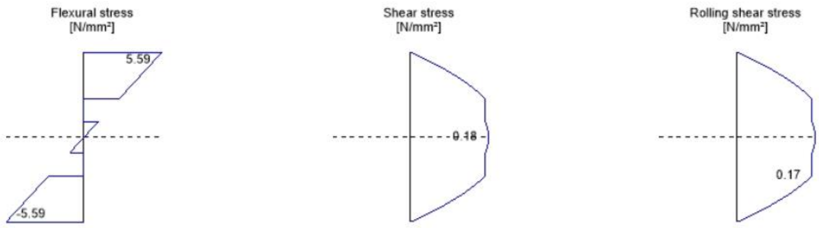
ULS Shear analysis

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	7.2	4.00	1.25	0.80	2.56	-29.14	0.18	7%	LCO2
2	0.0	4.00	1.25	0.80	2.56	29.14	0.18	7%	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	7.2	1.15	1.25	0.80	0.74	-29.14	0.17	23%	LCO2
2	0.0	1.15	1.25	0.80	0.74	29.14	0.17	23%	LCO2

Stress diagram



Flexural stress analysis

$M_{y,d}$ =	-41.10	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	
$\sigma_{m,y,d}$ =	5.59	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							**33%**

Shear stress analysis

V_d =	-29.14	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
				$k_{h,v}$ =	0.00	-	
$\tau_{v,d}$ =	0.18	N/mm²	<	$f_{v,d}$ =	2.56	N/mm²	✓
Utilization ratio							**7%**

Rolling shear analysis

V_d =	-29.14	kN		$f_{r,k}$ =	1.15	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
$\tau_{r,d}$ =	0.17	N/mm²	<	$f_{r,d}$ =	0.74	N/mm²	✓
Utilization ratio							**23%**

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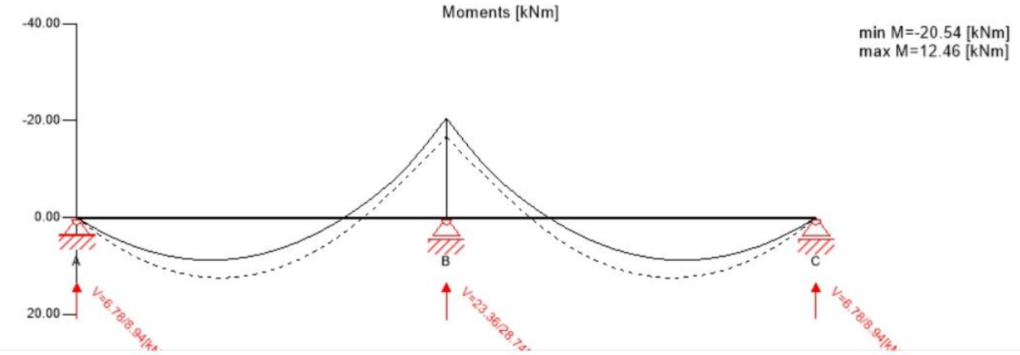
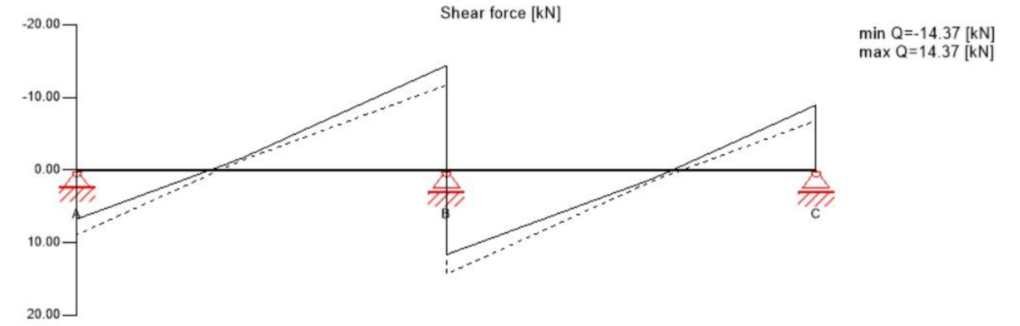
Ultimate limit state (ULS) fire design - results





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	7.2	24.00	1.00	1.00	1.10	1.15	30.36	-20.54	-7.89	26%	LCO4
2	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-20.54	-7.89	26%	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	7.2	4.00	1.00	1.00	1.15	4.60	-14.37	0.16	3%	LCO4
2	0.0	4.00	1.00	1.00	1.15	4.60	14.37	0.16	3%	LCO4

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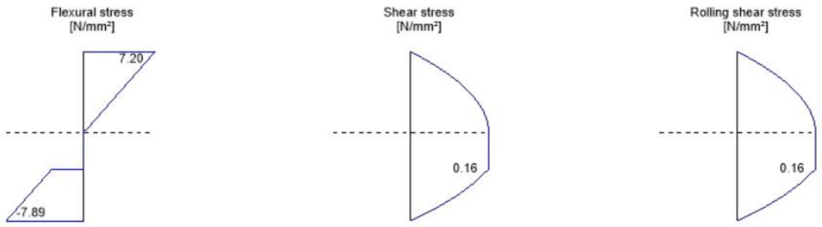
ULS Fire Rolling shear

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	7.2	1.15	1.00	1.00	1.15	1.32	-14.37	0.16	12%	LCO4
2	0.0	1.15	1.00	1.00	1.15	1.32	14.37	0.16	12%	LCO4

Stress diagram



Flexural stress analysis Fire

$M_{y,d}$ =	-20.54	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
$\sigma_{m,y,d}$ =	-7.89	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						26%

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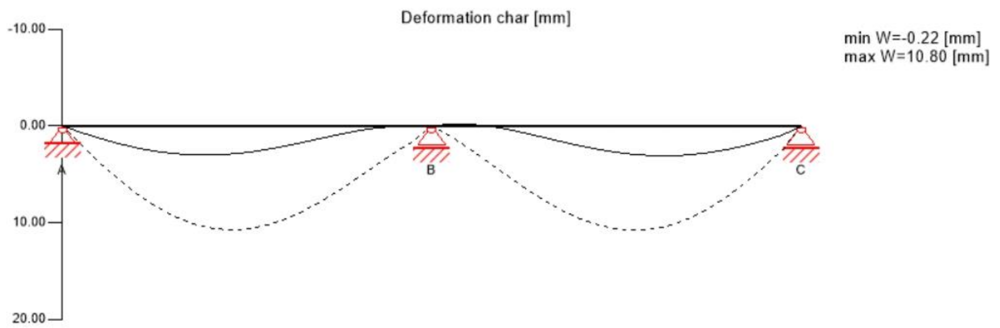
Shear stress analysis Fire							
V_d =	-14.37	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				$k_{h,v}$ =	0.00	-	
				k_{fi} =	1.15	-	
$\tau_{v,d}$ =	0.16	N/mm²	<	$f_{v,d}$ =	4.60	N/mm²	✓
Utilization ratio							3%

Rolling shear analysis Fire							
V_d =	-14.37	kN		$f_{r,k}$ =	1.15	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				k_{fi} =	1.15	-	
$\tau_{r,d}$ =	0.16	N/mm²	<	$f_{r,d}$ =	1.32	N/mm²	✓
Utilization ratio							12%

Service limit state design (SLS) - design results



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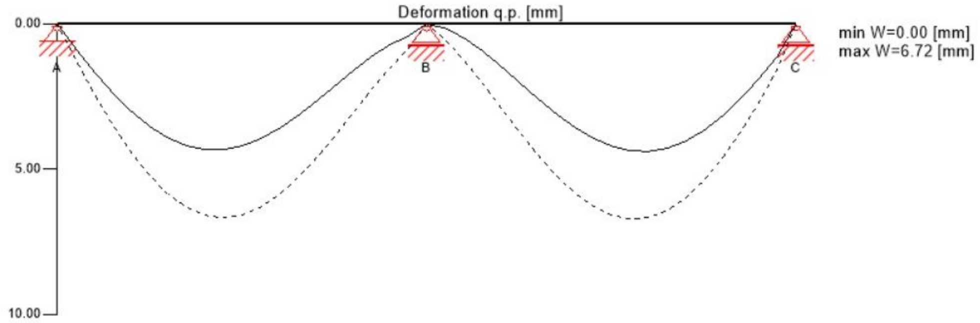
Service limit state design (SLS) - design results



w_{inst} = w[char]

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	24.0	10.7	45%
2	0.8	L/300	24.0	10.8	45%

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

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/250	28.8	16.1	56%
2	0.8	L/250	28.8	16.2	56%

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

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	24.0	12.0	50%
2	0.8	L/300	24.0	12.1	50%

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Vibration analysis

General

Total mass	38.17	[t]
Tributary width	3.6	[m]
Stiffness Longitudinal direction	9712.0	[kNm²]
Stiffness Cross direction	936.0	[kNm²]
Modal damping	4.0	[%]
α	0.1	[-]
Man weight	700.0	[N]
Modal mass	6947.8	[kg]

Analysis

Criterion	Calc.	Class I	Class II	Class I	Class II	Cl. I	Cl. II
Frequency criterion min	5.802 [Hz]	4.5 [Hz]	4.5 [Hz]	78 %	78 %	✓	✓
Frequency criterion	5.802 [Hz]	8.0 [Hz]	6.0 [Hz]	138 %	103 %		
Acceleration criterion	0.049 [m/s²]	0.05 [m/s²]	0.1 [m/s²]	99 %	49 %	✓	✓
Stiffness criterion	0.22 [mm]	0.25 [mm]	0.5 [mm]	88 %	44 %	✓	✓

Support design

Nr.	Type	Width	Area	k_{mod}	γ_m	$k_{c,90}$	$f_{c,k}$	$f_{c,d}$	V_{max}	V_{min}	$\sigma_{c,90,d}$		Ratio
		[mm]	[cm²]	[-]	[-]	[-]	[N/mm²	[N/mm²	[kN]	[kN]	[N/mm²]		
A	Rigid plate	140	1700.00	0.80	1.25	1.50	2.50	2.40	19.04	0.00	0.11	LCO2	5%
B	Rigid plate	140	2000.00	0.80	1.25	1.80	2.50	2.88	58.29	0.00	0.29	LCO2	10%
C	Rigid plate	140	1700.00	0.80	1.25	1.50	2.50	2.40	19.04	0.00	0.11	LCO2	5%

Support reaction

Load case category	k_{mod}	A_V	B_V	C_V
			[kN]	
self-weight structure	0.6	3.00	9.85	3.00
		3.00	9.85	3.00
dead load	0.6	4.08	13.43	4.08
		4.08	13.43	4.08
live load cat. A: domestic, residential areas	0.8	6.32	17.91	6.32
		-0.88	0.00	-0.88

Reference documents for this analysis

English title	Description
EN 338	EN 338 - Structural timber ? Strength classes

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Reference documents for this analysis	
English title	Description
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

3.6.2. Dimenzioniranje međukatne konstrukcije – konzola

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Međukatna ploča - konzola

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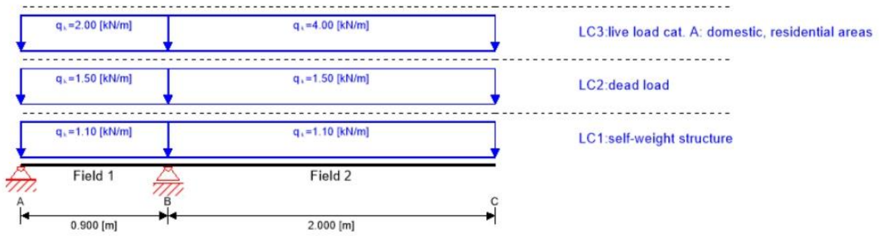
System

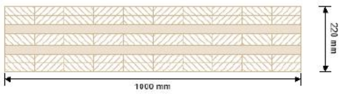


Global utilization ratio 38%

ULS	19%	ULS Fire	10%	SLS	38%	Vibration	21%	Support	7%

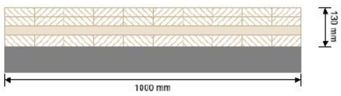
Product data

Section: CLT 220 L7s - 2



Layer	Thickness	Orientation	Material
1	30.0 mm	0°	C24 spruce ETA (2022)
2	30.0 mm	0°	C24 spruce ETA (2022)
3	30.0 mm	90°	C24 spruce ETA (2022)
4	40.0 mm	0°	C24 spruce ETA (2022)
5	30.0 mm	90°	C24 spruce ETA (2022)
6	30.0 mm	0°	C24 spruce ETA (2022)
7	30.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**220.0 mm**		

Section Fire: CLT 220 L7s - 2



Layer	Thickness	Orientation	Material
1	30.0 mm	0°	C24 spruce ETA (2022)
2	30.0 mm	0°	C24 spruce ETA (2022)
3	30.0 mm	90°	C24 spruce ETA (2022)
4	40.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**130.0 mm**		

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Section Fire: CLT 220 L7s - 2

Fire resistance class: R 90

Time **90 min**

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	82.0	89.0	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	1.10
2	1.10

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	2.00
2	4.00

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

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Međukatna ploča - konzola

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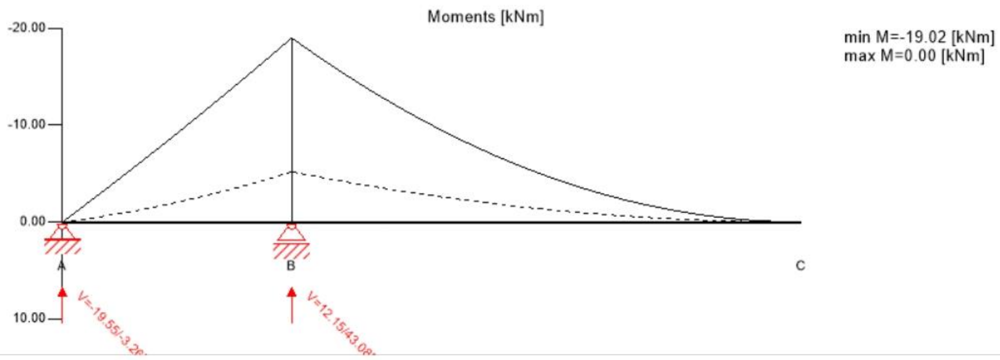
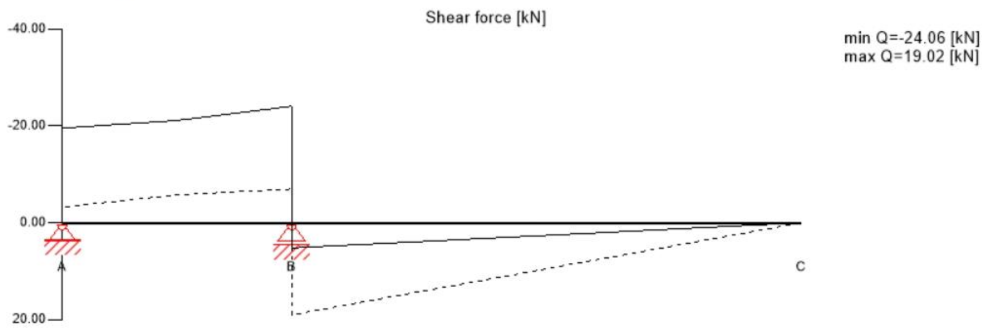
SLS Quasi-permanent Combination

	Combination rule
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	0.9	24.00	1.25	0.80	1.10	16.90	-19.02	2.59	15%	LCO2
2	0.0	24.00	1.25	0.80	1.10	16.90	-19.02	2.59	15%	LCO2

Diplomski rad
Međukatna ploča - konzola

Monika Spajić

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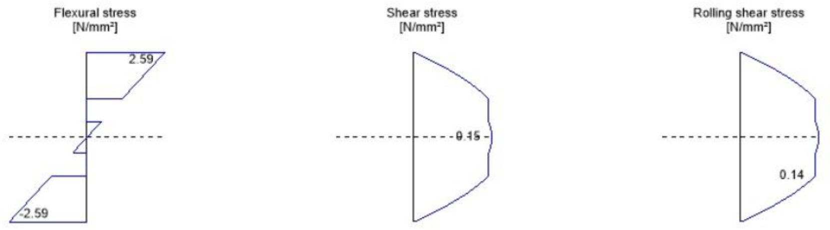
ULS Shear analysis

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	0.9	4.00	1.25	0.80	2.56	-24.06	0.15	6%	LCO2
2	0.0	4.00	1.25	0.80	2.56	19.02	0.12	5%	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	0.9	1.15	1.25	0.80	0.74	-24.06	0.14	19%	LCO2
2	0.0	1.15	1.25	0.80	0.74	19.02	0.11	15%	LCO2

Stress diagram



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Flexural stress analysis								
$M_{y,d}$ =	-19.02	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	
$\sigma_{m,y,d}$ =	2.59	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							**15%**

