Snimak stanja stare krovne konstrukcije i prijedlog sanacije

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Sveučilište u Zagrebu

GRAĐEVINSKI FAKULTET

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ZAVRŠNI ISPIT

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Komentor: dr. sc. Nikola Perković

Zagreb, 2024.

University of Zagreb

FACULTY OF CIVIL ENGINEERING

Enia Klanac

ASSESMENT OF THE OLD ROOF STRUCTURE AND SANATION PROPOSAL

FINAL EXAM

Supervisor: prof. dr. sc. Vlatka Rajčić

Commentator: dr. sc. Nikola Perković

Zagreb, 2024.

SAŽETAK

U ovom radu je prikazan način snimka stanja stare krovne konstrukcije i prijedlog sanacije na primjeru Stare gradske vijećnice u Zagrebu, Ćirilometodska ul. 5, 10000 Zagreb u njenoj zoni 1. Poseban naglasak je stavljen na vizualni pregled te nerazorna ispitivanja vlagomjerom i rezistografom. Rezultati su korišteni za izradu statičkog modela u programu DLUBAL RFEM 6 te proračun konstrukcije prema Eurokodu 5: Projektiranje drvenih konstrukcija i hrvatskim nacionalnim dodacima za projektiranje drvenih konstrukcija, osiguravajući sigurnost i trajnost konstrukcije.

Ključne riječi: drvene konstrukcije; krovište; nerazorna ispitivanja; statički proračun; prijedlog sanacije

SUMMARY

In this paper, the method for recording the condition of an old roof structure and the proposed remediation is demonstrated using the example of the Old City Hall in Zagreb, Ćirilometodska Street 5, 10000 Zagreb, in its Zone 1. Special emphasis is placed on visual inspection as well as non-destructive testing with a moisture meter and resistograph. The results were used to create a static model in the DLUBAL RFEM 6 software and to calculate the structure according to Eurocode 5: Design of Timber Structures and Croatian national annexes for the design of timber structures, ensuring the safety and durability of the structure.

Key words: timber structures; roofing; non-destructive testing; structural analysis; remediation proposal

SADRŽAJ

1. UVOD

Tema i cilj ovog rada je prikazati način snimka stanja stare krovne konstrukcije i prijedlog sanacije na primjeru Stare gradske vijećnice u Zagrebu, Ćirilometodska ul. 5, 10000 Zagreb. Na krovištu Stare gradske vijećnice u Zagrebu, proveden je vizualni pregled uz korištenje nerazornih metoda ispitivanja. Upotrebom vlagomjera i rezistografa izvršena je analiza stanja drvene konstrukcije s posebnim naglaskom na detekciju vlage i ocjenu mehaničkih svojstava elemenata krovišta. Ovi podaci poslužili su kao temelj za daljnje projektne aktivnosti. Na osnovi prikupljenih mehaničkih i geometrijskih karakteristika, izrađen je statički model krovišta pomoću softverskog alata DLUBAL RFEM 6. Statički proračun obuhvaćao je provjeru graničnih stanja nosivosti i uporabljivosti drvene konstrukcije u skladu s Eurokodom 5 koji definira smjernice za projektiranje drvenih konstrukcija. Prilikom analize korišteni su i hrvatski nacionalni dodaci kako bi proračun bio usklađen s lokalnim standardima. Na kraju ovisno o rezultatima proračuna predlaže se prijedlog sanacije ako je sanacija potrebna.

2. OCJENA STANJA KONSTRUKCIJE

Drvo je prirodni materijal koji se ističe visokom ekološkom vrijednošću i tehničkom svestranošću te je u posljednjim godinama ponovno stekao značaj. Ključne mehaničke, fizičke i kemijske karakteristike drva su od presudne važnosti za njegovu široku primjenu u građevinskoj industriji. [1]

Prvi dio ovog završnog rada se sastojao od vizualnog pregleda krovišta Stare gradske vijećnice u Zagrebu te provođenja nerazornih ispitivanja kako bismo utvrdili stanje u kojem se krovište nalazi.

Najjednostavnija i najčešće korištena metoda nedestruktivnog ispitivanja drvenih konstrukcija je vizualni pregled. Ovo je prvi korak u ocjeni stanja konstrukcije jer pruža osnovne, ali važne informacije o vidljivim oštećenjima kao što su pukotine, truljenje, oštećenje vlakana, puzanje i ozbiljne raspukline. Vizualni pregled omogućava uočavanje prirodnih nedostataka i propadanja drva, koji mogu negativno utjecati na mehanička svojstva materijala. Biološki napadi često uzrokuju smanjenje gustoće drva i kemijske reakcije koje dovode do truljenja. [2] Vizualnim pregledom nismo uočili značajnija oštećenja drvene konstrukcije.

Jedan od ključnih čimbenika koji utječe na ponašanje i karakteristike drvene građe je vlažnost drva. Količina vode prisutne u drvetu značajno utječe na njegovu težinu, čvrstoću, obradivost, osjetljivost na biološke napade i dimenzijsku stabilnost elemenata. Udio vlage određuje se mjerenjem mase drva u vlažnom stanju i usporedbom s masom drva u suhom stanju, pri čemu se rezultat izražava u postocima ili kao u ovom slučaju, mjerenjem specifičnog električnog otpora drva vlagomjerom. [3]

Provođenjem ispitivanja vlagomjerom, utvrdili smo da se drvo nalazi u 1. razredu uporabljivosti.

Rezistograf je instrument koji služi za otkrivanje truljenja i šupljina u drveću i drvenim materijalima. Pomoću njega analiziramo unutarnju strukturu drva te omogućuje identifikaciju truleži, faze raspadanja, šuplja područja, pukotine i strukturu godova. Rezultati mjerenja prikazani su u obliku linija: ravna linija označava odsutnost otpora bušilici, što upućuje na šuplje ili trulo područje, dok nazubljena linija ukazuje na prisutnost otpora i čvrsto drvo [4]. Na kraju, naš rezultat je upravo bio takav – pokazao je čvrsto drvo.

U nastavku su prikazane slike krovišta i rezultata mjerenja.

Slika 1. Krovište

Slika 2. Krovište

Slika 3. Krovište

Slika 4. Detalj krovišta

Slika 5. Detalj krovišta

Slika 6. Detalj krovišta

Slika 7. Prvo mjerenje vlagomjerom

Slika 8. Drugo mjerenje vlagomjerom

Slika 9. i Slika 10. Treće mjerenje vlagomjerom

3. STATIČKI PRORAČUN

Nakon vizualnog pregleda i nerazornih ispitivanja, ključno je bilo provesti proračun graničnih stanja nosivosti i uporabljivosti prema Eurokodu 5 za proračun drvenih konstrukcija, specifično u ovom radu za zonu 1 krovišta. Model krovišta izrađen je pomoću programa Dlubal RFEM 6, a cilj je bio utvrditi zadovoljava li postojeće stanje krovišta zahtjeve sigurnosti nosivih konstrukcija (GSN i GSU).[5,6] U proračun su uzeta u obzir sva relevantna opterećenja, uključujući vlastitu težinu konstrukcije, dodatna stalna opterećenja te opterećenja uzrokovana vjetrom i snijegom kako bi se osigurala sveobuhvatna analiza.

U nastavku su prikazani rezultati završnog statičkog izvještaja izrađenog u programu Dlubal RFEM 6.

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Obala kralja P. Krešimira IV., 23450 Obrovac

Model: Enia Klanac_1.zona krovišta – kopija (2)

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MODEL

Structural Analysis

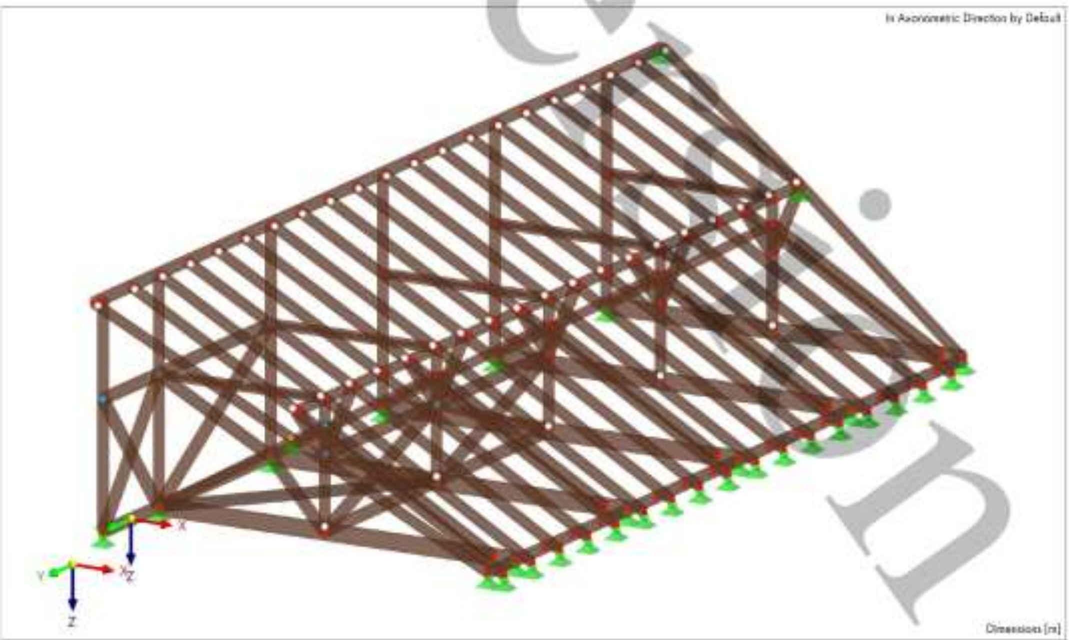
CLIENT

CREATED BY

PROJECT

Chapters

MODEL



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Model: Enia Klanac_1.zona krovišta – kopija (2)

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MODEL

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Model: Enia Klanac_1.zona krovišta - kopija (2)

A MODEL - LOCATION

Location

Country	:	Croatia
Street	:	Zrinjevac 7
Zip / Postal code	:	10000
City	:	Zagreb
State	:	
Latitude	:	deg
Longitude	:	deg
Altitude	:	122.000 m

1 Basic Objects

Enia Klanac
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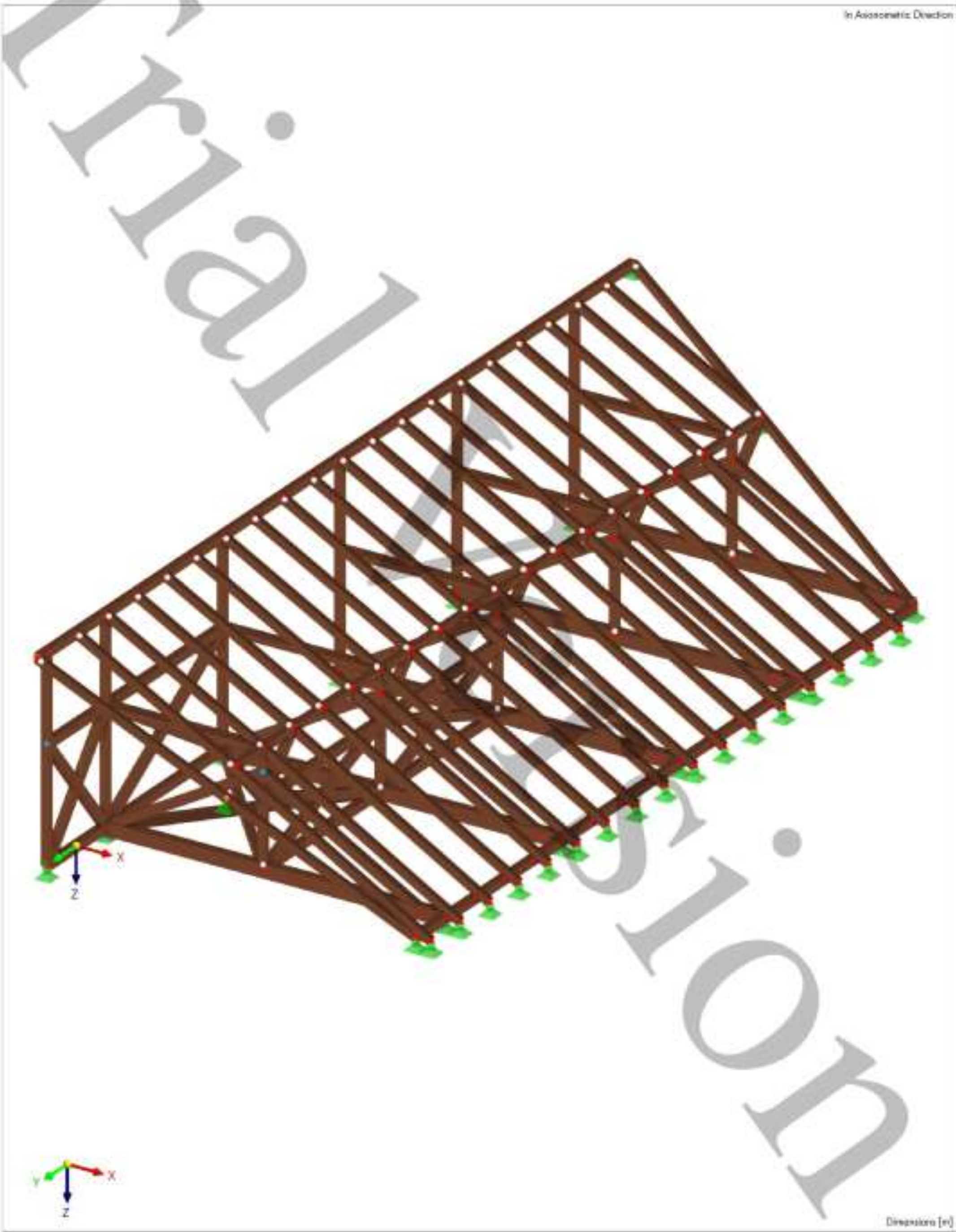
Model: Enia Klanac_1.zona krovišta – kopija (2)

1.1 **MODEL, IN AXONOMETRIC DIRECTION**



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Model:
Enia Klanac_1.zona krovišta - kopija (2)

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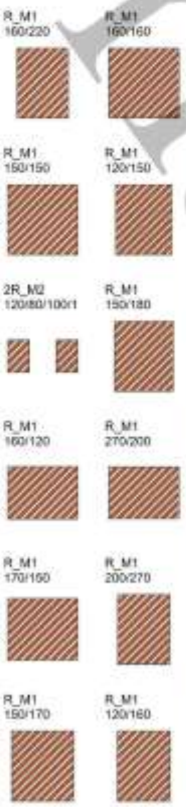
MODEL

1.2 MATERIALS

Legend
Stiffness modification

Material No.	Material Name	Material Type	Analysis Model	Options
1	D50 | Isotropic | Linear Elastic	Timber	Isotropic | Linear Elastic	

1.3 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 160/220 | 1 - D50							
	1	Parametric - Massive I		16696.63	14197.33	7509.33	160.0	220.0
				352.00	293.33	293.33		
2	R_M1 160/160 | 1 - D50							
	1	Parametric - Massive I		9229.65	5461.33	5461.33	160.0	160.0
				256.00	213.33	213.33		
3	R_M1 150/150 | 1 - D50							
	1	Parametric - Massive I		7129.69	4218.75	4218.75	150.0	150.0
				225.00	187.50	187.50		
4	R_M1 120/150 | 1 - D50							
	1	Parametric - Massive I		4434.08	3375.00	2160.00	120.0	150.0
				180.00	150.00	150.00		
5	2R_M2 120/80/100/1 | 1 - D50							
	1	Parametric - Massive II		2426.18	2304.00	16576.01	260.0	120.0
				192.00	0.00	160.93		
6	R_M1 150/180 | 1 - D50							
	1	Parametric - Massive I		10046.00	7290.00	5062.50	150.0	180.0
				270.00	225.00	225.00		
7	R_M1 160/120 | 1 - D50							
	1	Parametric - Massive I		4976.26	2304.00	4096.00	160.0	120.0
				192.00	160.00	160.00		
8	R_M1 270/200 | 1 - D50							
	1	Parametric - Massive I		39242.99	18000.00	32805.00	270.0	200.0
				540.00	450.00	450.00		
9	R_M1 170/150 | 1 - D50							
	1	Parametric - Massive I		9030.75	4781.25	6141.25	170.0	150.0
				255.00	212.50	212.50		
10	R_M1 200/270 | 1 - D50							
	1	Parametric - Massive I		39242.99	32805.00	18000.00	200.0	270.0
				540.00	450.00	450.00		
11	R_M1 150/170 | 1 - D50							
	1	Parametric - Massive I		9030.75	6141.25	4781.25	150.0	170.0
				255.00	212.50	212.50		
12	R_M1 120/160 | 1 - D50							
	1	Parametric - Massive I		4976.26	4096.00	2304.00	120.0	160.0
				192.00	160.00	160.00		

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Model: Enia Klanac_1.zona krovišta – kopija (2)