Shear stress analysis							
V_d =	-24.06	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 =	-24.06	kN		$f_{r,k}$ =	1.15	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.80	-	
$\tau_{r,d}$ =	0.14	N/mm²	<	$f_{r,d}$ =	0.74	N/mm²	✓
Utilization ratio							**19%**

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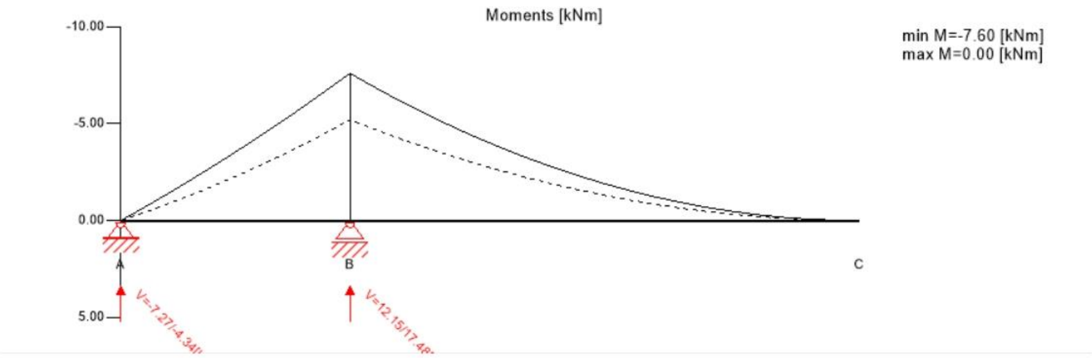
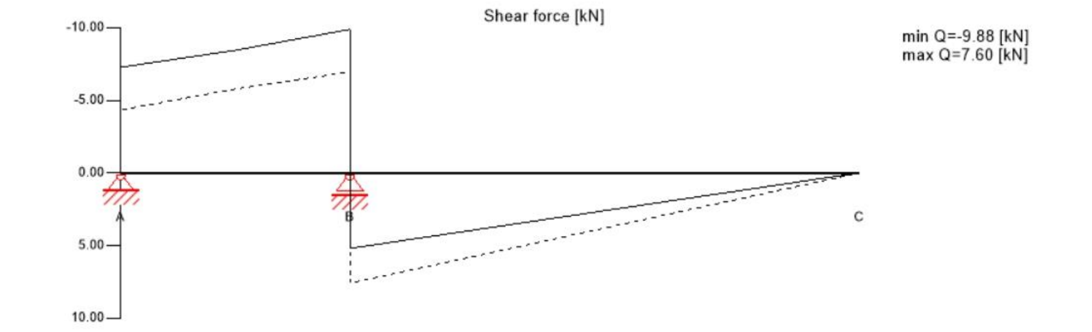
Ultimate limit state (ULS) fire design - results





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	0.9	24.00	1.00	1.00	1.10	1.15	30.36	-7.60	-2.92	10%	LCO4
2	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-7.60	-2.92	10%	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	0.9	4.00	1.00	1.00	1.15	4.60	-9.88	0.11	2%	LCO4
2	0.0	4.00	1.00	1.00	1.15	4.60	7.60	0.08	2%	LCO4

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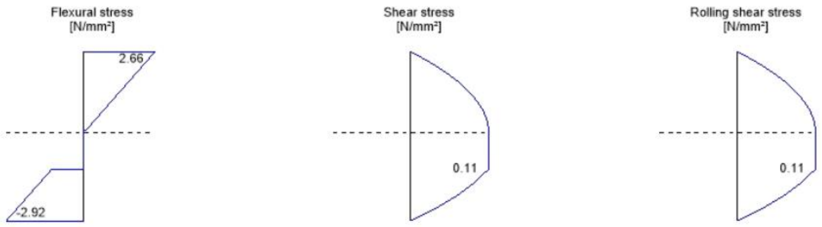
ULS Fire Rolling shear

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	0.9	1.15	1.00	1.00	1.15	1.32	-9.88	0.11	8%	LCO4
2	0.0	1.15	1.00	1.00	1.15	1.32	7.60	0.08	6%	LCO4

Stress diagram



Flexural stress analysis Fire

$M_{y,d}$ =	-7.60	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	
$\sigma_{m,y,d}$ =	-2.92	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							10%

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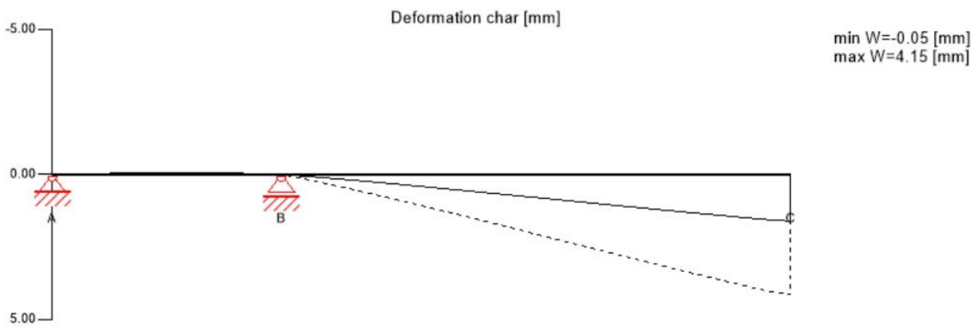
Shear stress analysis Fire

V_d =	-9.88	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	-	
$\tau_{v,d}$ =	0.11	N/mm²	<	$f_{v,d}$ =	4.60	N/mm²	✓
Utilization ratio							2%

Rolling shear analysis Fire

V_d =	-9.88	kN		$f_{r,k}$ =	1.15	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				k_{fi} =	1.15	-	
$\tau_{r,d}$ =	0.11	N/mm²	<	$f_{r,d}$ =	1.32	N/mm²	✓
Utilization ratio							8%

Service limit state design (SLS) - design results



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Međukatna ploča - konzola
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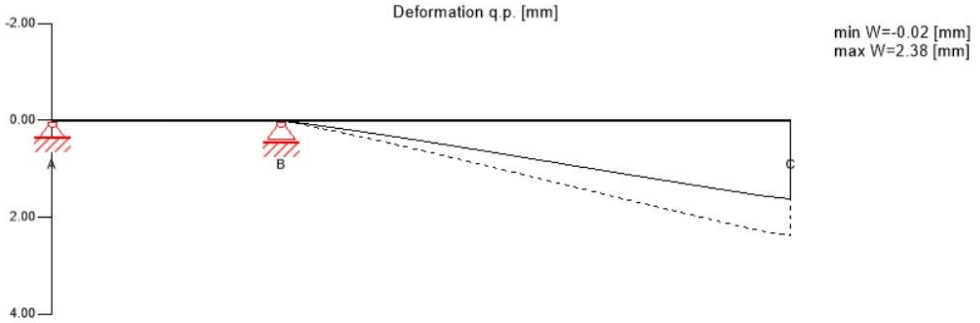
Service limit state design (SLS) - design results



w_{inst} = w[char]					
Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	3.0	0.0	0%
2	0.8	L/300	13.3	4.1	31%

w_{fin} = w[char] + w[q.p.]*kdef					
Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/250	3.6	0.0	0%
2	0.8	L/250	16.0	6.1	38%

$w_{net,fin}$ = w[q.p.] + w[q.p.]*kdef					
Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	3.0	0.0	0%
2	0.8	L/300	13.3	4.3	32%

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Vibration analysis

General

Total mass	2.23	[t]
Tributary width	1.0	[m]
Stiffness Longitudinal direction	9712.0	[kNm²]
Stiffness Cross direction	936.0	[kNm²]
Modal damping	4.0	[%]
α	0.0	[-]
Man weight	700.0	[N]
Modal mass	148.5	[kg]

Analysis

Criterion	Calc.	Class I	Class II	Class I	Class II	Cl. I	Cl. II
Frequency criterion min	21.118 [Hz]	4.5 [Hz]	4.5 [Hz]	21 %	21 %	✓	✓
Frequency criterion	21.118 [Hz]	8.0 [Hz]	6.0 [Hz]	38 %	28 %		
Acceleration criterion	0.005 [m/s²]	0.05 [m/s²]	0.1 [m/s²]	10 %	5 %		
Stiffness criterion	0.017 [mm]	0.25 [mm]	0.5 [mm]	7 %	3 %	✓	✓

Support design

Nr.	Type	Width	Area	k_{mod}	γ_m	$k_{c,90}$	$f_{c,k}$	$f_{c,d}$	V_{max}	V_{min}	$\sigma_{c,90,d}$		Ratio
		[mm]	[cm²]	[-]	[-]	[-]	[N/mm²	[N/mm²	[kN]	[kN]	[N/mm²]		
A	Rigid plate	140	1700.00	0.60	1.25	1.50	2.50	1.80	0.00	-6.22	0.00	LCO1	0%
B	Rigid plate	140	2000.00	0.80	1.25	1.80	2.50	2.88	43.08	0.00	0.22	LCO2	7%

Support reaction

Load case category	k_{mod}	A_V	B_V
		[kN]	
self-weight structure	0.6	-1.95	5.14
		-1.95	5.14
dead load	0.6	-2.66	7.01
		-2.66	7.01
live load cat. A: domestic, residential areas	0.8	0.90	17.79
		-8.89	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

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Reference documents for this analysis	
English title	Description
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

3.6.3. Dimenzioniranje krovne ploče

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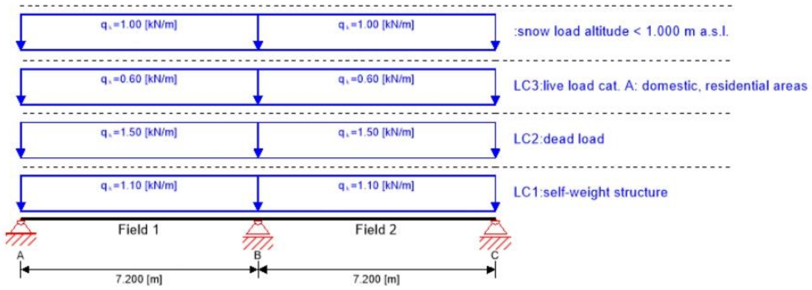
System

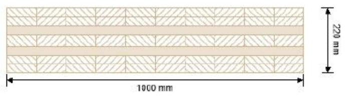


Global utilization ratio	99%

ULS	25%	ULS Fire	23%	SLS	43%	Vibration	99%	Support	8%

Product data

Section: CLT 220 L7s - 2



Layer	Thickness	Orientation	Material
1	30.0 mm	0°	C24 spruce ETA (2022)
2	30.0 mm	0°	C24 spruce ETA (2022)
3	30.0 mm	90°	C24 spruce ETA (2022)
4	40.0 mm	0°	C24 spruce ETA (2022)
5	30.0 mm	90°	C24 spruce ETA (2022)
6	30.0 mm	0°	C24 spruce ETA (2022)
7	30.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**220.0 mm**		

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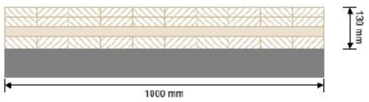
Section Fire: CLT 220 L7s - 2



Layer	Thickness	Orientation	Material
1	30.0 mm	0°	C24 spruce ETA (2022)
2	30.0 mm	0°	C24 spruce ETA (2022)
3	30.0 mm	90°	C24 spruce ETA (2022)
4	40.0 mm	0°	C24 spruce ETA (2022)
t_{CLT}	**130.0 mm**		
Time	**90 min**		

Fire resistance class: R 90

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	82.0	89.0	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

LC1:self-weight structure

continuous load

Field	Load at start
	[kN/m]
1	1.10

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continuous load	
Field	Load at start [kN/m]
2	1.10

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	0.60
2	0.60

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

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

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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 *
LCO5	1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * + 1.50/0.00 * 0.70 * LC3

ULS Combinations Fire	
	Combination rule
LCO6	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO7	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3
LCO8	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 1.00/0.00 * 0.00 *
LCO9	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 *
LCO10	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.00 * + 1.00/0.00 * 0.30 * LC3

SLS Characteristic Combination	
	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 * LC3 + 1.00/0.00 * 0.50 *
LCO13	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * + 1.00/0.00 * 0.70 * LC3

SLS Quasi-permanent Combination	
	Combination rule
LCO14	1.00/1.00 * LC1 + 1.00/1.00 * LC2
LCO15	1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3 + 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

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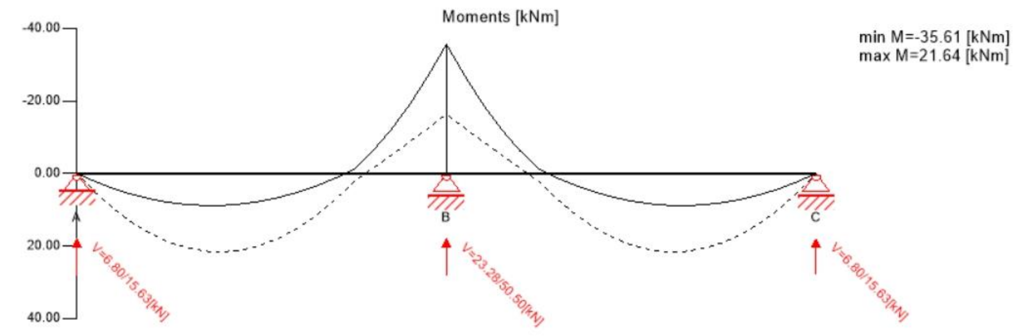
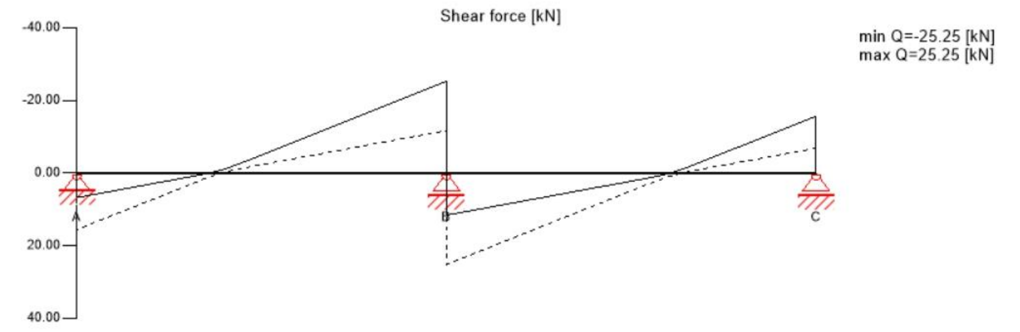
Ultimate limit state (ULS) - design results





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	7.2	24.00	1.25	0.90	1.10	19.01	-35.61	4.84	25%	LCO5
2	0.0	24.00	1.25	0.90	1.10	19.01	-35.61	4.84	25%	LCO5

ULS Shear analysis

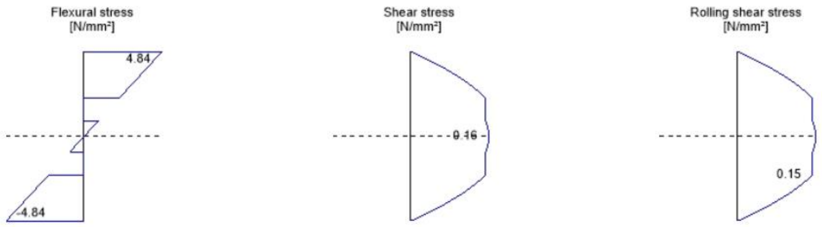
Field	Dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	Ratio	
	[m]	[N/mm²]	[-]	[-]	[N/mm²]	[kN]	[N/mm²]		
1	7.2	4.00	1.25	0.90	2.88	-25.25	0.16	5%	LCO5
2	0.0	4.00	1.25	0.90	2.88	25.25	0.16	5%	LCO5

Diplomski_ploča		**2**	6/13
Kont_2_polja_krovna		Austria	10/09/2024
Monika Spajić	Domusplus	Checker	

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	7.2	1.15	1.25	0.90	0.83	-25.25	0.15	18%	LCO5
2	0.0	1.15	1.25	0.90	0.83	25.25	0.15	18%	LCO5

Stress diagram



Flexural stress analysis

$M_{y,d}$ =	-35.61	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} =	0.90	-	
				$k_{sys,y}$ =	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		$f_{t,0,d}$ =	10.08	N/mm²	
$\sigma_{m,y,d}$ =	4.84	N/mm²		$f_{m,y,d}$ =	19.01	N/mm²	
$\sigma_{m,z,d}$ =	0.00	N/mm²	<	$f_{m,z,d}$ =	0.00	N/mm²	✓
Utilization ratio							25%