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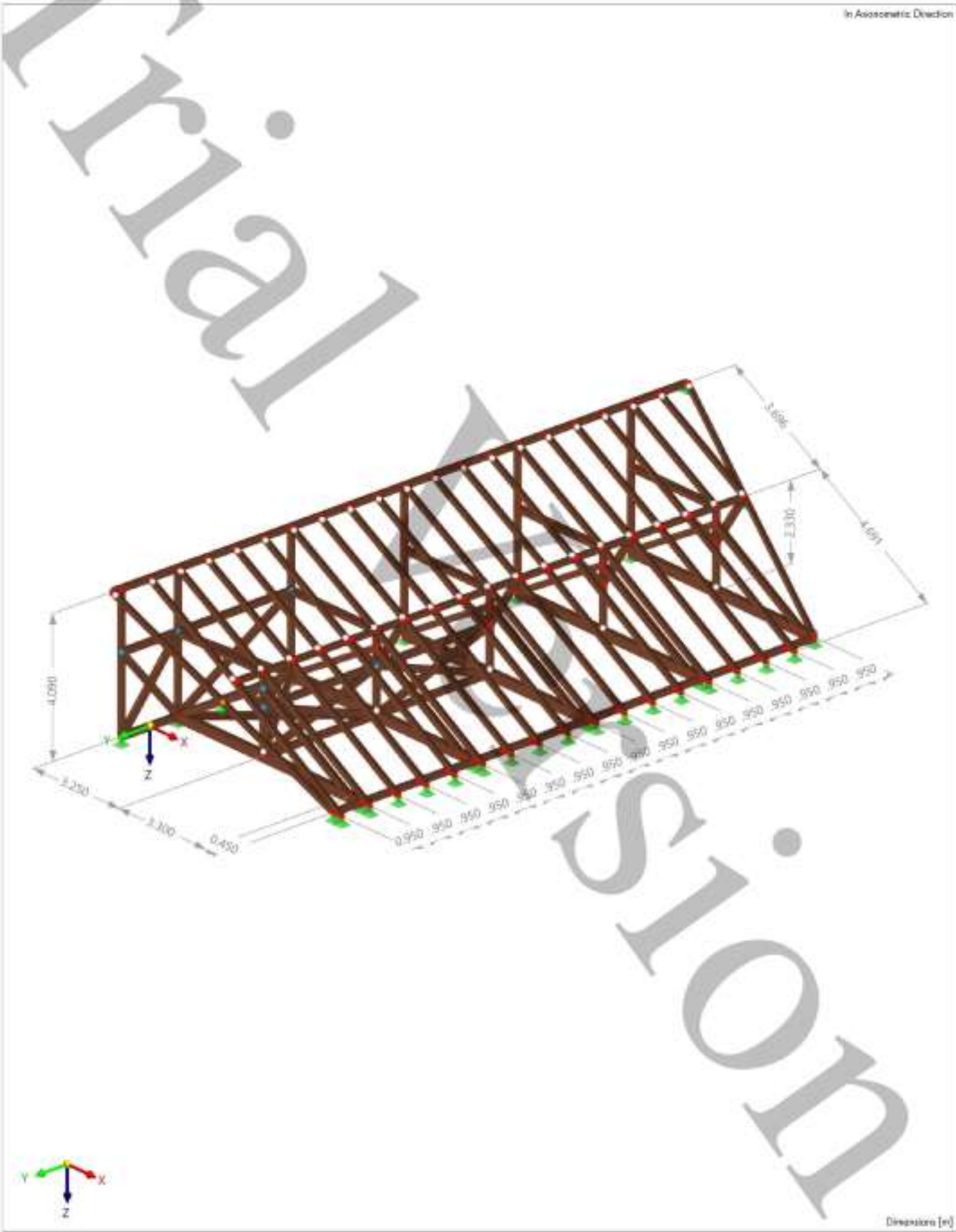
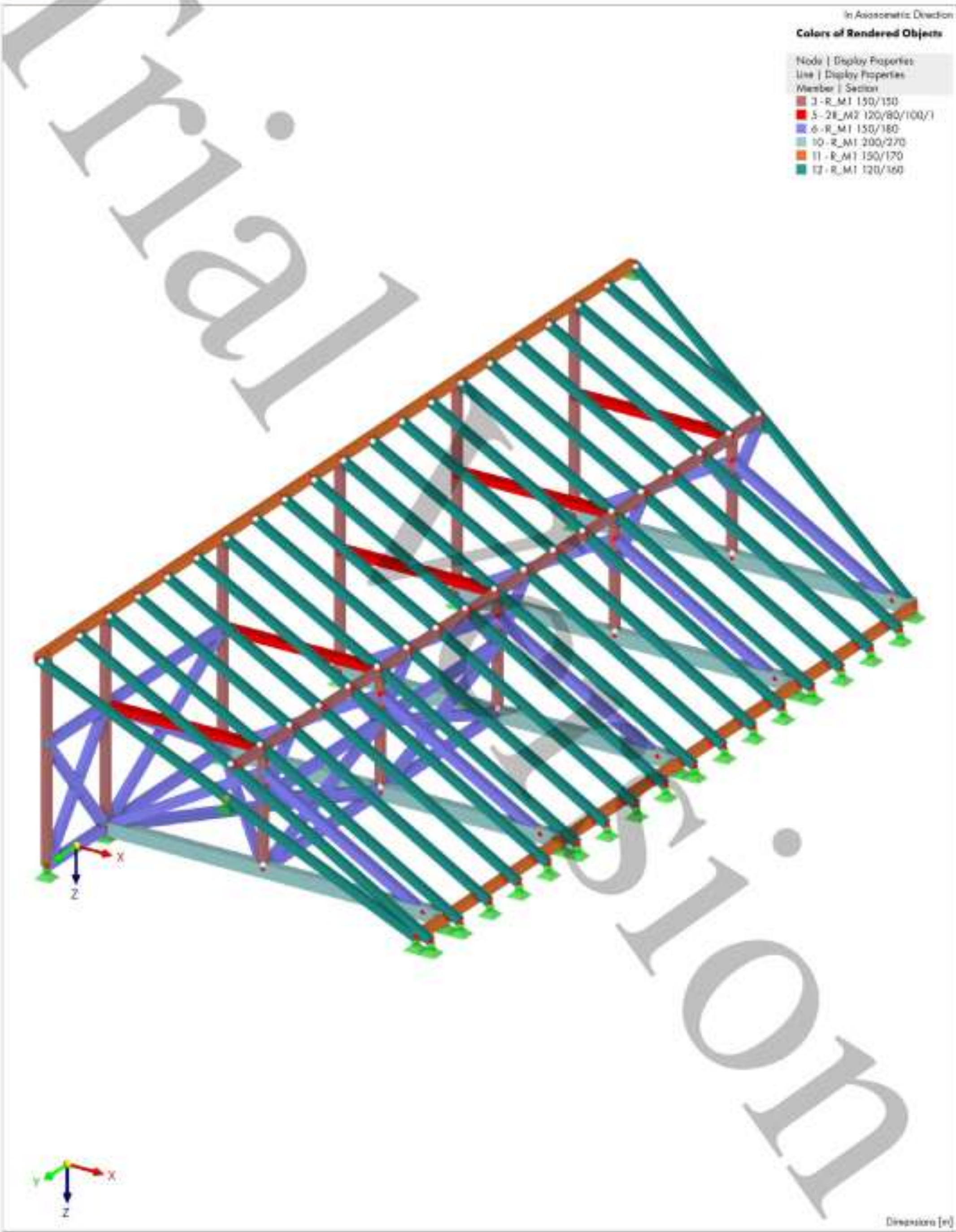
MODEL

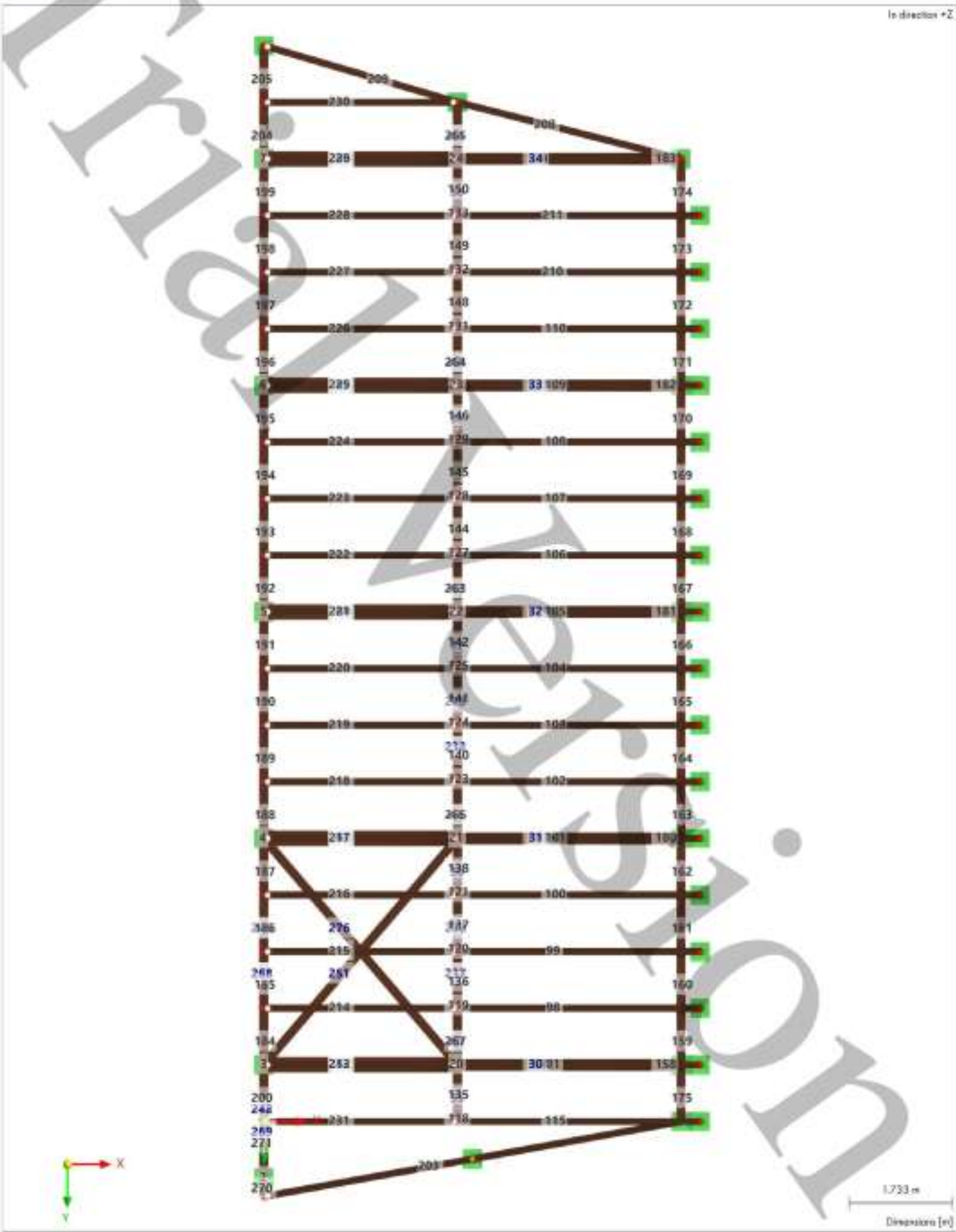
1.4 **DIMENZIJE**



1.5 POPREČNI PRESJECI



1.6 MEMBER SET - NUMBERING



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Dlubal

Model: Enia Klanac_1.zona krovišta - kopija (2)

2 Types for Nodes

2.1 NODAL SUPPORTS

Support No.	Nodes No.	Coordinate System	Translation Spring [kN/m] $C_{u,X}$	$C_{u,Y}$	$C_{u,Z}$	Rotation Spring [kNm/rad] $C_{\varphi,X}$	$C_{\varphi,Y}$	$C_{\varphi,Z}$
1	☑☑☑ ☐☐☑ | Hinged							
	71,141,145,149,153,158,172,183	1 - Global XYZ	☒	☒	☒	☐	☐	☒
2	☑☑☑ ☐☐☑							
	3,5,7,9,11,13,84,110-122,127,157,173,174	1 - Global XYZ	☒	☒	☒	☐	☐	☒

3 Types for Members

3.1 MEMBER HINGES

Hinge No.	Coordinate System	Translation Spring [kN/m] $C_{u,x}$	$C_{u,y}$	$C_{u,z}$	Rotation Spring [kNm/rad] $C_{\varphi,x}$	$C_{\varphi,y}$	$C_{\varphi,z}$
1	☐☐☐ ☐☑☑ | Local xyz						
	Local xyz	☐	☐	☐	☐	☒	☒