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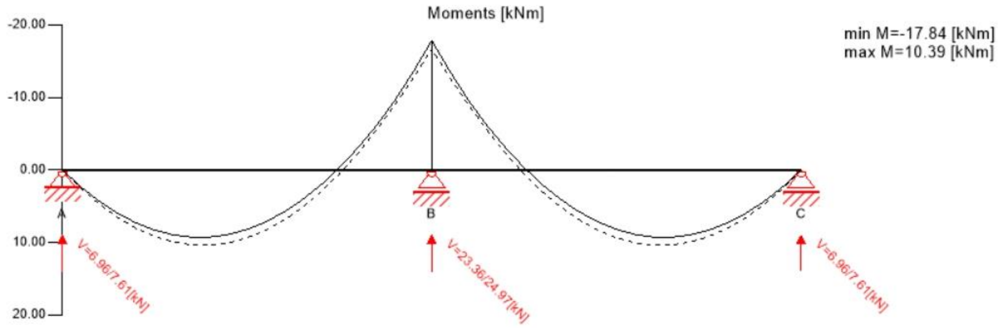
Shear stress analysis							
V_d =	-25.25	kN		$f_{v,k}$ =	4.00	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.90	-	
				$k_{h,v}$ =	0.00	-	
$\tau_{v,d}$ =	0.16	N/mm²	<	$f_{v,d}$ =	2.88	N/mm²	✓
Utilization ratio							**5%**

Rolling shear analysis							
V_d =	-25.25	kN		$f_{r,k}$ =	1.15	N/mm²	
				γ_m =	1.25	-	
				k_{mod} =	0.90	-	
$\tau_{r,d}$ =	0.15	N/mm²	<	$f_{r,d}$ =	0.83	N/mm²	✓
Utilization ratio							**18%**

Ultimate limit state (ULS) fire design - results



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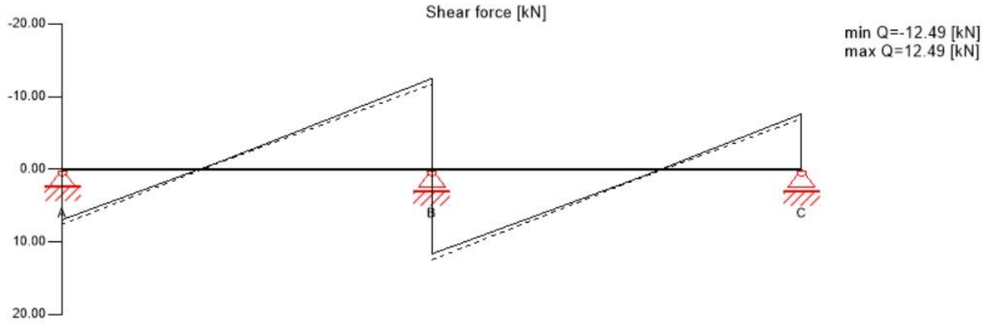
Ultimate limit state (ULS) fire design - results



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	7.2	24.00	1.00	1.00	1.10	1.15	30.36	-17.84	-6.86	23%	LCO7
2	0.0	24.00	1.00	1.00	1.10	1.15	30.36	-17.84	-6.86	23%	LCO7

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	7.2	4.00	1.00	1.00	1.15	4.60	-12.49	0.14	3%	LCO7
2	0.0	4.00	1.00	1.00	1.15	4.60	12.49	0.14	3%	LCO7

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	7.2	1.15	1.00	1.00	1.15	1.32	-12.49	0.14	10%	LCO7
2	0.0	1.15	1.00	1.00	1.15	1.32	12.49	0.14	10%	LCO7

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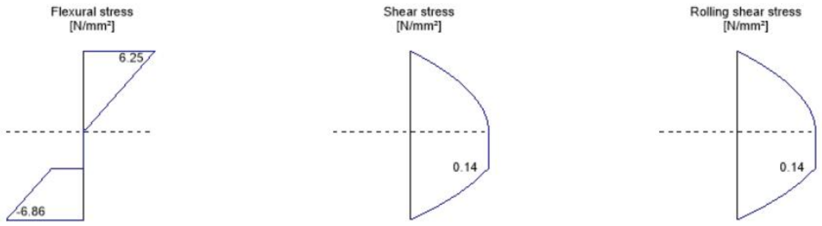
Stress diagram



Flexural stress analysis Fire

$M_{y,d}$ =	-17.84	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	
$\sigma_{m,y,d}$ =	-6.86	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							23%

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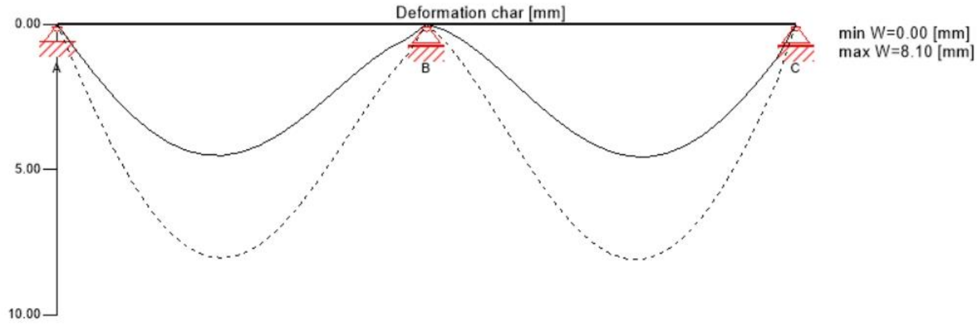
Shear stress analysis Fire

V_d =	-12.49	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 =	-12.49	kN		$f_{r,k}$ =	1.15	N/mm²	
				γ_m =	1.00	-	
				k_{mod} =	1.00	-	
				k_{fi} =	1.15	-	
$\tau_{r,d}$ =	0.14	N/mm²	<	$f_{r,d}$ =	1.32	N/mm²	✓
Utilization ratio							**10%**

Service limit state design (SLS) - design results



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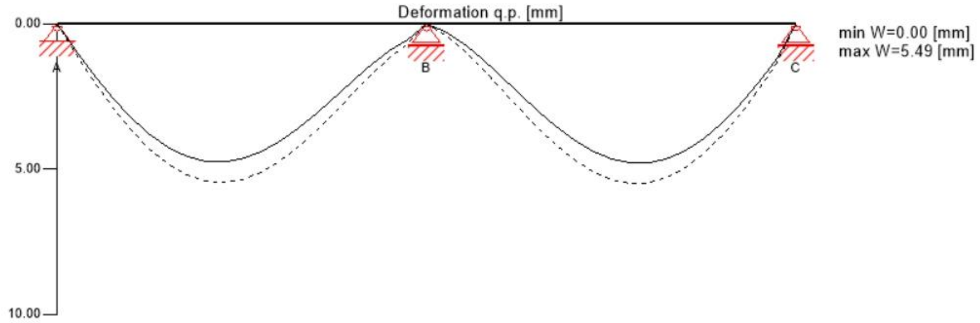
Service limit state design (SLS) - design results



w_{inst} = w[char]

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	24.0	8.1	34%
2	0.8	L/300	24.0	8.1	34%

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

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/250	28.8	12.4	43%
2	0.8	L/250	28.8	12.5	43%

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

Field	K_{def}	Limit	w_{limit}	$w_{calc.}$	Ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	24.0	9.8	41%
2	0.8	L/300	24.0	9.9	41%

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Vibration analysis

General

Total mass	38.17	[t]
Tributary width	3.6	[m]
Stiffness Longitudinal direction	9712.0	[kNm²]
Stiffness Cross direction	936.0	[kNm²]
Modal damping	4.0	[%]
α	0.1	[-]
Man weight	700.0	[N]
Modal mass	6947.8	[kg]

Analysis

Criterion	Calc.	Class I	Class II	Class I	Class II	Cl. I	Cl. II
Frequency criterion min	5.802 [Hz]	4.5 [Hz]	4.5 [Hz]	78 %	78 %	✓	✓
Frequency criterion	5.802 [Hz]	8.0 [Hz]	6.0 [Hz]	138 %	103 %		
Acceleration criterion	0.049 [m/s²]	0.05 [m/s²]	0.1 [m/s²]	99 %	49 %	✓	✓
Stiffness criterion	0.22 [mm]	0.25 [mm]	0.5 [mm]	88 %	44 %	✓	✓

Support design

Nr.	Type	Width	Area	k_{mod}	γ_m	$k_{c,90}$	$f_{c,k}$	$f_{c,d}$	V_{max}	V_{min}	$\sigma_{c,90,d}$		Ratio
		[mm]	[cm²]	[-]	[-]	[-]	[N/mm²	[N/mm²	[kN]	[kN]	[N/mm²]		
A	Rigid plate	140	1700.00	0.90	1.25	1.50	2.50	2.70	15.63	0.00	0.09	LCO5	3%
B	Rigid plate	140	2000.00	0.90	1.25	1.80	2.50	3.24	50.50	0.00	0.25	LCO5	8%
C	Rigid plate	140	1700.00	0.90	1.25	1.50	2.50	2.70	15.63	0.00	0.09	LCO5	3%

Support reaction

Load case category	k_{mod}	A_V	B_V	C_V
			[kN]	
self-weight structure	0.6	3.00	9.85	3.00
		3.00	9.85	3.00
dead load	0.6	4.08	13.43	4.08
		4.08	13.43	4.08
live load cat. A: domestic, residential areas	0.8	1.90	5.37	1.90
		-0.26	0.00	-0.26
snow load altitude < 1.000 m a.s.l.	0.9	2.72	8.95	2.72
		0.00	0.00	0.00

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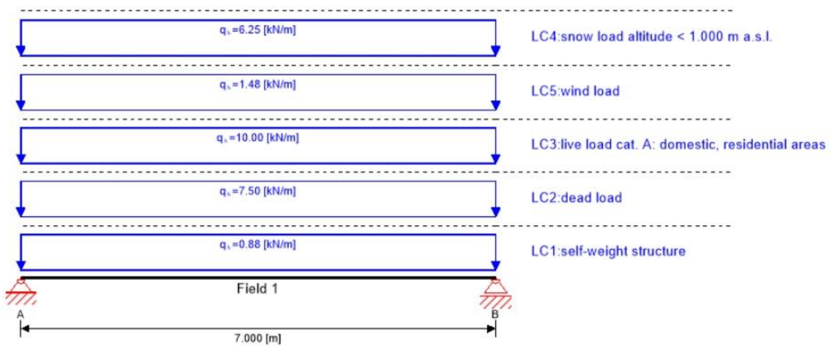
Reference documents for this analysis	
English title	Description
EN 338	EN 338 - Structural timber ? Strength classes
EN 1995-1-1	EN 1995-1-1 - Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
ETA-14/0349	European Technical Assessment ETA-14/0349
Expertise 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

3.7. Dimenzioniranje čelične grede (HEA 300) – Stora Enso

System



Global utilization ratio			79 %
ULS	50 %	SLS	79 %

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 300	290	300	14	8.5	112.5	18260	6310	1260	420.6	1200000	85.17	1.274	0.749	1383	641.2

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

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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	0.88

LC2:dead load

continuous load	
Field	Load at start [kN/m]
1	7.50

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

continuous load	
Field	Load at start [kN/m]
1	10.00

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

continuous load	
Field	Load at start [kN/m]
1	6.25

LC5:wind load

continuous load	
Field	Load at start [kN/m]
1	1.48

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

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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.	LCO7			
M_{Ed} =	199.21	kNm		M_{Rd} =	447.30	kNm		
Ratio	45	%	<		100	%	✓	
Utilization ratio							**45%**	

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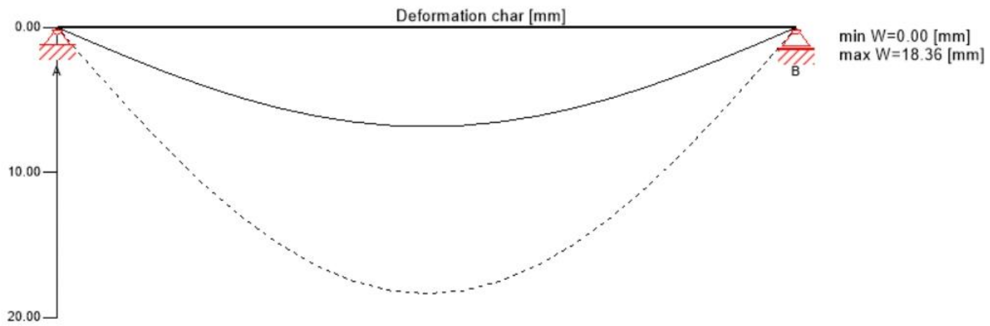
Shear analysis							
Qkl =	3			Comb.	LCO7		
V_{Ed} =	113.83	kN		V_{Rd} =	763.47	kN	
Ratio	15	%	<		100	%	✓
Utilization ratio							15%

Flexural design + Shear analysis							
Qkl =	3			Comb.	LCO7		
V_{Ed} =	11.38	kN		V_{Rd} =	763.47	kN	
M_{Ed} =	197.22	kNm		M_{Rd} =	447.30	kNm	
Ratio	44	%	<		100	%	✓
Utilization ratio							44%

Lateral torsional buckling design							
Qkl =	3			Comb.	LCO7		
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} =	199.21	kNm		M y_{Rd} =	401.37	kNm	
Ratio	50	%	<		100	%	✓
Utilization ratio							50%

Service limit state design (SLS) - design results



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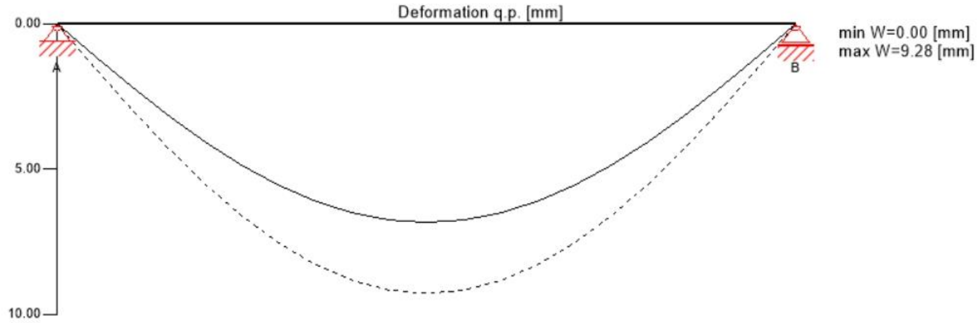
Service limit state design (SLS) - design results



w_{inst} = w[char]

Field	Limit	w_{limit}	$w_{calc.}$	Ratio
	[-]	[mm]	[mm]	
1	L/300	23.3	18.4	79%

Support reaction

Load case category	k_{mod}	A_V	B_V
		[kN]	
self-weight structure	1	3.09	3.09
		3.09	3.09
dead load	1	26.25	26.25
		26.25	26.25
live load cat. A: domestic, residential areas	1	35.00	35.00
		0.00	0.00
snow load altitude < 1.000 m a.s.l.	1	21.88	21.88
		0.00	0.00
wind load	1	5.18	5.18
		0.00	0.00

Diplomski rad
Čelična greda

Monika Spajić

7/7
08/09/2024

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

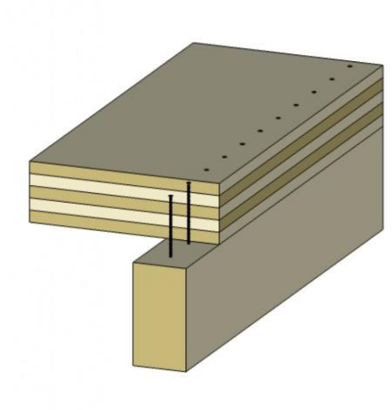
3.8. Proračun karakterističnih spojeva – Stora Enso

3.8.1.1. Detalj A – spoj grede (GL32h) s međukatnom pločom (CLT)

storaenso

Diplomski rad 1/4
Spoj grede s međukatnom konstrukcijom 10/09/2024
Monika Spajić

Connection



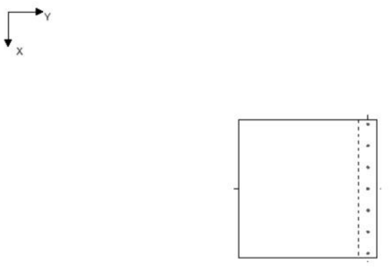
F_x	7.772	kN/lm
F_y	12.674	kN/lm
K_{mod}	0.8	-
Material 1	C24 spruce ETA (2022)	
ρ_k	3.85	kN/m³
Panel 1	CLT 220 L7s - 2	
Orientation cover layer	X direction	
Material 2	C24 spruce	
ρ_k	3.5	kN/m³
Connector type	Rothoblaas TBS	
Connectors	8/300	
Setup	Vertical	
Diameter	8	mm
Head diameter	19	mm
Length	300	mm
Thread length	100	mm
Pre-drilled	×	
Timber beam width	140	mm
Timber beam height	480	mm

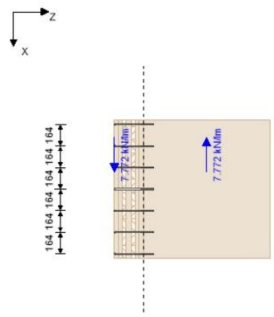
Analysis

Analysis	Existing	Limit	Unit	Utilization
Width 1	140	72	mm	51%
Width 2	140	72	mm	51%
Thickness 1	220	42	mm	19%
Thickness 2	80	45	mm	56%
Fv	2434.387	2434.387	N	100%
Count	6.107	25	Count / lm	24%

Diplomski rad 2/4
Spoj grede s međukatnom konstrukcijom 10/09/2024
Monika Spajić

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 top	32	20	48	48	20	48
Timber beam bottom	40	32	32	80	24	24

Result in layers

Element 1

X [mm]	Thick [mm]	Typ	α [°]	l_{eff} [mm]	$l_{eff,v}$ [mm]	$F_{ax,Rk}$ [N]
0	30	L	90	0	0	0
30	30	L	90	0	0	0
60	30	C	90	0	0	0
90	40	L	90	0	0	0
130	30	C	90	0	0	0
160	30	L	90	0	0	0
190	10	L	90	0	0	0
200	15	L	90	15	15	1515
215	5	L	90	0	0	0

Diplomski rad 3/4
Spoj grede s međukatnom konstrukcijom 10/09/2024
Monika Spajić

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]
72	72	21.21	19.68	1.08	220.00	80.00	15.00	65.00	42	45	1515.24	6084.00

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	4048.27	4048.27	20.100	0.000	3955.88	2434.39	14.87	2491.24	0.00	6.11	25.00	164

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

Diplomski rad 4/4
Spoj grede s međukatnom konstrukcijom 10/09/2024
Monika Spajić

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

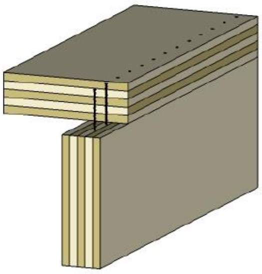
Mjerodavni odabrani razmak je 150 mm.