4 Types for Timber Design

4.1 SERVICE CLASSES

Class No.	Assigned to Members	Member Sets	Surfaces	Surface Sets	Service Class Type	Comment
1	Service Class 1 (Members : 2-7,20-44,81,98-110,115,118-121,123-125,127-129,131-133,135-138,140-142,144-146,148-150,152-200,203-205,208-211,213-234,237,238,241-244,248,251,258-276)					
	2-7,20-44,81,98-110,115,118-121,123-125,127-129,131-133,135-138,140-142,144-146,148-150,152-200,203-205,208-211,213-234,237,238,241-244,248,251,258-276				1 - Dry	

5 Load Cases & Combinations

5.1 LOAD CASES

LC No.	Settings	Value	Unit	To Solve
1	G Stalno			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	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		
2	Qs Snijeg			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Action category	Qs Snow/Ice loads - H <= 1000 m		
	Load duration	Short-term		
3	Qw Vjetar 1			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Action category	Qw Wind		
	Load duration	Short-term		

5.2 ACTIONS

Action No.	Settings	Value	Active
1	G Permanent		
	Action Category	G Permanent	☒
	Action Type	Simultaneously	
2	Qs Snow/Ice loads - H <= 1000 m		
	Action Category	Qs Snow/Ice loads - H <= 1000 m	☒
	Action Type	Alternatively	
3	Wind		
	Action Category	Wind	☒
	Action Type	Alternatively	

5.3 DESIGN SITUATIONS

DS No.	Settings	Value	Active
1	ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Design situation type	ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Combination wizard	1	
	Consider inclusive/exclusive load cases	☐	
2	S Ch SLS - Characteristic		
	Design situation type	S Ch SLS - Characteristic	☒
	Combination wizard	1	
	Consider inclusive/exclusive load cases	☐	
3	SLS - Quasi-permanent		
	Design situation type	SLS - Quasi-permanent	☒
	Combination wizard	1	
	Consider inclusive/exclusive load cases	☐	

5.4 ACTION COMBINATIONS

AC No.	Settings	Value	Active
1	1.35 * A1		
	Design Situation	DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	1	
	Generated by	Design Situation No. 1	
2	1.35 * A1 + 1.50 * A2		
	Design Situation	DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	2	
	Generated by	Design Situation No. 1	
3	1.35 * A1 + 1.50 * A2 + 0.90 * A3		
	Design Situation	DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	3	
	Generated by	Design Situation No. 1	
4	1.35 * A1 + 1.50 * A3		
	Design Situation	DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	4	
	Generated by	Design Situation No. 1	
5	1.35 * A1 + 0.75 * A2 + 1.50 * A3		
	Design Situation	DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	5	
	Generated by	Design Situation No. 1	
6	S Ch A1		
	Design Situation	S Ch DS2 - SLS - Characteristic	☒
	Generated load combinations	6	
	Generated by	Design Situation No. 2	
7	S Ch A1 + A2		
	Design Situation	S Ch DS2 - SLS - Characteristic	☒
	Generated load combinations	7	
	Generated by	Design Situation No. 2	
8	S Ch A1 + A2 + 0.60 * A3		
	Design Situation	S Ch DS2 - SLS - Characteristic	☒
	Generated load combinations	8	
	Generated by	Design Situation No. 2	

5.4 ACTION COMBINATIONS

AC No.	Settings	Value	Active
9	S Ch A1 + A3		
	Design Situation	S Ch DS2 - SLS - Characteristic	☒
	Generated load combinations	9	
	Generated by	Design Situation No. 2	
10	S Ch A1 + 0.50 * A2 + A3		
	Design Situation	S Ch DS2 - SLS - Characteristic	☒
	Generated load combinations	10	
	Generated by	Design Situation No. 2	
11	S Qp 1.60 * A1		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent	☒
	Generated load combinations	11	
	Generated by	Design Situation No. 3	
12	S Qp 1.60 * A1 + A2		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent	☒
	Generated load combinations	12	
	Generated by	Design Situation No. 3	
13	S Qp 1.60 * A1 + A2 + 0.60 * A3		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent	☒
	Generated load combinations	13	
	Generated by	Design Situation No. 3	
14	S Qp 1.60 * A1 + A3		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent	☒
	Generated load combinations	14	
	Generated by	Design Situation No. 3	
15	S Qp 1.60 * A1 + 0.50 * A2 + A3		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent	☒
	Generated load combinations	15	
	Generated by	Design Situation No. 3	

5.5 LOAD COMBINATIONS

CO No.	Settings	Value	Unit	To Solve
1	STR/G 1.35 * LC1			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	STR/G DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Structure modification	1		
	Load duration	Permanent		
2	STR/G 1.35 * LC1 + 1.50 * LC2			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	STR/G DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Structure modification	1		
	Load duration	Short-term		
3	STR/G 1.35 * LC1 + 1.50 * LC2 + 0.90 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	STR/G DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Structure modification	1		
	Load duration	Short-term		
4	STR/G 1.35 * LC1 + 1.50 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	STR/G DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Structure modification	1		
	Load duration	Short-term		
5	STR/G 1.35 * LC1 + 0.75 * LC2 + 1.50 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	STR/G DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Structure modification	1		
	Load duration	Short-term		
6	S Ch LC1			
	Analysis type	Static Analysis		☒

5.5 LOAD COMBINATIONS

CO No.	Settings	Value	Unit	To Solve
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Permanent		
7	S Ch LC1 + LC2			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Short-term		
8	S Ch LC1 + LC2 + 0.60 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Short-term		
9	S Ch LC1 + LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Short-term		
10	S Ch LC1 + 0.50 * LC2 + LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Short-term		
11	S Eq.ct 1.60 * LC1			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Eq.ct DS3 - SLS - Quasi-permanent		
	Load duration	Permanent		
12	S Eq.ct 1.60 * LC1 + LC2			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Eq.ct DS3 - SLS - Quasi-permanent		
	Load duration	Short-term		
13	S Eq.ct 1.60 * LC1 + LC2 + 0.60 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Eq.ct DS3 - SLS - Quasi-permanent		
	Load duration	Short-term		
14	S Eq.ct 1.60 * LC1 + LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Eq.ct DS3 - SLS - Quasi-permanent		
	Load duration	Short-term		
15	S Eq.ct 1.60 * LC1 + 0.50 * LC2 + LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1		
	Design Situation	S Eq.ct DS3 - SLS - Quasi-permanent		
	Load duration	Short-term		

5.6 STATIC ANALYSIS SETTINGS

Settings No.	Description	Symbol	Value	Unit
1	Geometrically linear			
	Analysis type		Geometrically linear	
	Modify standard precision and tolerance settings		☐	
	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		☐	
2	Second-order (P-Δ) | Picard | 100 | 1			
	Analysis type		Second-order (P-Δ)	

5.6 STATIC ANALYSIS SETTINGS

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

5.7 COMBINATION WIZARDS

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

6 Loads

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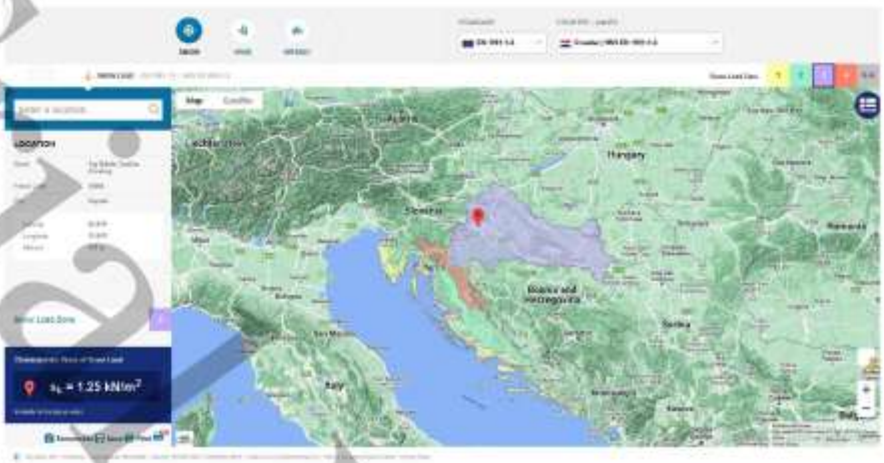
6.1.1 **SNIJEG.JPG**



6.2.1 **VJETAR.JPG**

6.3.1 OPTEREĆENJE.JPG

ANALIZA OPTEREĆENJA - Ministarstvo vanjskih poslova					
Pozicija		K1			
Opis pozicije		Krov			
Stalno opterećenje (g)	Sloj	Zapreminska težina [kg/m³]	Debljina sloja [cm]	Iznos površinskog opterećenja [kN/m²]	
1	Biber crijep			0,50	
2	Dodatno stalno			0,10	
	Ukupno:			0,60	
Promjenjivo opterećenje (q)	Položaj	Iznos opterećenja			
s	Snijeg	1,00		[kN/m²]	
w	Vjetar	Software			

Snijeg (s)

Područje:	3	kontinentalna Hrvatska	
Nadmorska visina:	122	[m.n.m.]	
α=	12	°	
s_k=	1,25	[kN/m²]	karakteristična vrijednost opterećenja snijegom na tlu
μ1(α)=	0,8		koeficijent oblika opterećenja snijegom
C_e =	1		koeficijent izloženosti
C_t =	1		toplinski koeficijent
s_d=	$\mu_{1(\alpha)} \cdot C_e \cdot C_t \cdot s_k$		
s_d=	1,00	[kN/m²]	