3.8.1.2. **Detalj B – spoj međukatne konstrukcije (CLT) sa zidnim panelima (CLT)**

storaenso

Diplomski rad 1/4
Spoj CLT panela na CLT zidne panele 10/09/2024
Monika Spajić

Connection



F_x	5.848	kN/lm
F_y	6.656	kN/lm
K_{mod}	0.8	-
Material 1	C24 spruce ETA (2022)	
ρ_k	3.85	kN/m³
Panel 1	CLT 220 L7s - 2	
Orientation cover layer	X direction	
Material 2	C24 spruce ETA (2022)	
ρ_k	3.85	kN/m³
Panel 2	CLT 140 L5s	
Orientation cover layer	✓	
Connector type	Rothoblaas HBS	
Connectors	10/360	
Setup	Vertical	
Diameter	10	mm
Head diameter	18.25	mm
Length	360	mm
Thread length	100	mm
Connector positions	×	
Pre-drilled	×	

Analysis

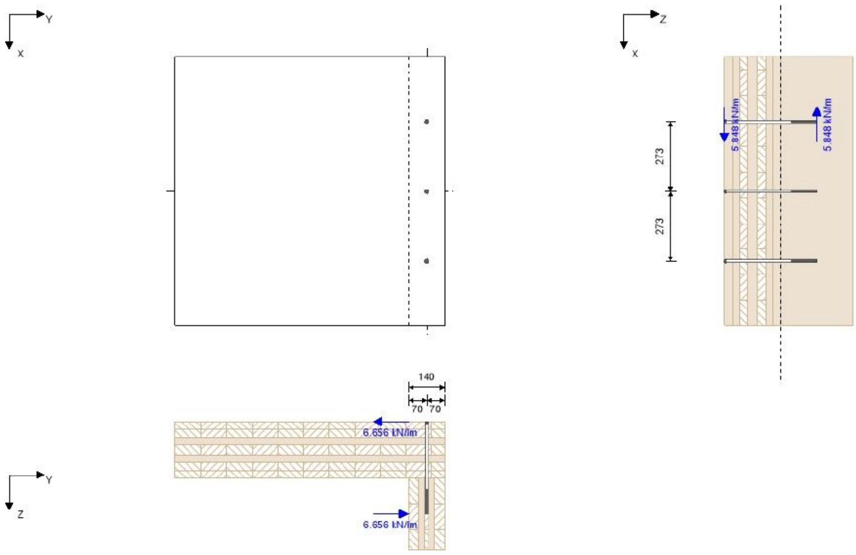
Analysis	Existing	Limit	Unit	Utilization
Width 1	140	120	mm	86%
Width 2	140	120	mm	86%
Thickness 1	220	47	mm	22%
Thickness 2	140	102	mm	73%
Fv	2419.803	2419.803	N	100%
Count	3.661	10	Count / lm	37%
Splitting stress analysis unreinforced	0.136	1.947	N/mm²	7%

Diplomski rad 2/4

Spoj CLT panela na CLT zidne panele 10/09/2024

Monika Spajić

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 top	40	25	60	60	25	60
CLT bottom	100	40	70	120	30	60

Result in layers

Element 1

X	Thick	Typ	α	l_{eff}	$l_{eff,v}$	$F_{ax,Rk}$
[mm]	[mm]		[°]	[mm]	[mm]	[N]
0	30	L	90	0	0	0
30	30	L	90	0	0	0
60	30	C	90	0	0	0
90	40	L	90	0	0	0
130	30	C	90	0	0	0
160	30	L	90	0	0	0
190	30	L	90	0	0	0

Diplomski rad 3/4
Spoj CLT panela na CLT zidne panele 10/09/2024
Monika Spajić

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]
120	120	18.97	6.32	3.00	220.00	140.00	0.00	100.00	47	102	0.00	12627.00

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]
35829.64	3734.97	3734.97	31.400	0.000	3932.18	2419.80	8.86	2298.45	0.00	3.66	10.00	273

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

Diplomski rad		4/4
Spoj CLT panela na CLT zidne panele		10/09/2024
Monika Spajić		

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

Mjerodavni odabrani razmak je 200 mm.

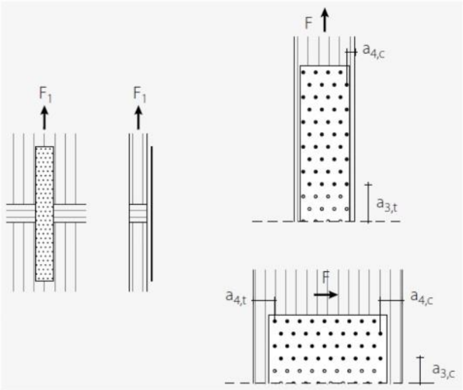
3.8.1.3. **Detalj C – spoj zidnih panela (CLT) vertikalno**

storaenso

Diplomski rad 1/2
Spoj zidnih CLT panela vertikalno 10/09/2024

Monika Spajić

Connection



F_1	43.31	kN
K_{mod}	0.8	-
Connectors	LBV160400 / Nail 4,0x60	
Space		mm

Design F_1

$F_{k,1}$ =	43.3	kN		$R_{k,1,Holz}$ =		kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,1}$ =	43.3	kN	<	$R_{d,1}$ =	57.0	kN	✓
Utilization ratio							76%

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

Diplomski rad 2/2
Spoj zidnih CLT panela vertikalno 10/09/2024

Monika Spajić

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

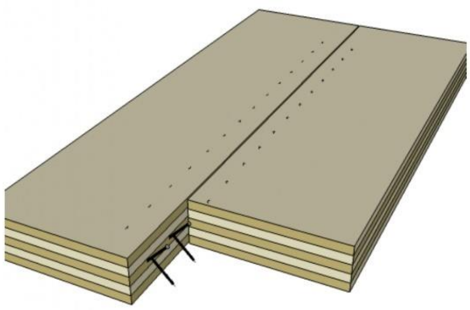
Disclaimer

3.8.1.4. **Detalj D – spoj panela međukatne konstrukcije (CLT) međusobno u ravnini**

Diplomski rad 1/4
Spoj CLT panela međusobno u ravnini 10/09/2024

Monika Spajić

Connection



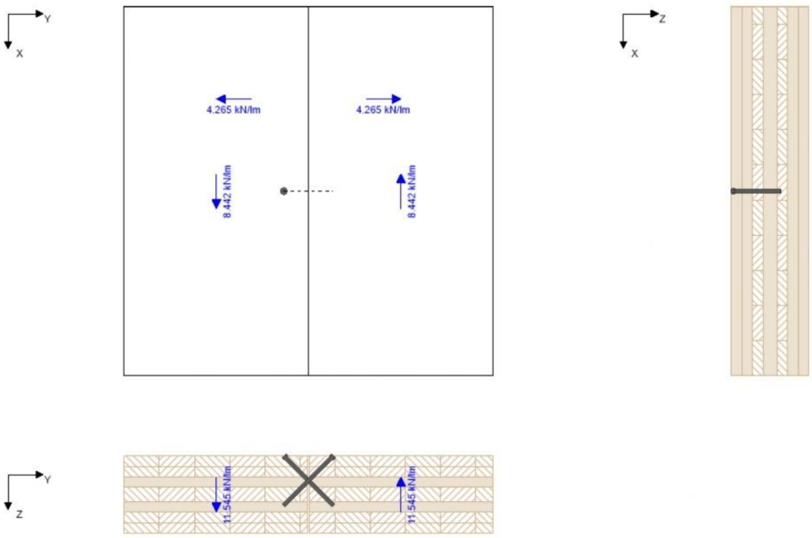
F_x	8.442	kN/lm
F_y	4.265	kN/lm
F_z	11.545	kN/lm
K_{mod}	0.8	-
Material 1	C24 spruce ETA (2022)	
ρ_k	3.85	kN/m³
Panel 1	CLT 220 L7s - 2	
Orientation cover layer	X direction	
Connector type	Rothoblaas VGS	
Connectors	11/200	
Setup	45° / 135° alternating	
Diameter	11	mm
Head diameter	19.3	mm
Length	200	mm
Thread length	190	mm
Pre-drilled	×	

Analysis

Analysis	Existing	Limit	Unit	Utilization
Thickness 1	100	60	mm	60%
Thickness 2	100	60	mm	60%
Fv	2324.887	4786.041	N	49%
Fax	6157.485	7044.453	N	87%
Combination	1	1	-	100%
Count	3.631	4.228	Count / lm	86%

Diplomski rad 2/4
Spoj CLT panela međusobno u ravnini 10/09/2024
Monika Spajić

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 left	55	28	66	66	44	66
CLT right	55	28	66	66	44	66

Result in layers

Element 1

X	Thick	Typ	α	l_{eff}	$l_{eff,v}$	$F_{ax,Rk}$
[mm]	[mm]		[°]	[mm]	[mm]	[N]
0	7	L	90	0	0	0
7	23	L	90	32.4	22.9	4504
30	30	L	90	42.4	30	5893
60	7	C	45	10.1	7.2	1281
67	23	C	45	0	0	0
90	40	L	90	0	0	0
130	30	C	45	0	0	0
160	30	L	90	0	0	0
190	30	L	90	0	0	0

Element 2

X	Thick	Typ	α	l_{eff}	$l_{eff,v}$	$F_{ax,Rk}$
[mm]	[mm]		[°]	[mm]	[mm]	[N]
0	30	L	90	0	0	0
30	30	L	90	0	0	0
60	14	C	45	0	0	0
74	16	C	45	22.3	15.8	2813
90	40	L	90	56.6	40	7857
130	4	C	45	6.2	4.4	777
134	26	C	45	0	0	0
160	30	L	90	0	0	0
190	30	L	90	0	0	0

Diplomski rad 3/4
Spoj CLT panela međusobno u ravnini 10/09/2024

Monika Spajić

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	18.09	18.09	1.00	100.00	100.00	85.00	85.00	60	60	11678.1	11447.23

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]
45905.37	11447.23	0.00	38.000	20.612	7777.32	4786.04	8.44	7044.45	22.36	3.63	4.23	275

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

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

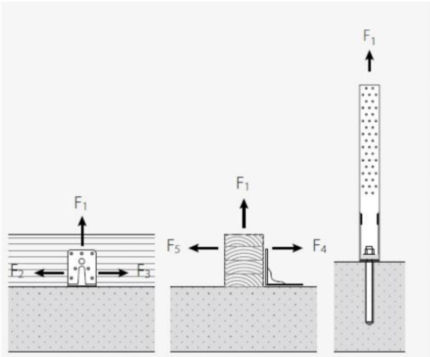
Mjerodavni maksimalni razmak spojnih sredstava je 200 mm.

3.8.1.5. Detalj E – spoj zidnih panela (CLT) s AB zidom

storaenso

Diplomski rad 1/3
Spoj CLT panela s betonskim zidom 10/09/2024
Monika Spajić

Connection



F_1	6.211	kN
F_{23}	6.991	kN
F_{45}	4.206	kN
K_{mod}	0.8	-
Connectors	AG922 / Nail CNA 4,0x50	
e_{45}		mm

Design F_1

$F_{k,1}$ =	6.2	kN		$R_{k,1,Holz}$ =	15.3	kN	
				$R_{k,1,Stahl}$ =		kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,1}$ =	6.2	kN	<	$R_{d,1}$ =	9.4	kN	✓
Utilization ratio							**66%**

Design F_{23}

$F_{k,23}$ =	7.0	kN		$R_{k,23,Holz}$ =	24.1	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,23}$ =	7.0	kN	<	$R_{d,23}$ =	14.8	kN	✓
Utilization ratio							**47%**

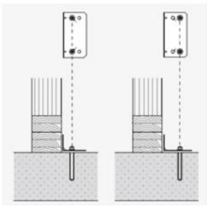
Diplomski rad 2/3
Spoj CLT panela s betonskim zidom 10/09/2024

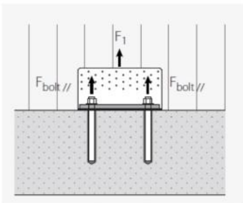
Monika Spajić

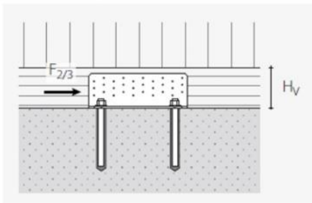
Design F_{45}							
$F_{k,45}$ =	4.2	kN		$R_{k,45,Holz}$ =	24.8	kN	
				γ_m =	1.3	-	
				k_{mod} =	0.80	-	
$F_{d,45}$ =	4.2	kN	<	$R_{d,45}$ =	15.3	kN	✓
Utilization ratio							28%

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

Diplomski rad	3/3
Spoj CLT panela s betonskim zidom	10/09/2024
Monika Spajić	

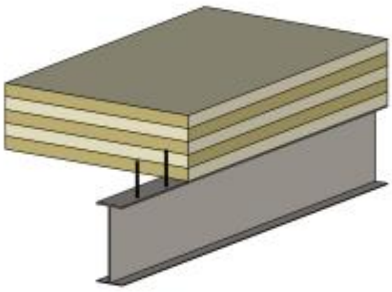
Reference documents for this analysis

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

3.8.1.6. **Detalj F – spoj međukatne konstrukcije (CLT) na čeličnu gredu**

Diplomski rad 1/4
Spoj CLT panela na čeličnu gredu 10/09/2024
Monika Spajić

Connection



F_x	39.61	kN/lm
F_z	7.59	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 220 L7s - 2	
Orientation cover layer	✓	
Connector type	Rothoblaas HBS	
Connectors	10/140	
Diameter	10	mm
Head diameter	18.25	mm
Length	140	mm
Thread length	60	mm
Number of rows	2	
Steel element width	300	mm
Steel element thickness	14	mm

Analysis

Analysis	Existing	Limit	Unit	Utilization
Width 2	300	100	mm	33%
Thickness 2	126	32	mm	25%
Fv	4543.161	4661.69	N	97%
Fax	870.553	3885.229	N	22%
Combination	1	1	-	100%
Count	8.719	50	Count / lm	17%

Diplomski rad 2/4
Spoj CLT panela na čeličnu gredu 10/09/2024
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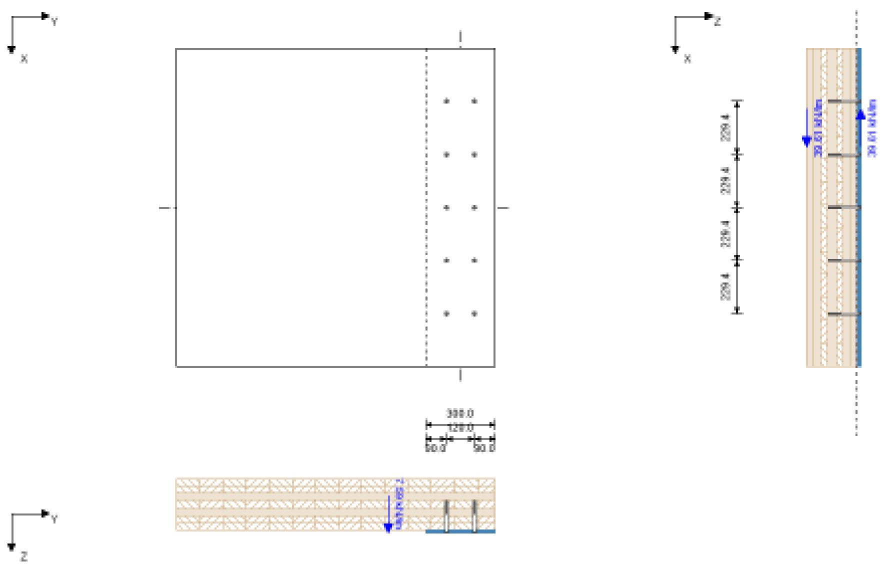
Structural system



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	40	25	60	60	25	60

Result in layers

Element 2

X [mm]	Thick [mm]	Typ	α [°]	l_{ef} [mm]	$l_{ef,v}$ [mm]	$F_{ax,Rk}$ [N]
0	5	L	90	0	0	0
5	25	L	90	25	25	3157
30	25	L	90	25	25	3157
55	5	L	90	0	0	0
60	30	C	90	0	0	0
90	40	L	90	0	0	0
130	30	C	90	0	0	0
160	30	L	90	0	0	0
190	30	L	90	0	0	0

Diplomski rad 3/4
Spoj CLT panela na čeličnu gredu 10/09/2024
Monika Spajić

Results

$b_{1,min}$	$b_{2,min}$	$f_{h,k,1}$	$f_{h,k,2}$	β	$t_{pen,1}$	$t_{pen,2}$	$l_{ef,1}$	$l_{ef,2}$	$t_{1,req}$	$t_{2,req}$	$F_{ax,Rk1}$	$F_{ax,Rk2}$
[mm]	[mm]	[N/mm²]	[N/mm²]	[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[N]	[N]
0	100	0.00	18.97	0.00	14.00	126.00	0.00	50.00	0	32	0.00	6313.50

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]
35829.64	6313.50	0.00	31.400	0.000	7575.25	4661.69	39.61	3885.23	7.59	8.72	50.00	229

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

Diplomski rad Spoj CLT panela na čeličnu gredu Monika Spajić		4/4 10/09/2024

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

Mjerodavni odabrani razmak spojnih sredstava je 200 mm.

4. ZAKLJUČAK

Kroz ovaj diplomski rad sam stekla bolje razumijevanje i osobno iskustvo u projektiranju drvenih konstrukcija, posebno križnolameliranog drva (CLT) i lameliranog drva (LLD). Projekt mi je omogućio da uvidim, ne samo tehničke aspekte inovativnih materijala, već i njihove potencijale u oblikovanju budućnosti građevinske industrije.

Prvi dojam koji sam dobila u radu s drvom, kao građevinskim materijalom, je da nudi jedinstvenu kombinaciju ekološke održivosti, energetske učinkovitosti i estetske privlačnosti. Njegovo korištenje u konstrukcijama, ne samo da doprinosi smanjenju emisije CO2, već i omogućava bržu i manje energetski intenzivnu gradnju u usporedbi s tradicionalnim materijalima poput betona i čelika. Ovi materijali, iako su se dugo vremena smatrali standardom u građevinskoj industriji, imaju svoje limite koje drvo može prevladati, poput bržeg vremena gradnje i manjeg ekološkog utjecaja.

Na taj način, ne samo da možemo unaprijediti tehniku gradnje, već i pridonijeti stvaranju održivijih i ekološki prihvatljivijih građevinskih praksi za buduće generacije.

Zaključno, rad na ovom projektu mi je pokazao da je istraživanje i primjena novih materijala ključ za napredak i poboljšanje građevinskih metoda. Važno je da ne ostanemo zatvoreni u okvirima tradicionalnih materijala kao što su beton i čelik. Kao i u svakom aspektu života, kako bismo unaprijedili nešto, u ovom slučaju govorimo o gradnji i izboru građevinskih materijala, potrebno je dati priliku nečemu novom da bismo mogli unaprijediti postojeće. Samo kroz kontinuirano istraživanje i primjenu novih materijala možemo postići značajna poboljšanja u kvaliteti i održivosti građevinskih projekata.

Vjerujem da će daljnje istraživanje i razvoj drvenih konstrukcija dovesti do još većih inovacija u građevinskoj industriji, omogućujući nam da stvaramo bolje, održivije i učinkovitije konstrukcije.

POPIS LITERATURE

[1] Jeleč,M.,Varevac,D.,Rajčić,V.: Križno lamelirano drvo (CLT) - pregled stanja područja, *GRAĐEVINAR, 70* (2018) 2, pp. 75-95, doi: https://doi.org/10.14256/JCE.2071.2017

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

[3] http://seizkarta.gfz.hr/karta.php.

[4] Plates and connectors for timber, Rothoblaas

[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.wsp.com/en-gl/projects/55-southbank

[7] https://radman-homes.eu/clt-gradnja-sto-je-i-koje-su-prednosti/

POPIS SLIKA

PRILOZI

001 – Tlocrt prizemlja, MJ 1:200

002 – Tlocrt 1.kata MJ 1:200

003 – Tlocrt 2.kata MJ 1:200

004 – Tlocrt 3.kata MJ 1:200

005 – Tlocrt 4. kata MJ 1:200

006 – Tlocrt 5.kata MJ 1:200

007 – Plan pozicija panela prizemlja MJ 1:200

008 – Plan pozicija panela 1. i 3. kata MJ 1:200

009 – Plan pozicija panela 2. kata MJ 1:200

010 – Plan pozicija panela 4. kata MJ 1:200

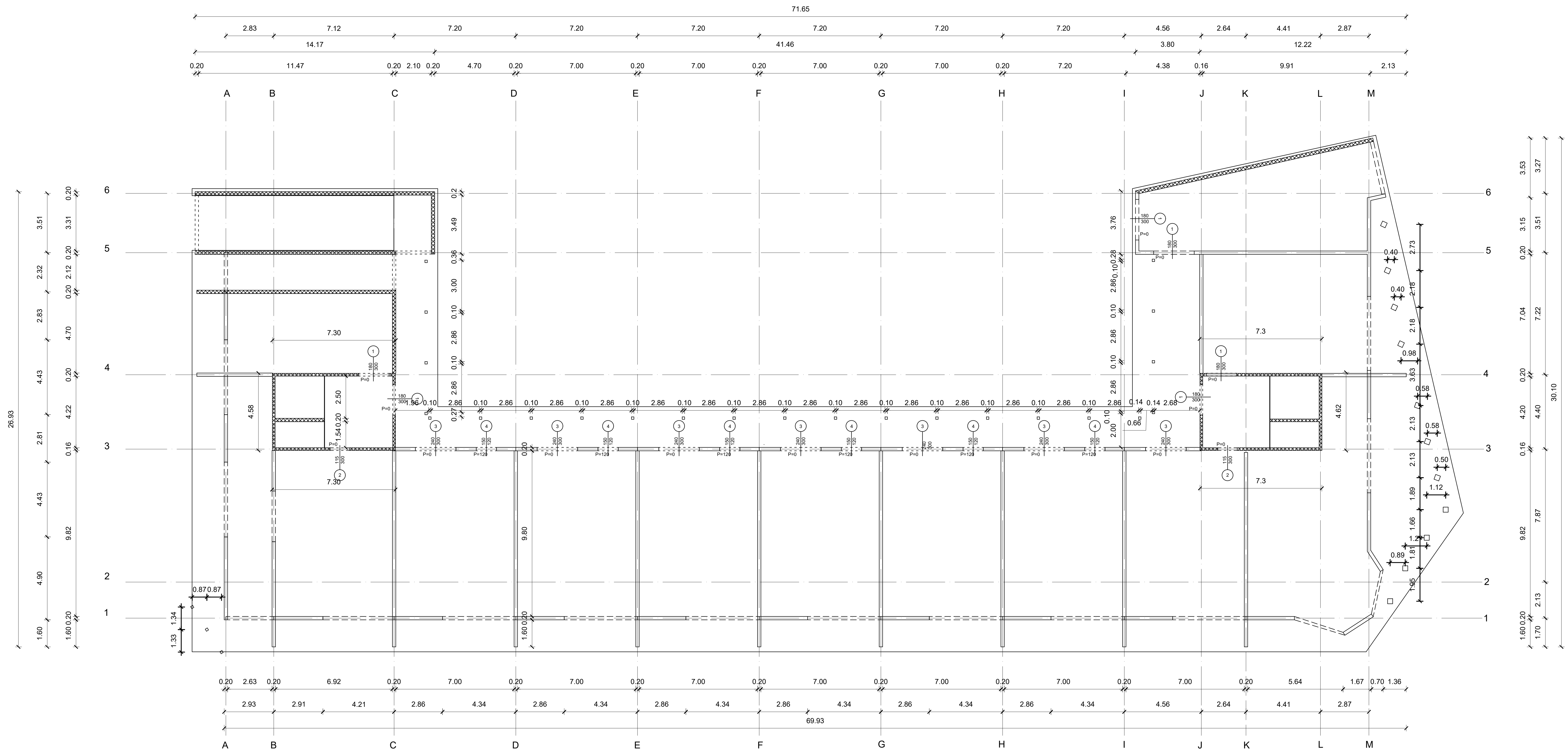
011 – Plan pozicija panela 5. kata - krova MJ 1:200

012 – Plan pozicija prizemlja MJ 1:200

013 – Plan pozicija 1. i 3. kata MJ 1:200

014 – Plan pozicija 2. i 4. kata MJ 1:200

015 – Plan pozicija 5. kata MJ 1:200



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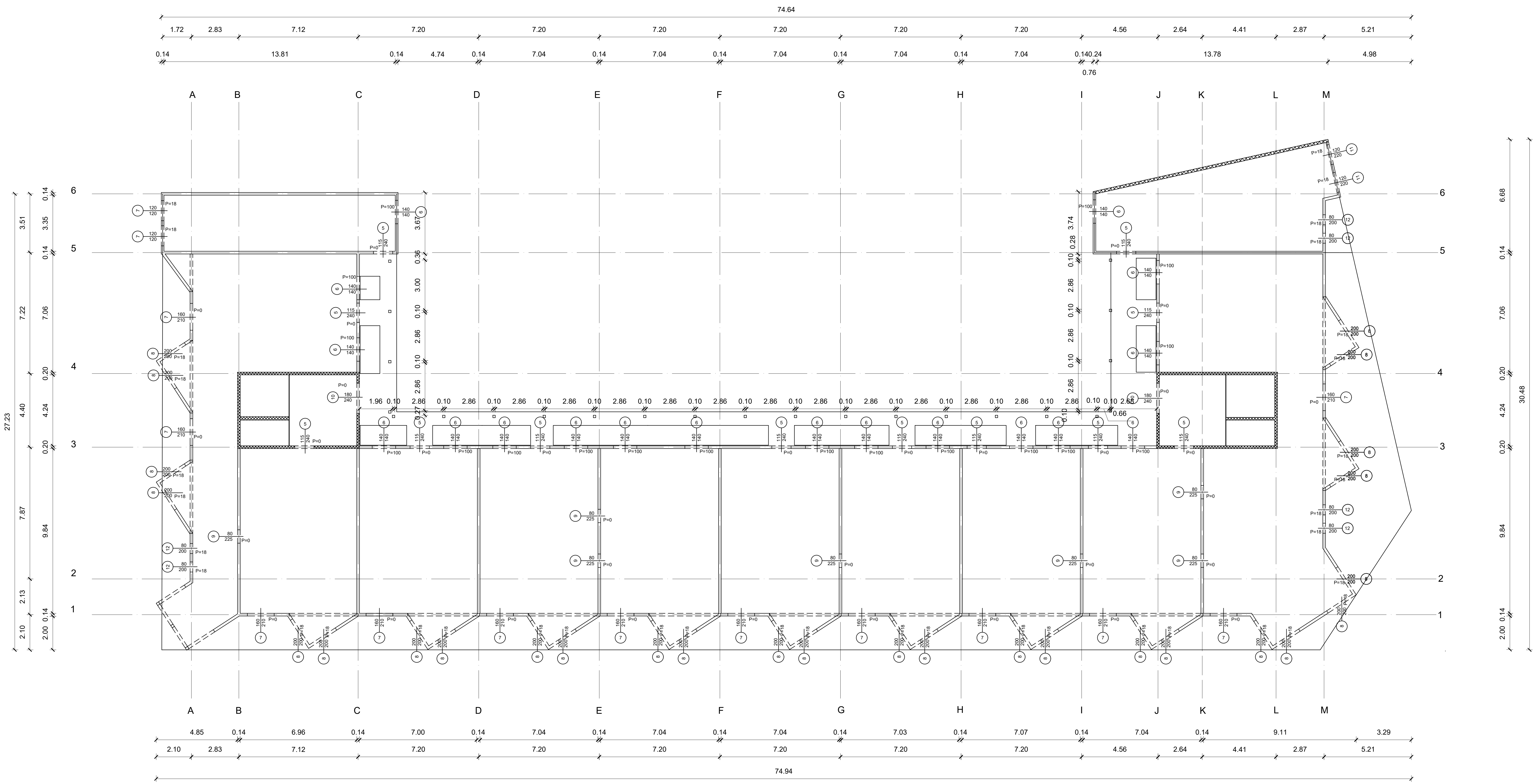
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Tlocrt prizemlja	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	001



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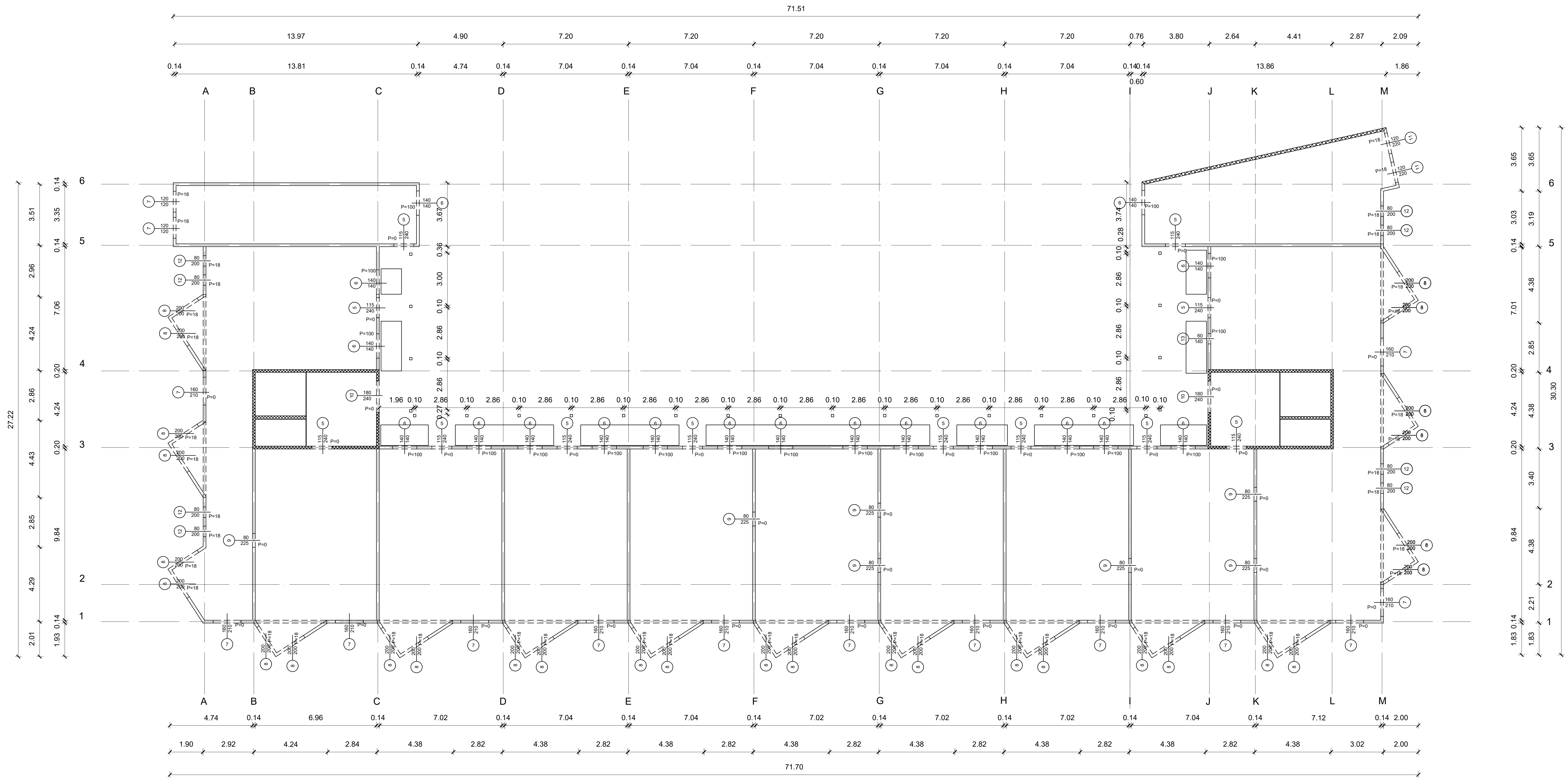
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Tlocrt 1. kata	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	002