Vjetar (w)

c_{dir}=	1		koeficijent smjera vjetra
c_{season}=	1		koeficijent godišnjeg doba
$v_{b,0}$=	20	[m/s]	fundamentalna vrijednost osnovne brzine vjetra
v_b= $c_{dir} \cdot c_{season} \cdot v_{b,0}$		[m/s]	osnovna brzina vjetra
v_b=	20	[m/s]	
ρ=	1,25	[kg/m³]	gustoća zraka
*kategorija terena:	III		
$c_e(z)$=	1,9		koeficijent izloženosti
q_b= 1/2·ρ·v_b^2		[kN/m²]	osnovni pritisak vjetra
q_b=	0,25	[kN/m²]	
$c_{pe}(H)$=	-0,96		koeficijent vanjskog pritiska
$c_{pe}(I)$=	-0,76	[m²]	koeficijent vanjskog pritiska
c_{pi}=	0,2	[m²]	koeficijent unutarnjeg pritiska
$w_e(H)$= $q_b \cdot c_e(z) \cdot c_{pe} \cdot c_{dir} \cdot c_{season}$ =	-0,55	[kN/m²]	opterećenje vjetrom uključujući unutarnji pritisak
$w_e(H)$= $q_b \cdot c_e(z) \cdot c_{pe} \cdot c_{dir} \cdot c_{season}$ =	-0,46	[kN/m²]	opterećenje vjetrom bez unutarnjeg pritiska
$w_e(I)$= $q_b \cdot c_e(z) \cdot c_{pe} \cdot c_{dir} \cdot c_{season}$ =	-0,46	[kN/m²]	opterećenje vjetrom uključujući unutarnji pritisak
$w_e(I)$= $q_b \cdot c_e(z) \cdot c_{pe} \cdot c_{dir} \cdot c_{season}$ =	-0,36	[kN/m²]	opterećenje vjetrom bez unutarnjeg pritiska

USVOJENE VRIJEDNOSTI ZA SVE PLOHE (POJEDNOSTAVLJENO)

6.4.1 LC1: LOADING, IN AXONOMETRIC DIRECTION

6.5.1 LC2: LOADING, IN AXONOMETRIC DIRECTION

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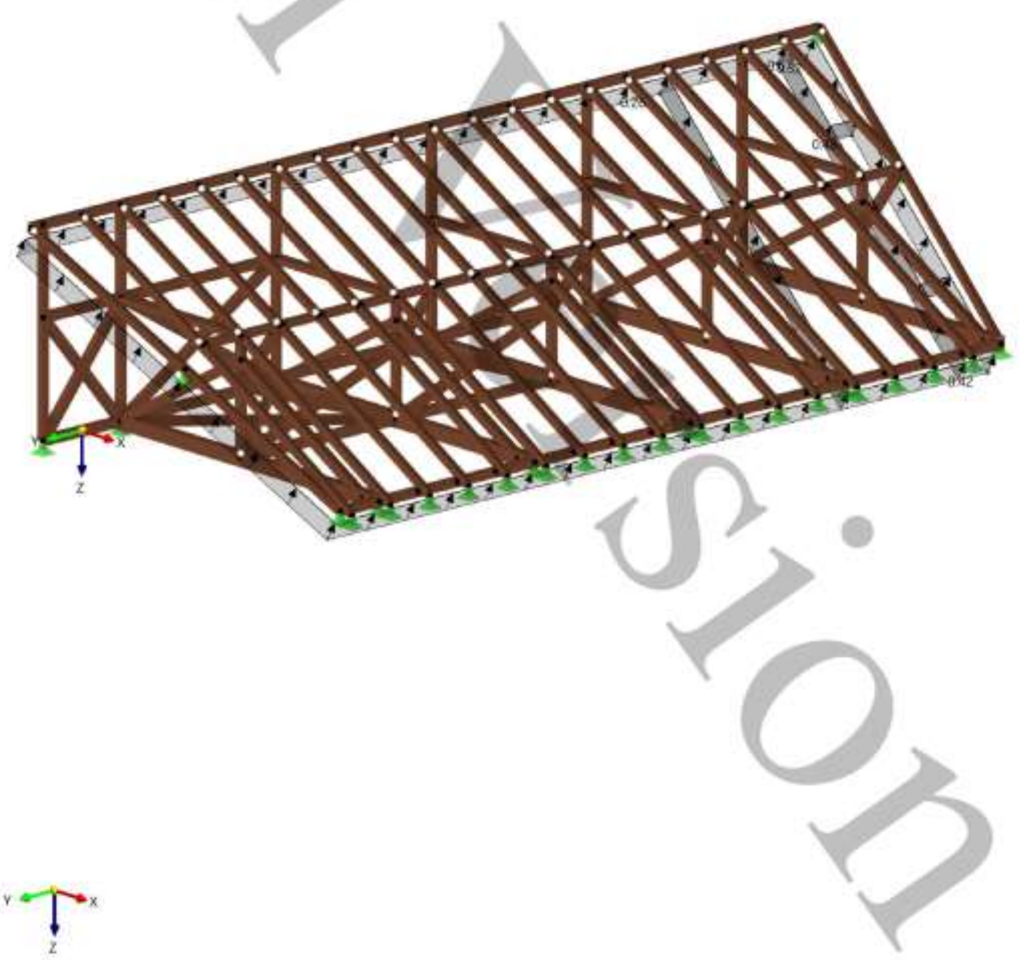
6.6.1 LC3: LOADING, IN AXONOMETRIC DIRECTION

LC3 - Vjetar 1
Loads [kN/m^2]

In Axonometric Direction



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7 Guide Objects

7.1 COORDINATE SYSTEMS

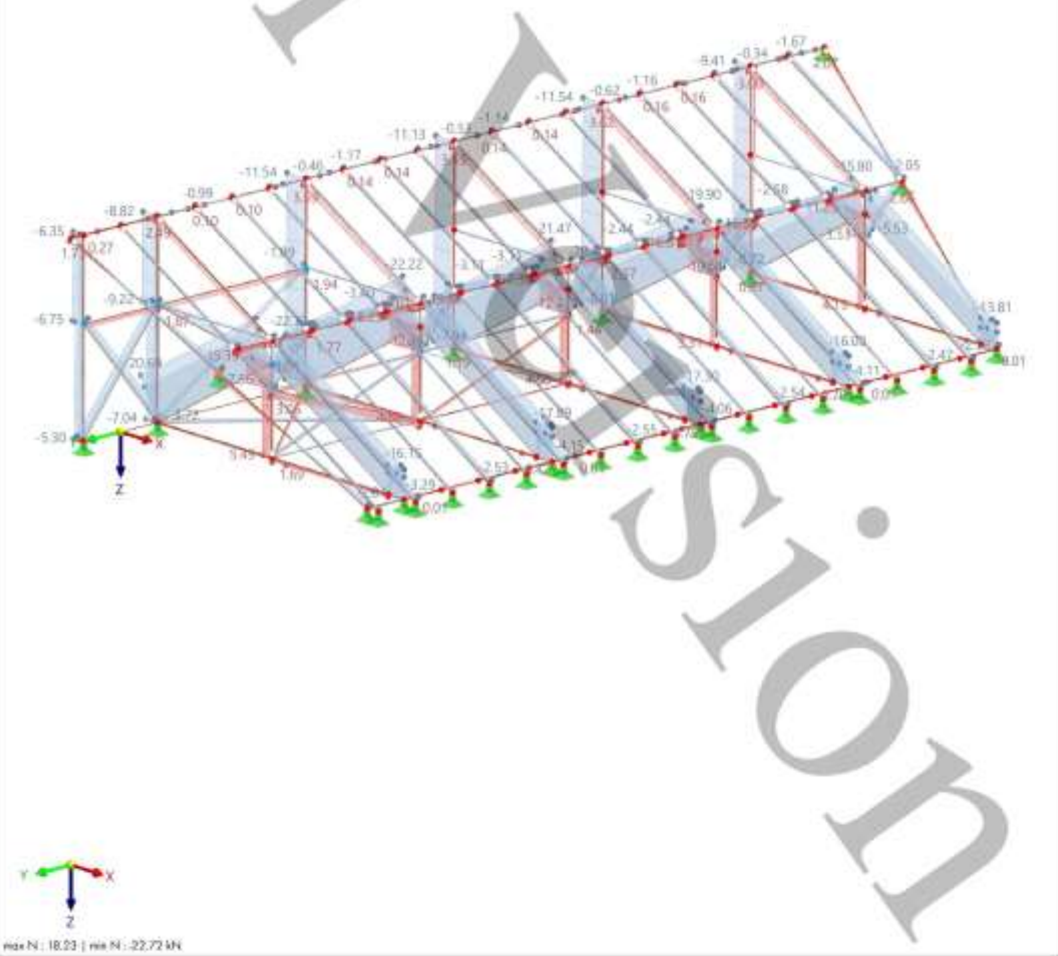
System No.	Type	Coordinates Symbol	Coordinates Value	Coordinates Unit	Rotation Sequence	Rotation Symbol	Rotation Value	Rotation Unit	Comment
1	Global XYZ								
2	3 Points | Load Wizard | Wind Load No. 1 | 0.000, -18.050, -4.090 m | 0.744, -17.543, -3.655 m | -0.504, -18.050, -3.227 m								
	3 Points	X_0	0.000	m					
		Y_0	-18.050	m					
		Z_0	-4.090	m					
		X_1	0.744	m					
		Y_1	-17.543	m					
		Z_1	-3.655	m					
		X_2	-0.504	m					
		Y_2	-18.050	m					
		Z_2	-3.227	m					

8 Static Analysis Results

8.1 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES N, IN AXONOMETRIC DIRECTION** **Static Analysis**