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Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Tlocrt 2. kata	Datum:	17.09.2024.
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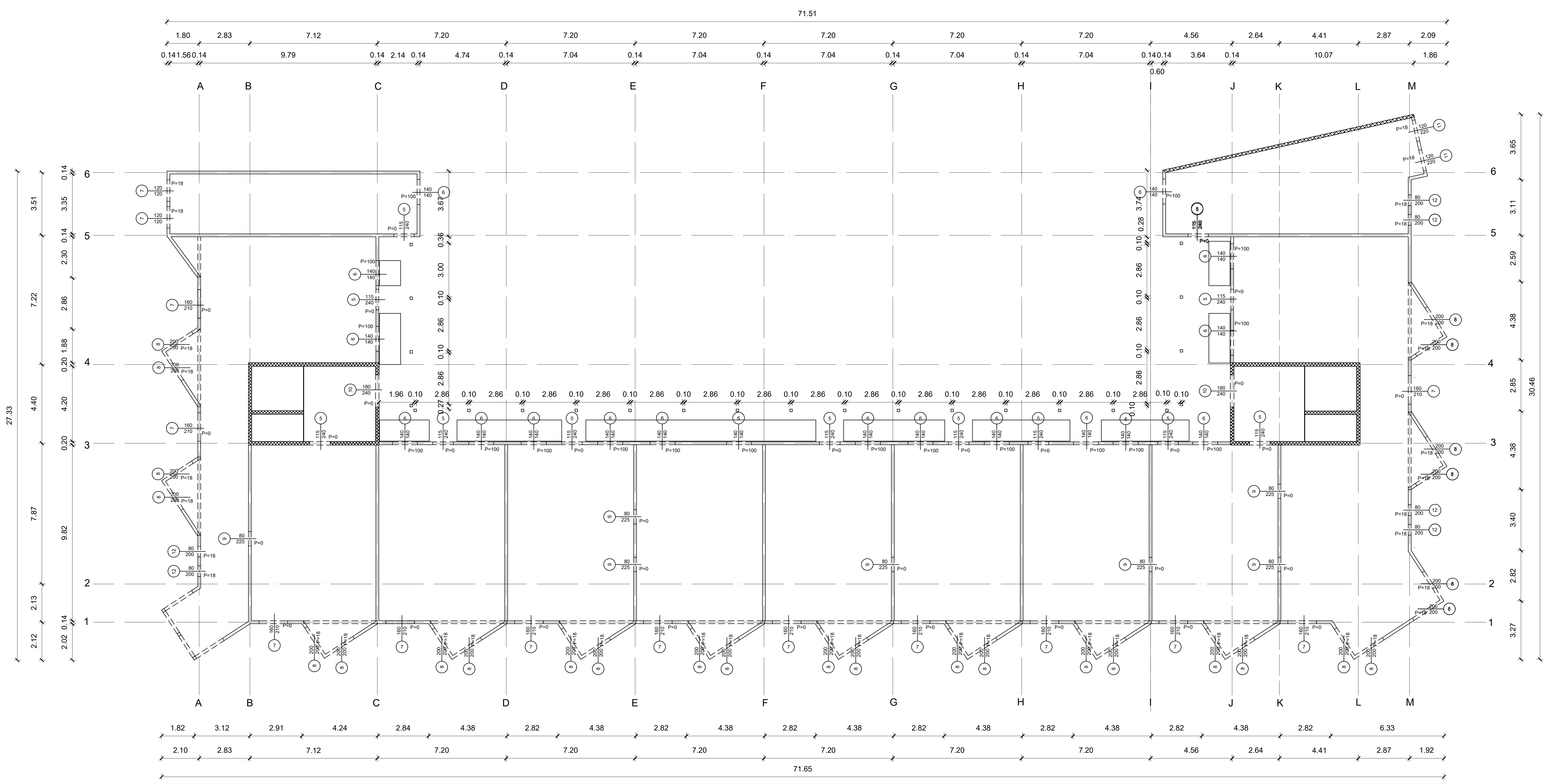

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Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Tlocrt 3. kata	Datum:	17.09.2024.
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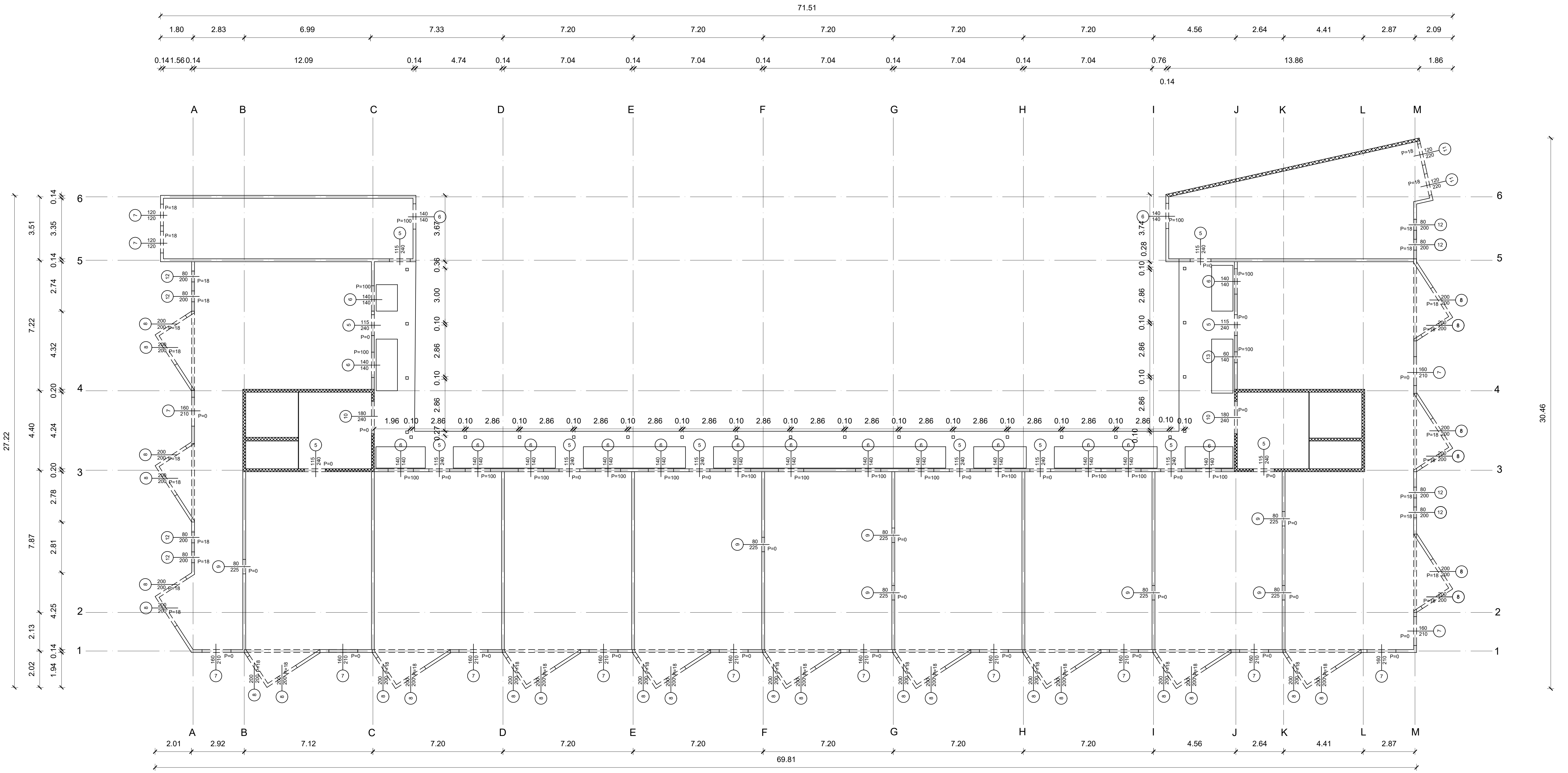
Izradila:	Monika Spajić	Broj nacrta:	004



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Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
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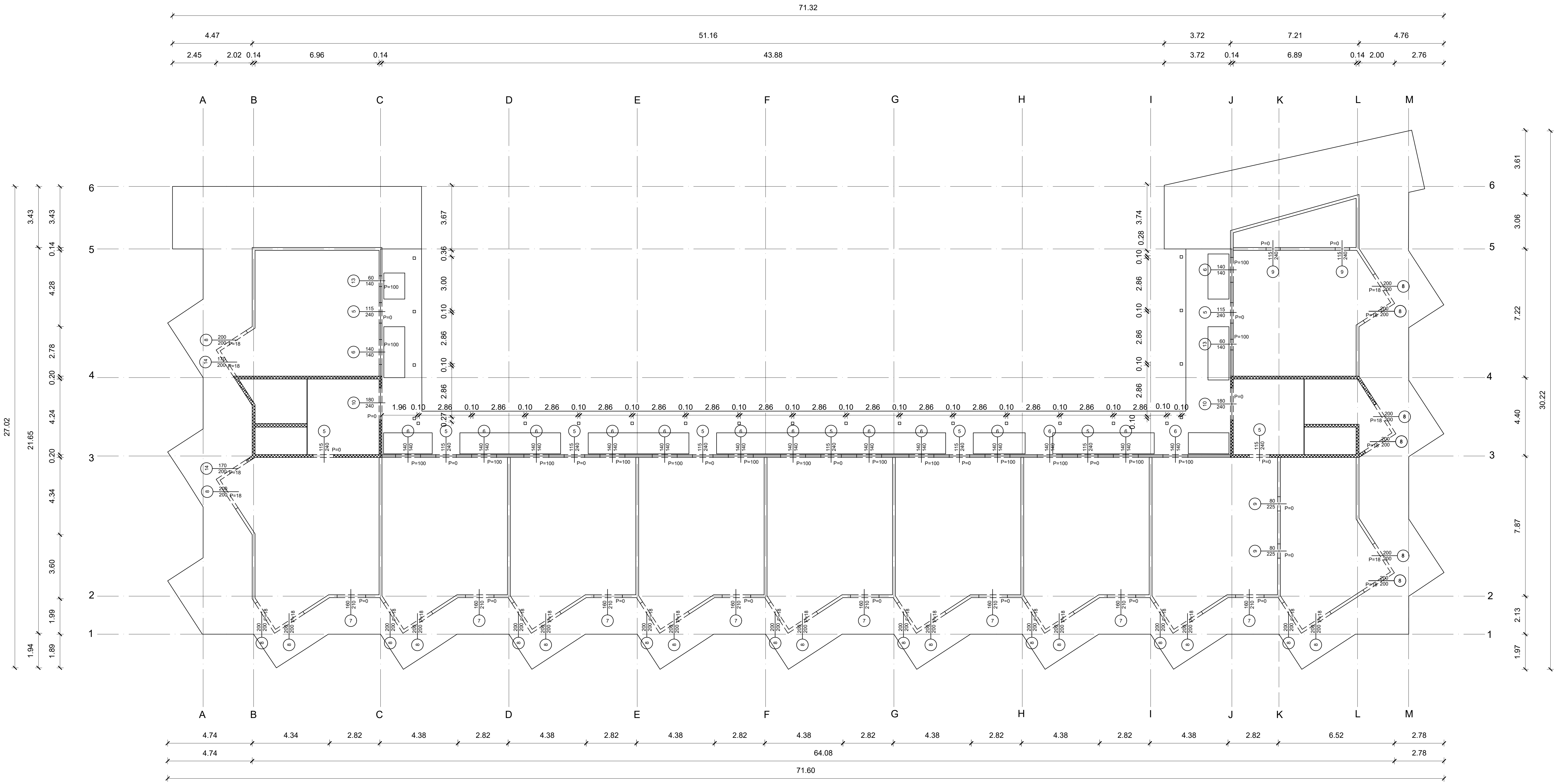
Izradila:	Monika Spajić	Broj nacrta:	005



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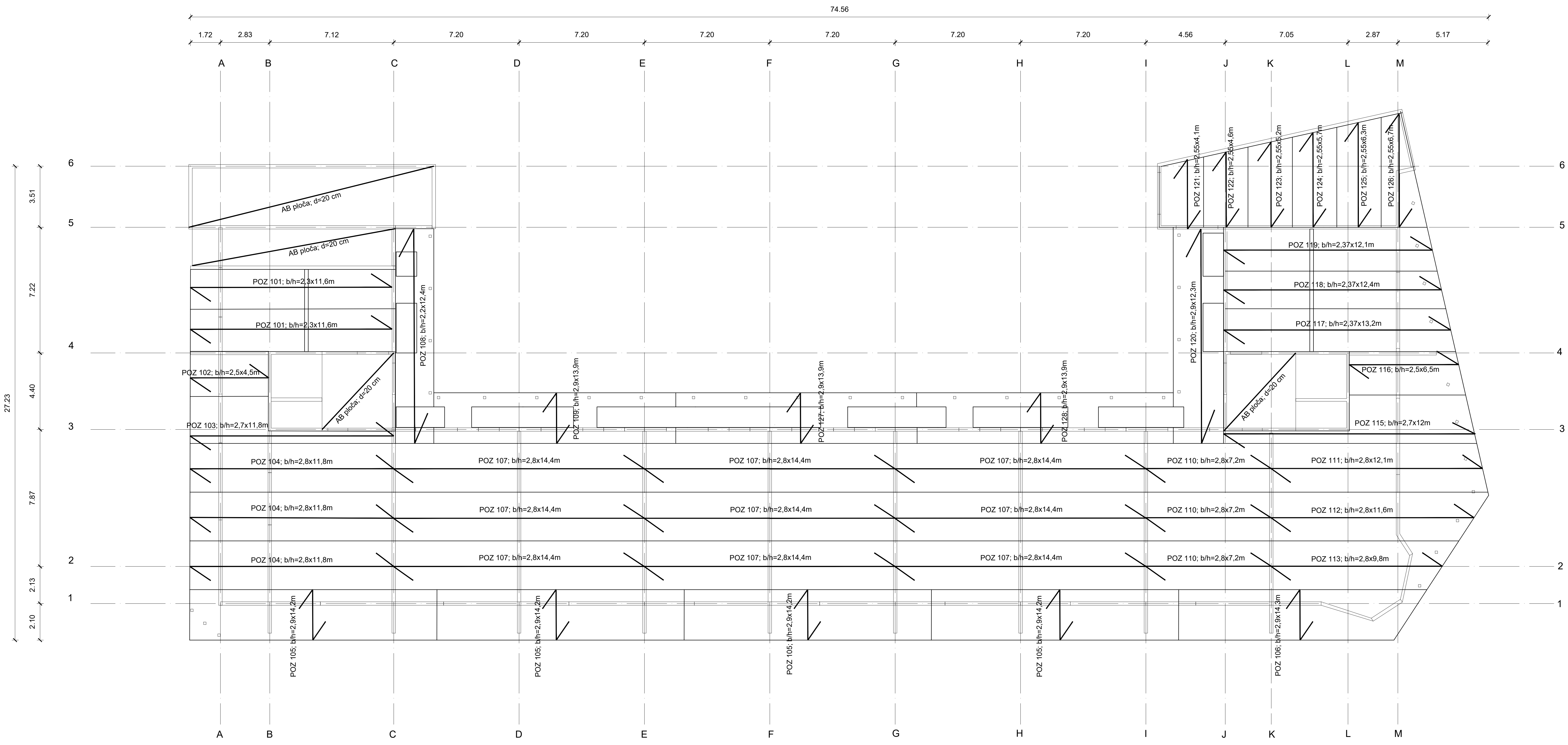
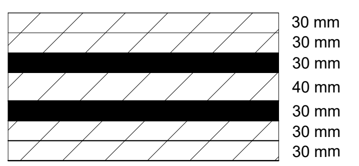
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Tlocrt 5.kata	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	006



POZ 101-128
CLT međukatni paneli - d = 220 mm; 7 slojeva; C24



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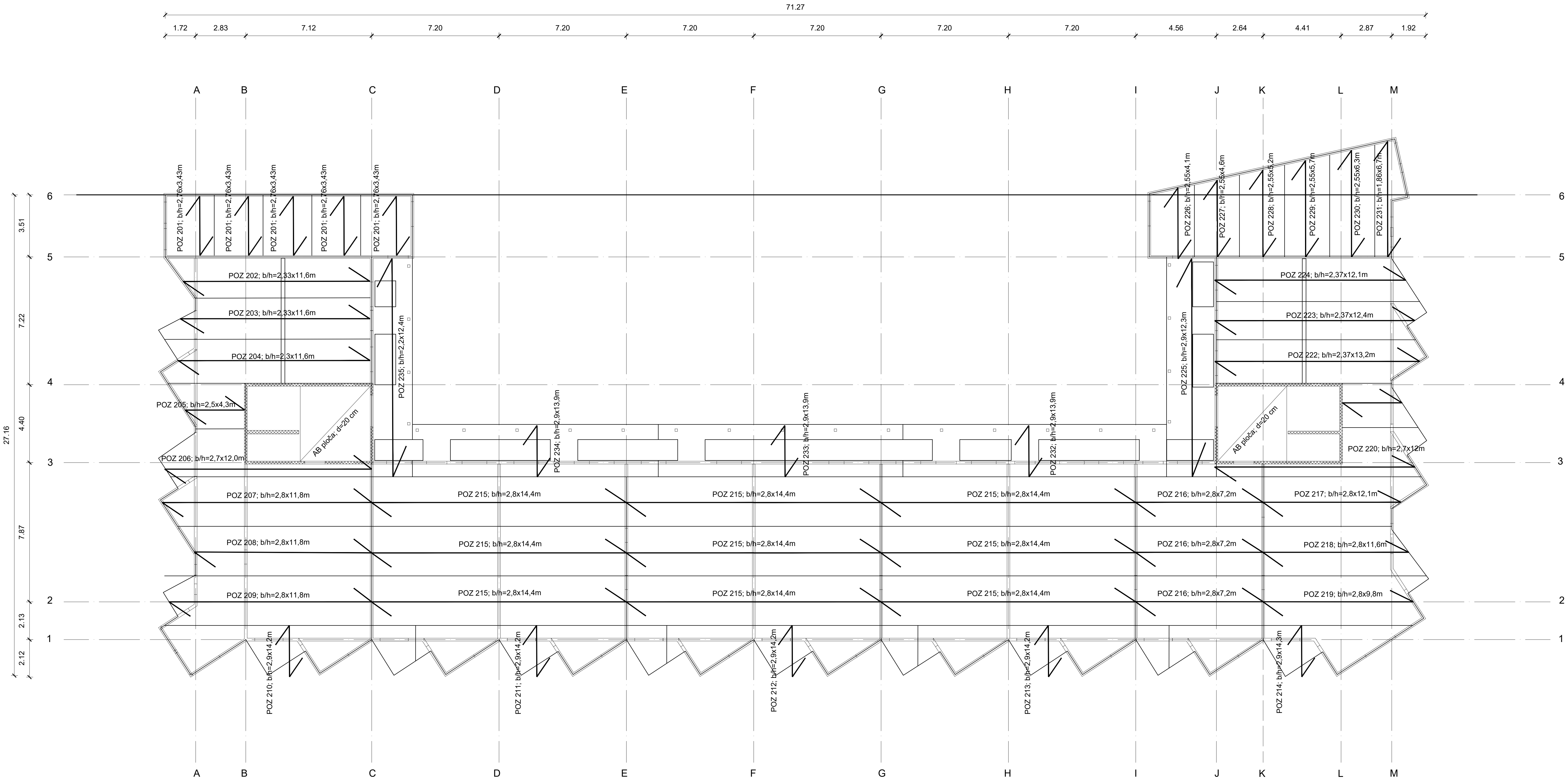
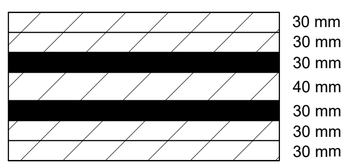
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija panela prizemlja	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	007



POZ 201-235
CLT međukatni paneli - d = 220 mm; 7 slojeva; C24



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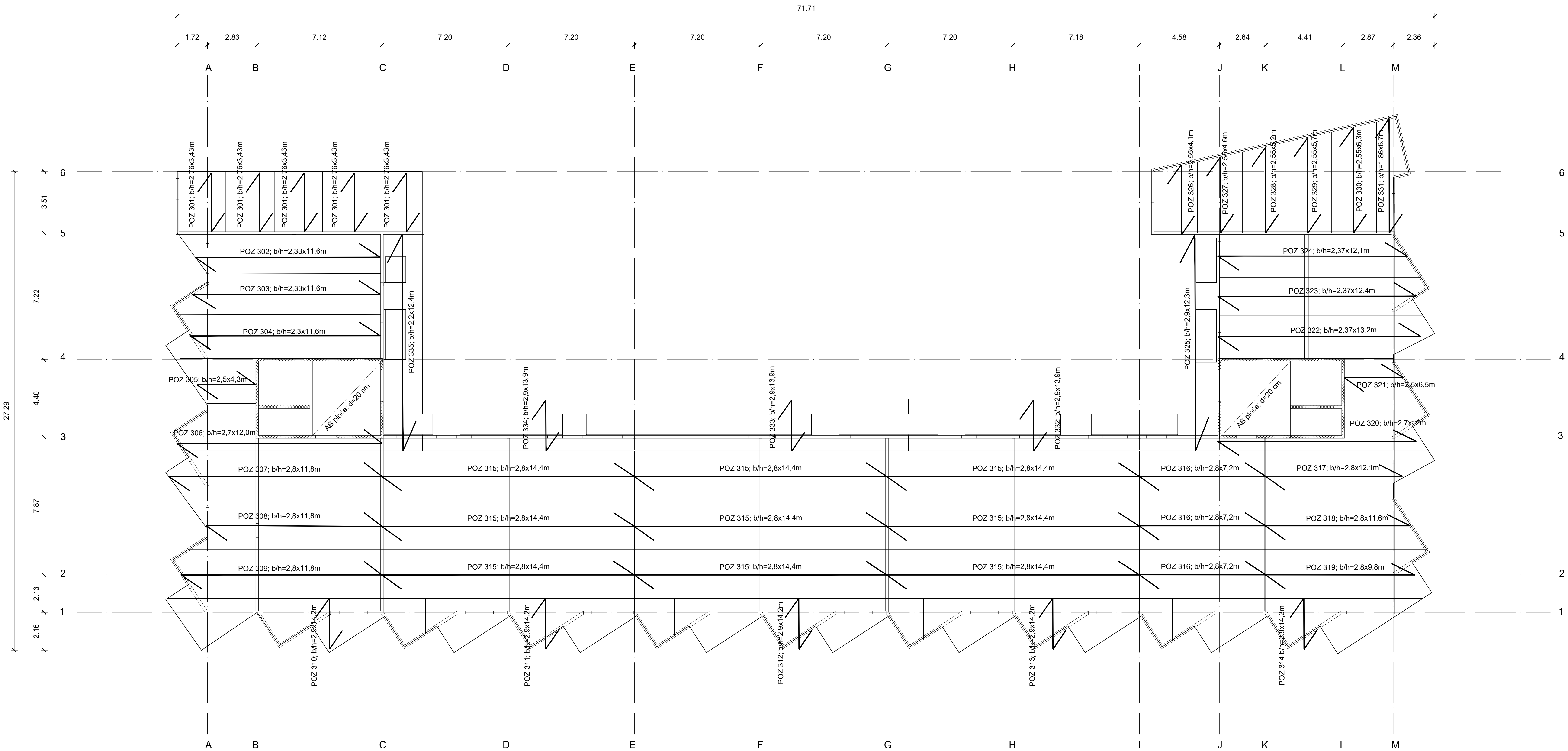
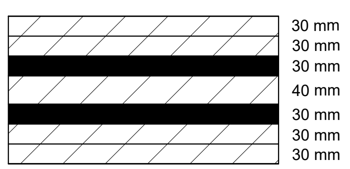
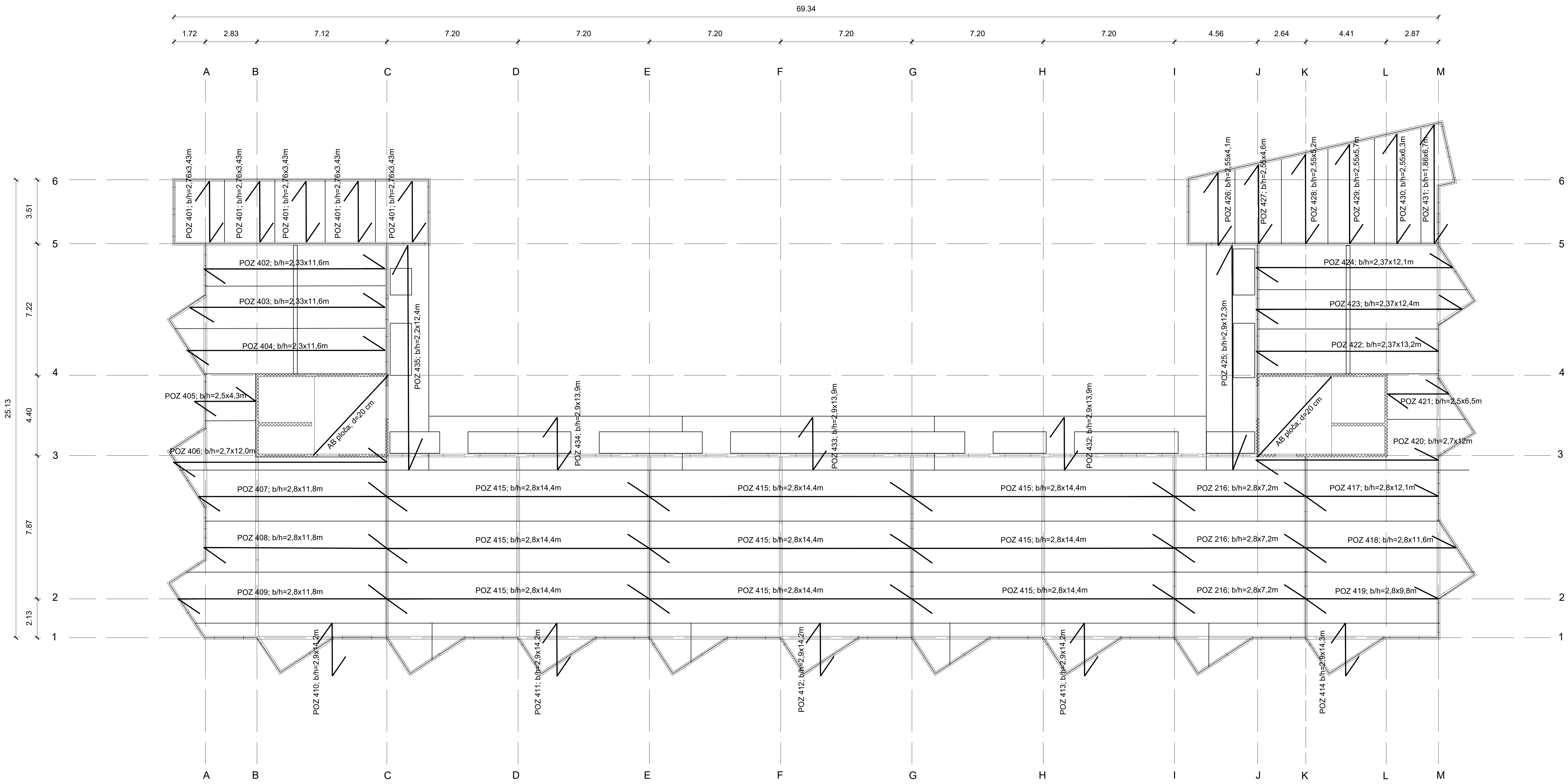
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija panela 1. i 3. kata	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	008



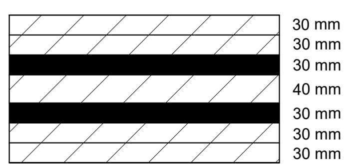
POZ 301-335
CLT međukatni paneli - d = 220 mm; 7 slojeva; C24



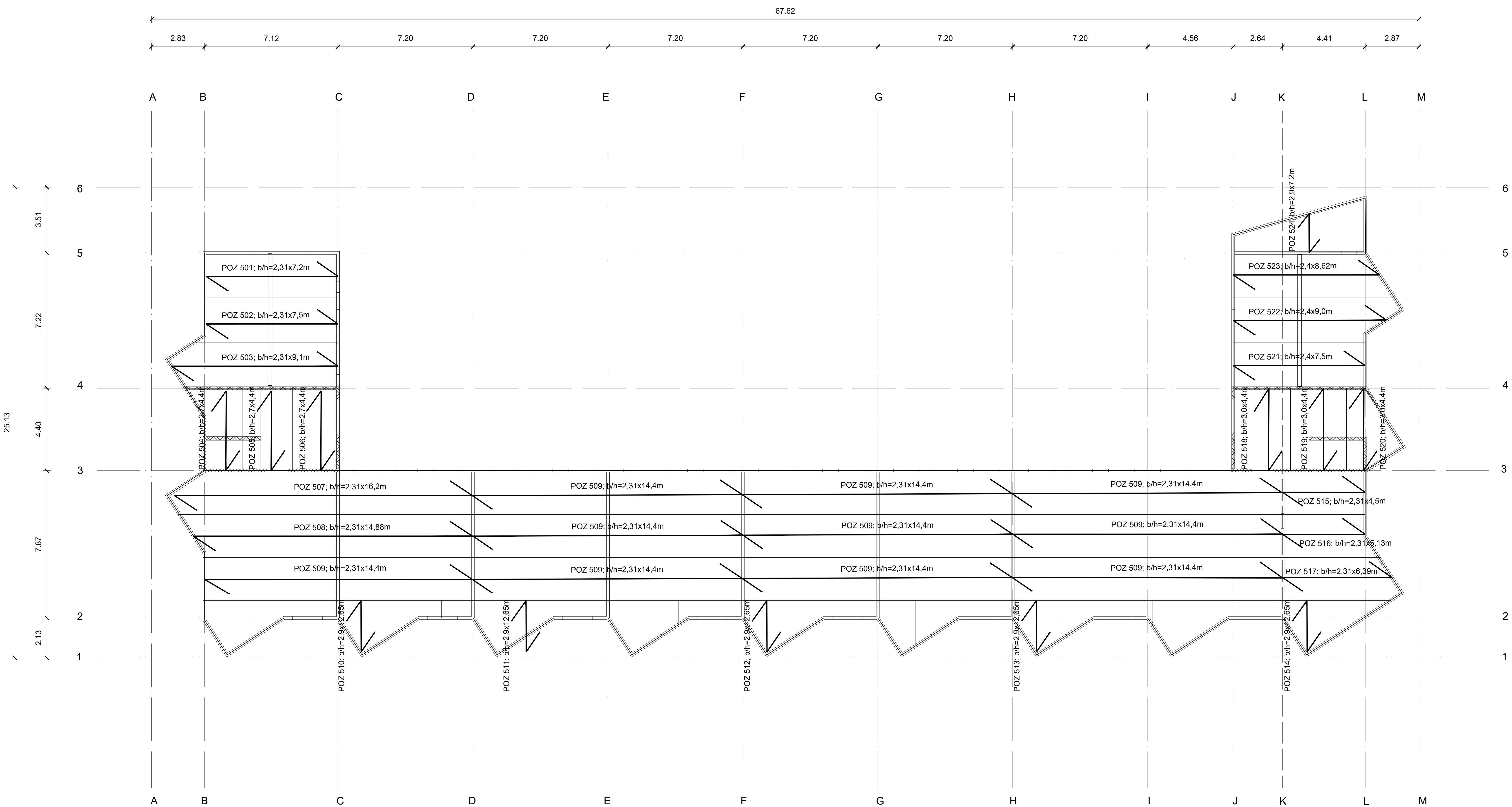
SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET		DIPLOMSKI RAD	
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija panela 2. kata	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	009



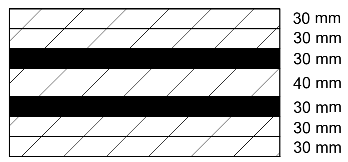
POZ 401-435
CLT međukatni paneli - d = 220 mm; 7 slojeva; C24