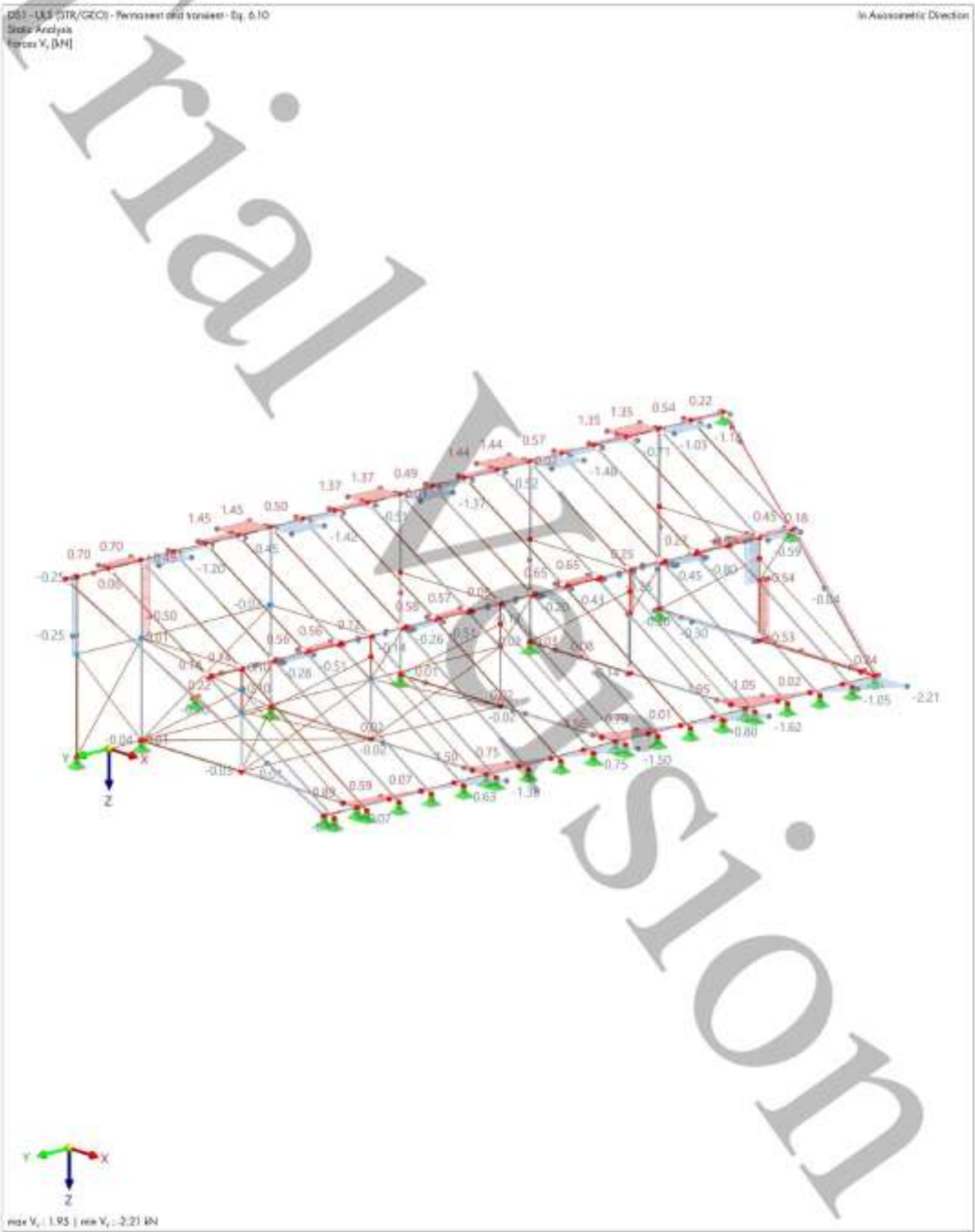
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Forces N [kN]

In Axonometric Direction



max N : 18.23 | min N : -22.72 kN

8.2 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES VY, IN AXONOMETRIC DIRECTION** **Static Analysis**



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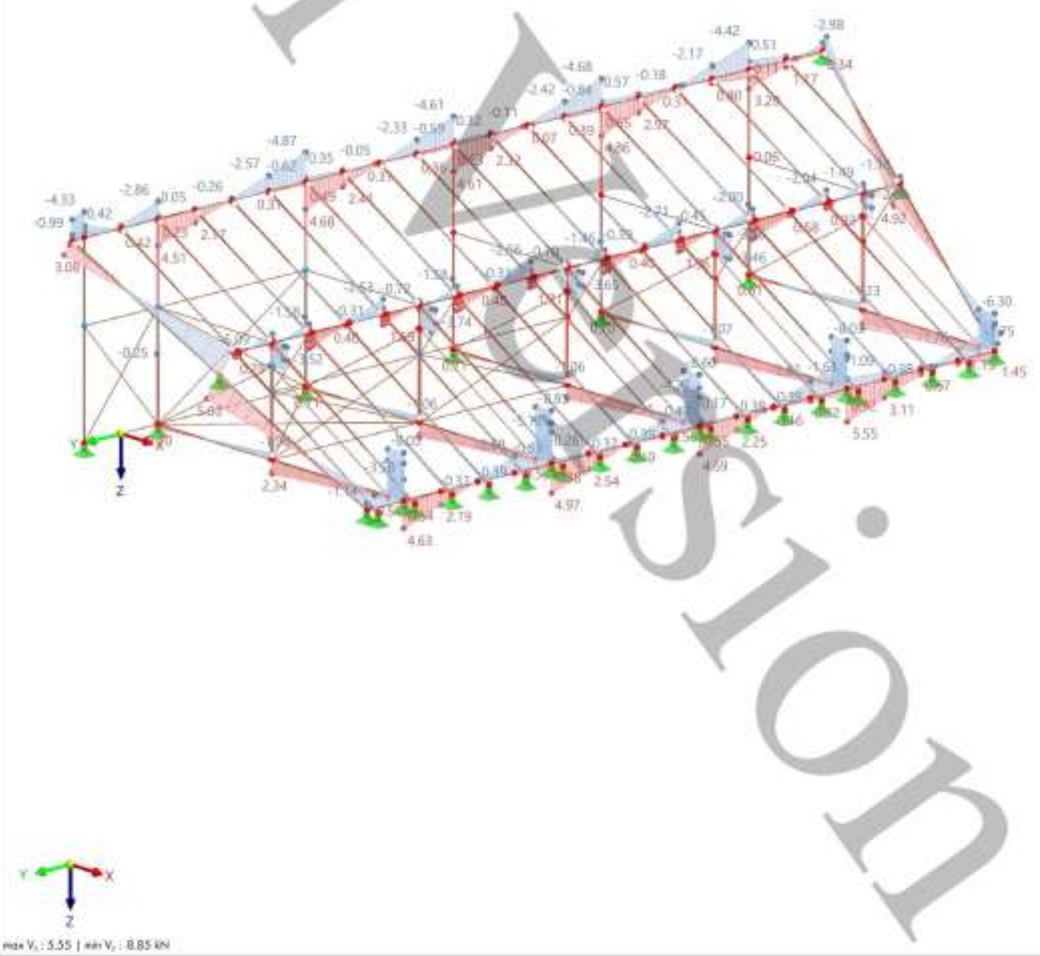
8.3 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES VZ, IN AXONOMETRIC DIRECTION** **Static Analysis**

DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Forces V_z [kN]

In Axonometric Direction



max V_z : 5.55 | min V_z : -8.85 kN

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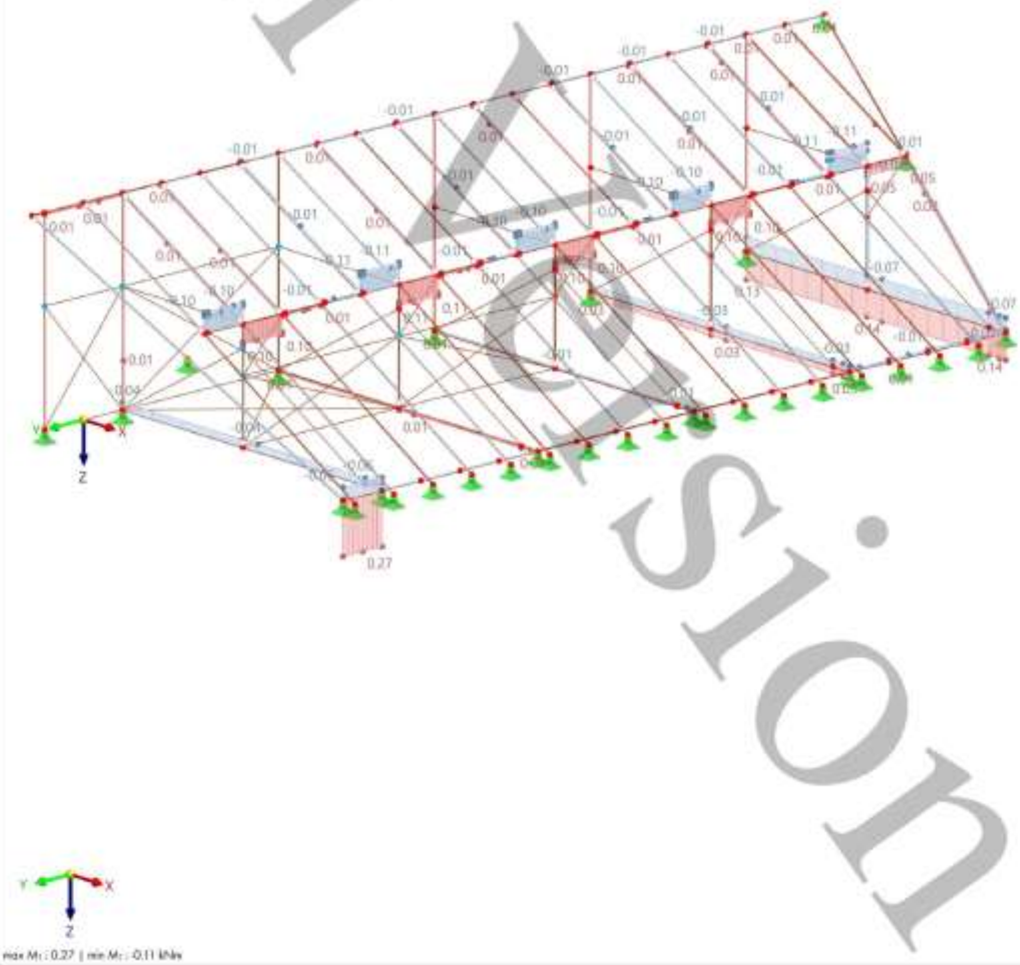
6.4 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES MT, IN AXONOMETRIC DIRECTION** **Static Analysis**

DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Moments M_T [kNm]

In Axonometric Direction

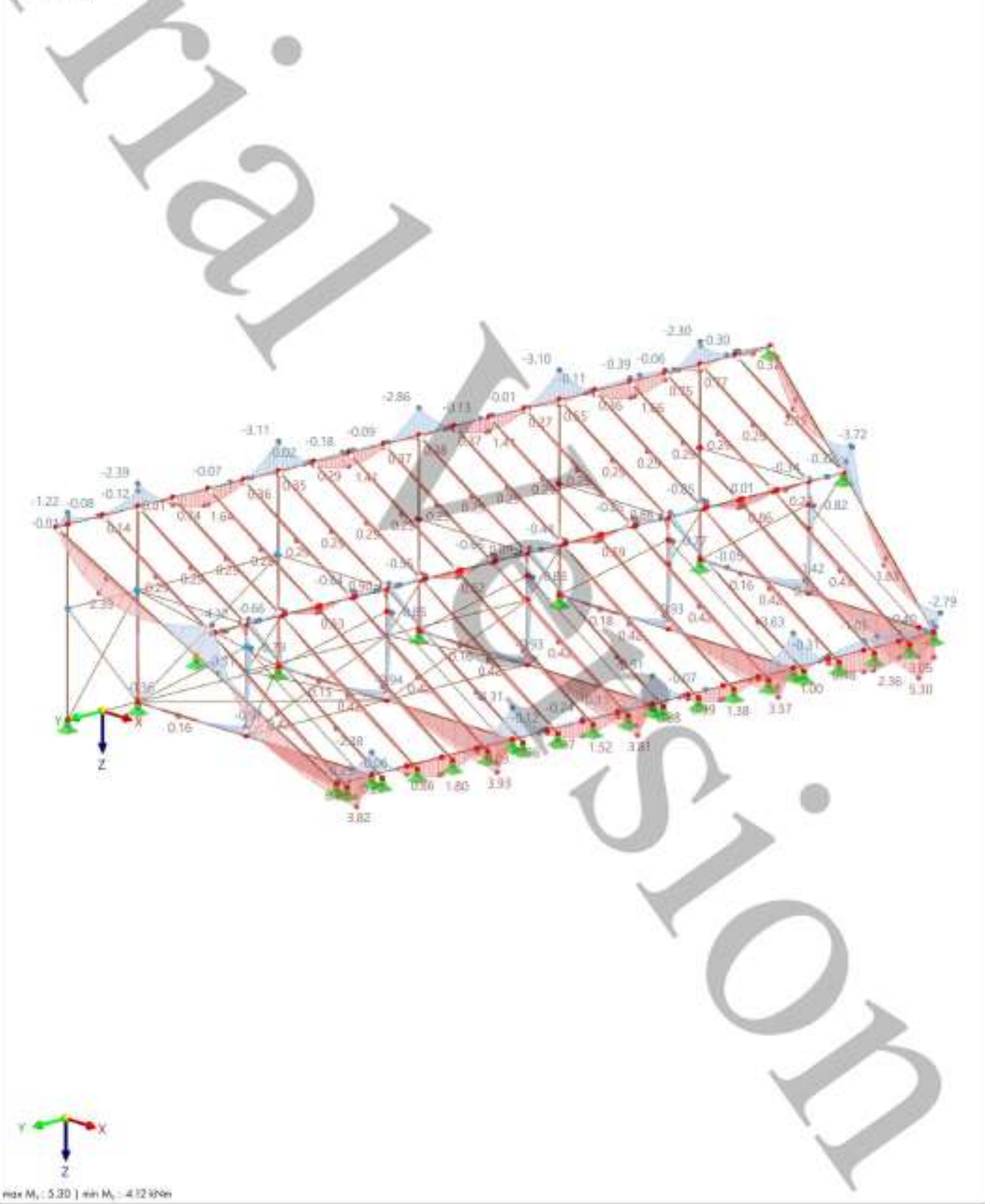


max M_T : 0.27 | min M_T : -0.11 kNm

8.5 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES MY, IN AXONOMETRIC DIRECTION** **Static Analysis**

DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Moments M_y [kNm]

In Axonometric Direction

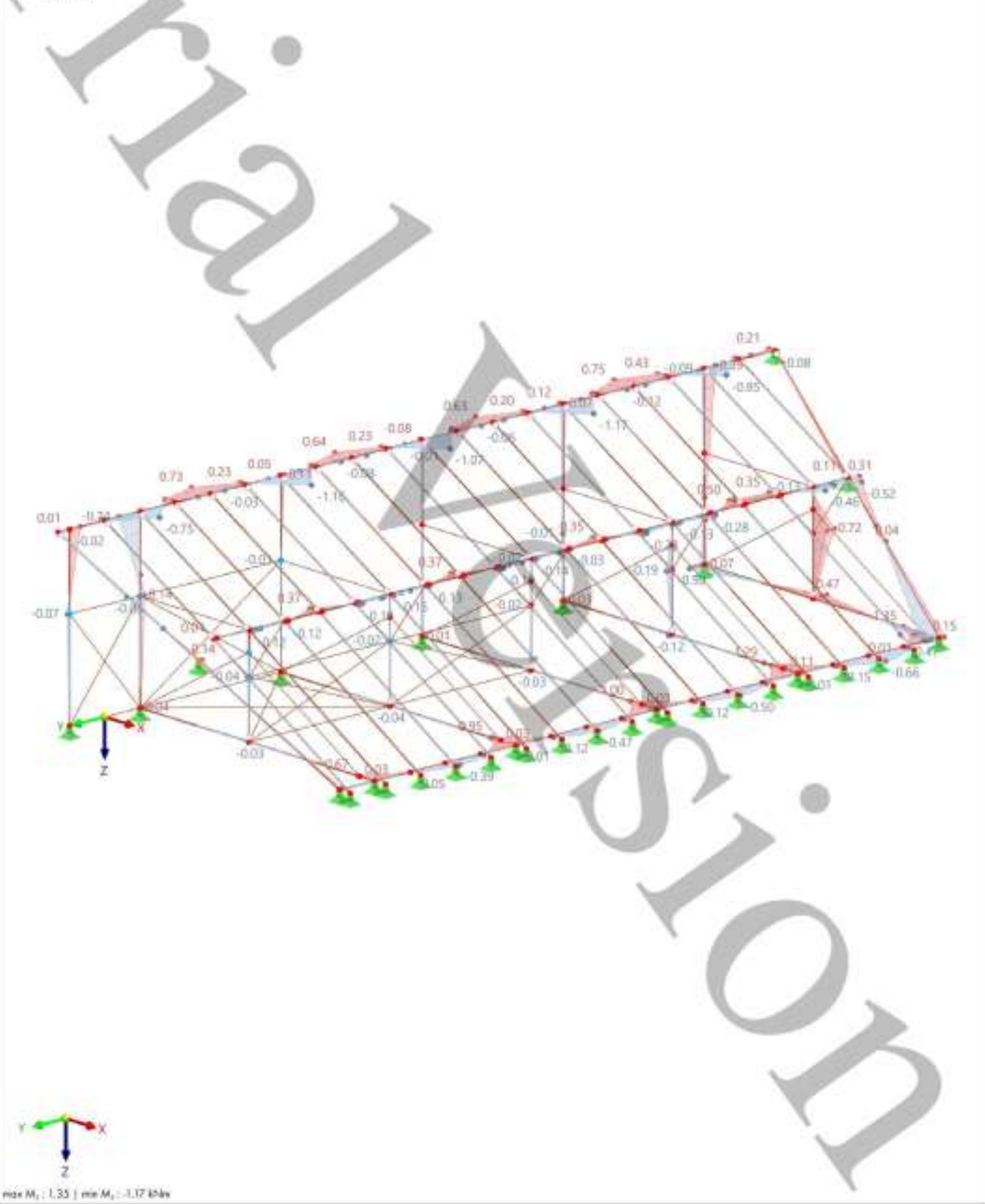


max M_y : 5.30 | min M_y : -4.12 kNm

8.6 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES MZ, IN AXONOMETRIC DIRECTION** **Static Analysis**

DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Moments M_z [kNm]

In Axonometric Direction

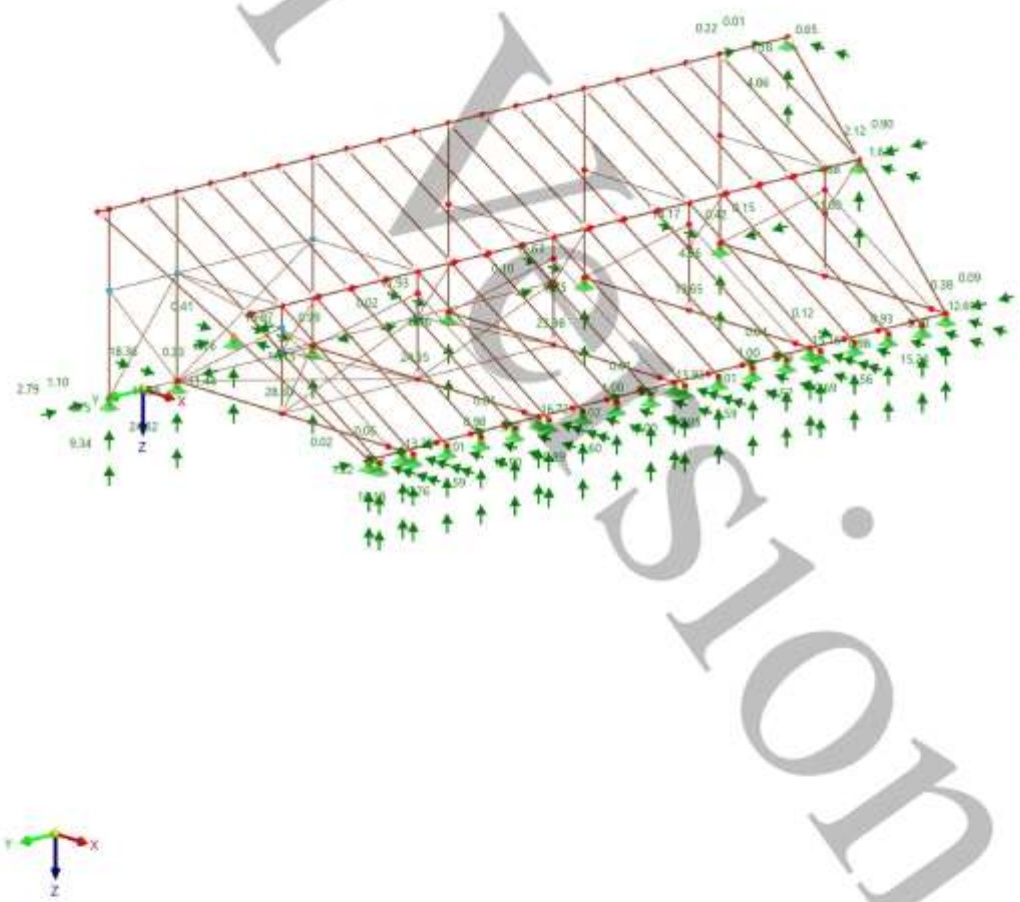


max M_z : 1.35 | min M_z : -1.17 kNm

8.7 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, NODAL SUPPORTS PX, NODAL SUPPORTS PY, NODAL SUPPORTS PZ, IN AXONOMETRIC DIRECTION** **Static Analysis**