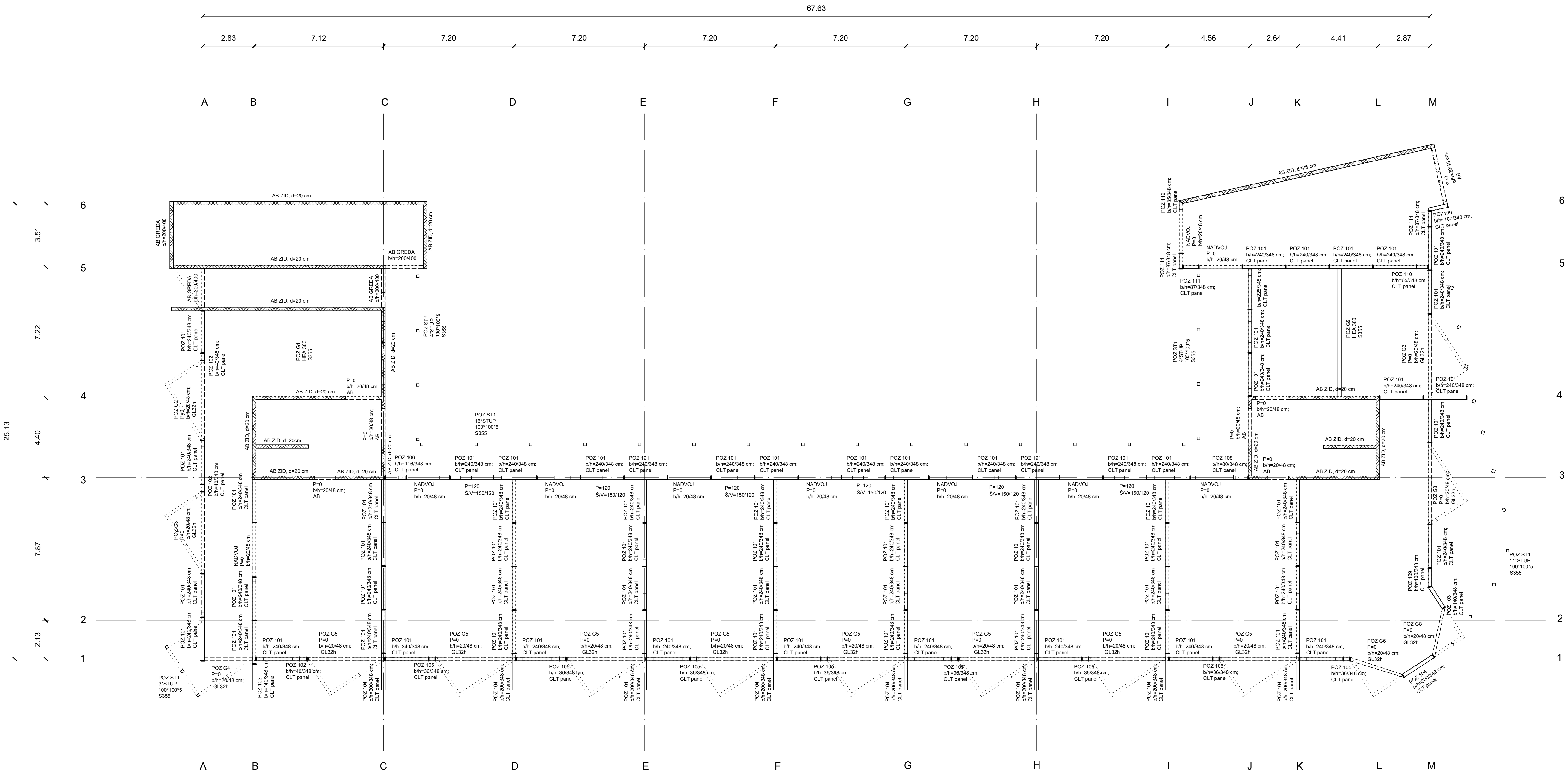
SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET		DIPLOMSKI RAD	
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija panela 4. kata	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	010



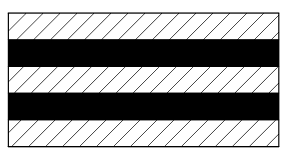
POZ 501-524
CLT međukatni paneli - d = 220 mm; 7 slojeva; C24



SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET		DIPLOMSKI RAD	
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija panela 5. kata - krova	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	011

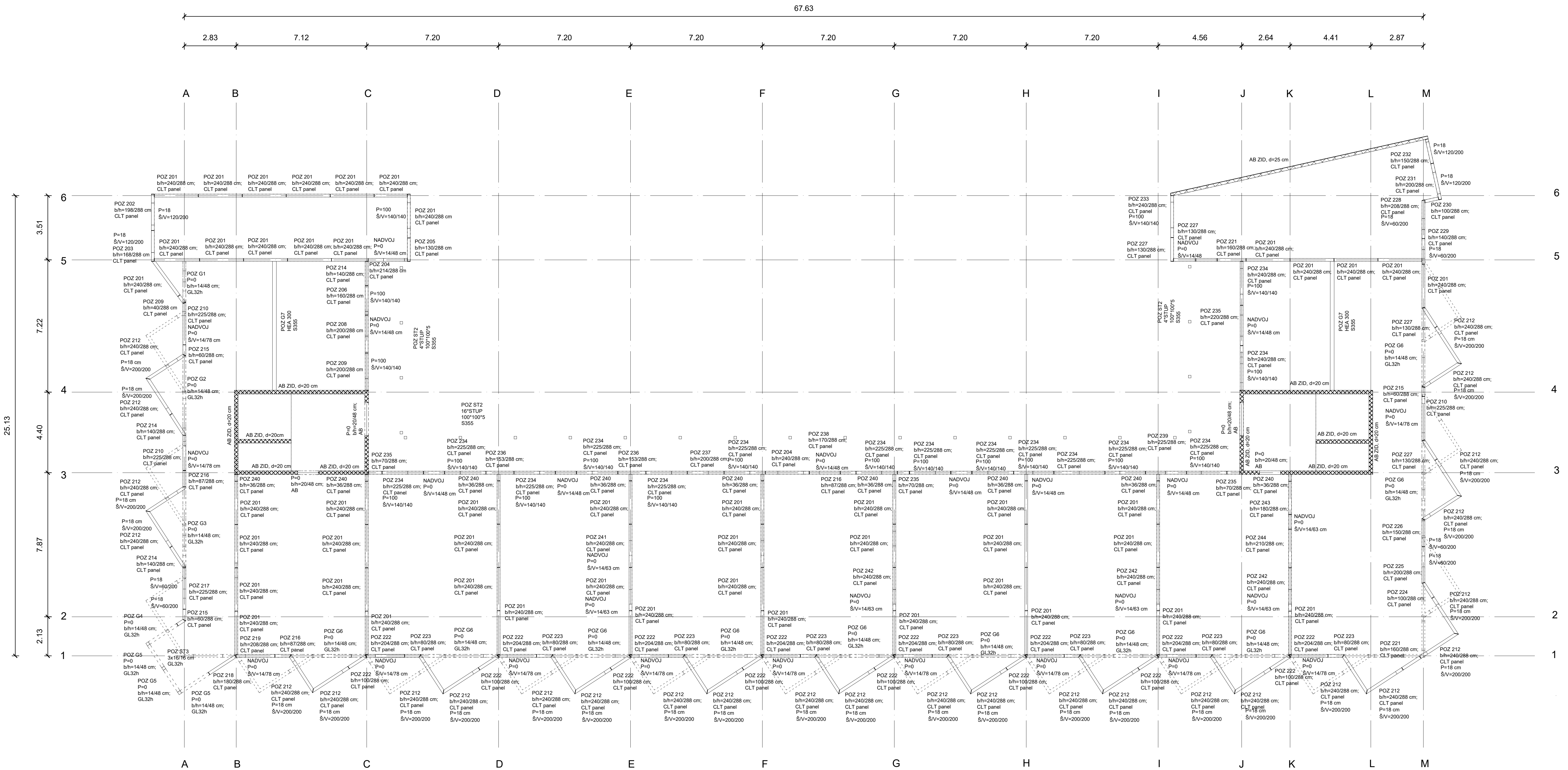


CLT zidni paneli - d = 200 mm; 5 slojeva; C24

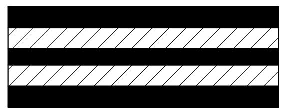


Napomena:
Dominantni smjer nosivosti zidnih panela je vertikalni.

SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET		DIPLOMSKI RAD	
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija prizemlja	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	012

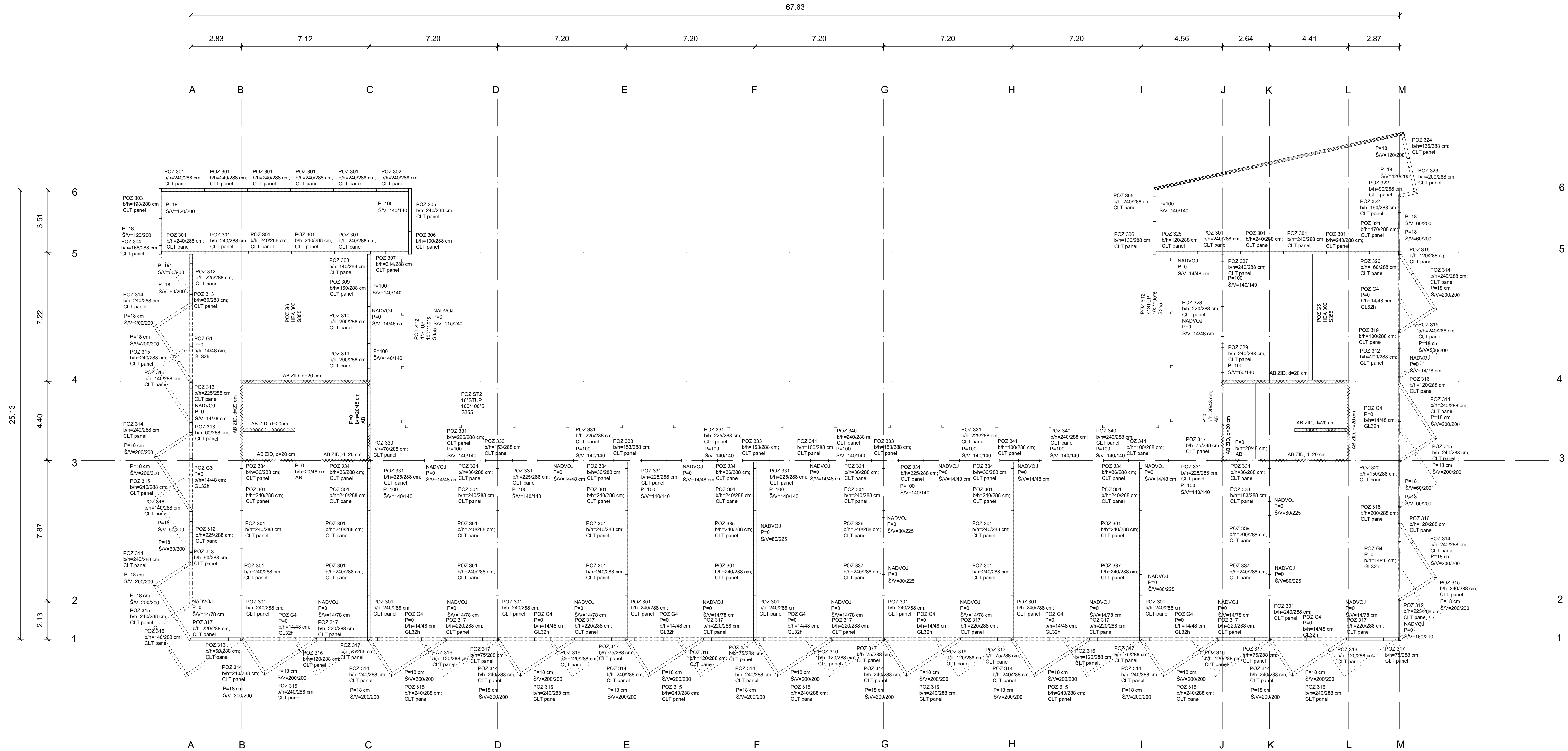


CLT zidni paneli - d =140 mm; 5 slojeva; C24

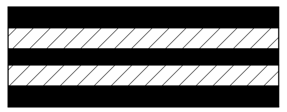


Napomena:
Dominantni smjer nosivosti zidnih panela je vertikalni,
osim zidova pozicija 212, 218, 222 i 227.

SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET		DIPLOMSKI RAD	
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija 1. i 3. kata	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	013

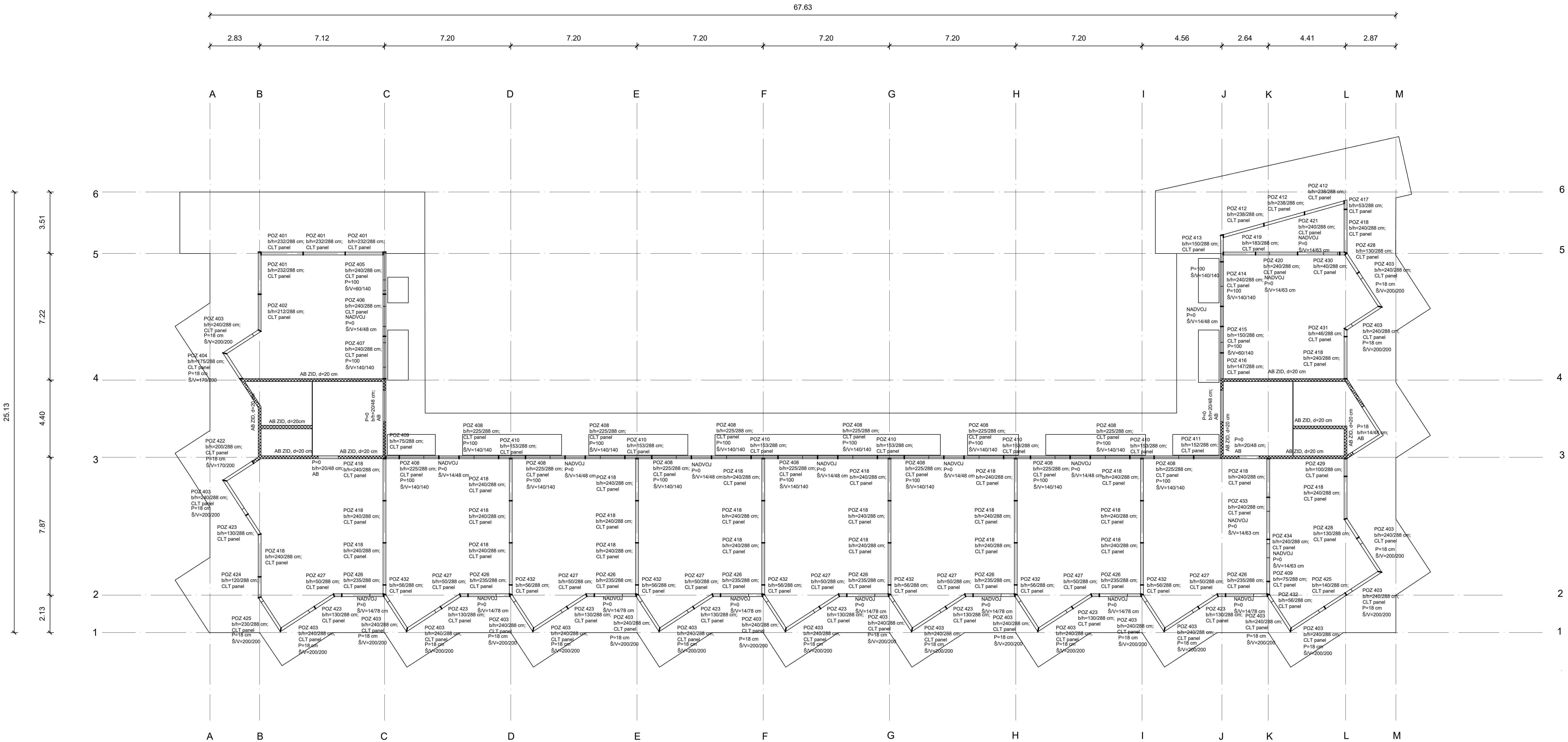


CLT zidni paneli - d =140 mm; 5 slojeva; C24

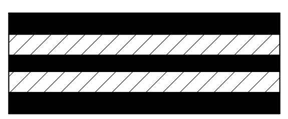


Napomena:
Dominantni smjer nosivosti zidnih panela je vertikalni, osim zidova pozicija 314,315 i 316.

SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET		DIPLOMSKI RAD	
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija 2. i 4. kata	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	014



CLT zidni paneli - d =140 mm; 5 slojeva; C24



Napomena:
Dominantni smjer nosivosti zidnih panela je vertikalni.

SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET		DIPLOMSKI RAD	
Razina obrade:	Projekt konstrukcije	Kolegij:	Drvene konstrukcije 2.
Građevina:	Stambeno poslovna zgrada P + 5 od CLT-a	Akad. godina:	2023./2024.
Sadržaj nacrta:	Plan pozicija 5.kata	Datum:	17.09.2024.
Mentorica:	prof.dr.sc. Vlatka Rajčić	Mjerilo:	1:200
Izradila:	Monika Spajić	Broj nacrta:	015