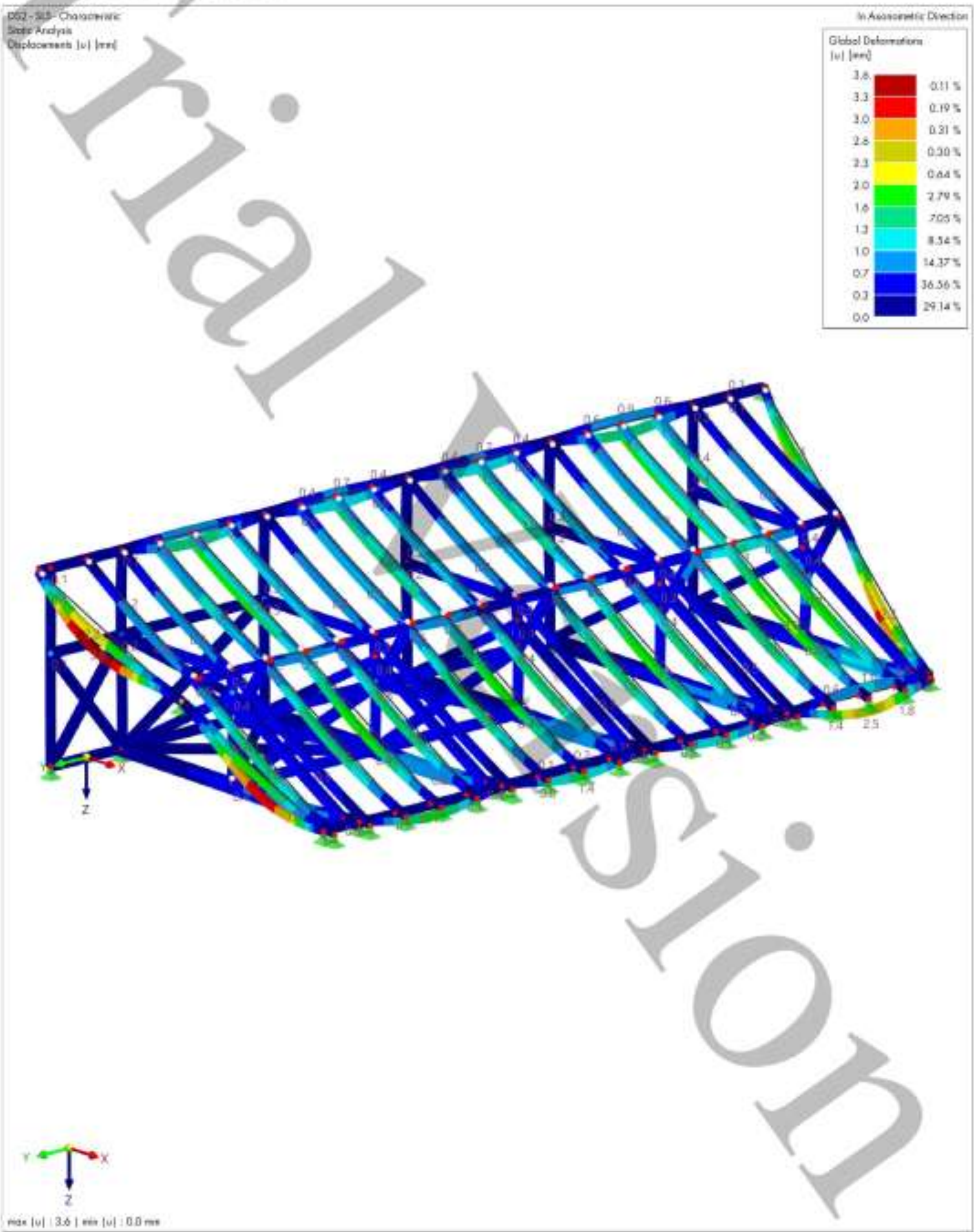
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Local Reaction Forces P_x, P_y, P_z [kN]

In Axonometric Direction



max P_x : 16.72 | min P_x : -18.36 kN
max P_y : 2.79 | min P_y : -2.12 kN
max P_z : 28.30 | min P_z : 0.36 kN

8.8 **DS2: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS IUI, IN AXONOMETRIC DIRECTION** **Static Analysis**



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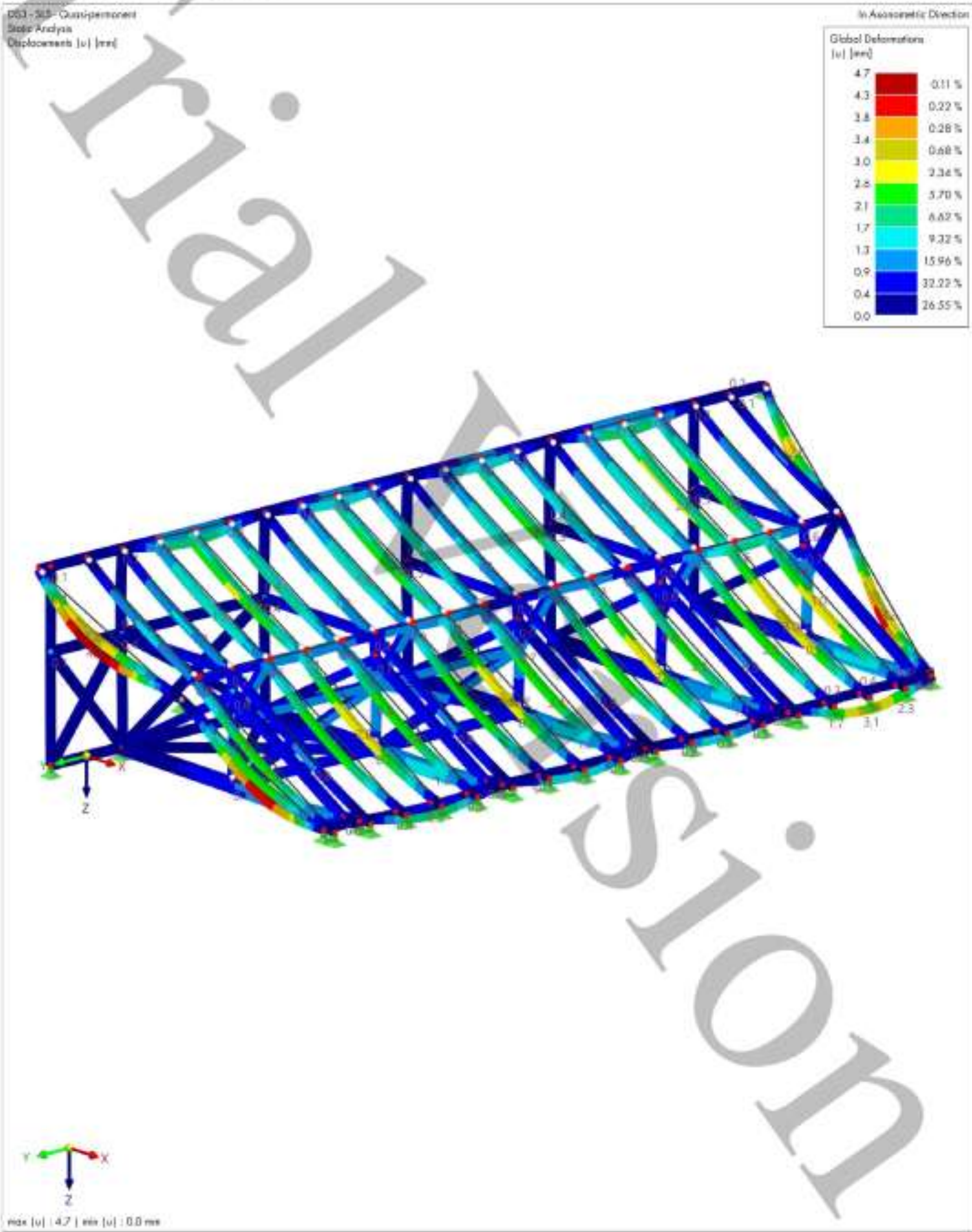
8.9 **DS3: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS IUI, IN AXONOMETRIC DIRECTION** — **Static Analysis**



9 Timber Design

9.1 OBJECTS TO DESIGN

Object Type	Design All	Objects to Design: Selected	To Calculate	Removed	Not Valid / Deact.	Comment
Members	☒	2-7,20-44,81,98-110,115,118-121,123-125,127-129,131-133,135-138,140-142,144-146,148-150,152-200,203-205,208-211,213-234,237,238,241-244,248,251,258-276	2-7,20-44,81,98-110,115,118-121,123-125,127-129,131-133,135-138,140-142,144-146,148-150,152-200,203-205,208-211,213-234,237,238,241-244,248,251,263-276		258-262	

9.2 DESIGN SITUATIONS

DS No.	EN 1990 | Timber | CEN | 2010-04 Design Situation Type	To Design	Active	EN 1995 | CEN | 2014-05 Design Situation Type	Combinations to Design for Enumeration Method
1	ULS ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒	☒	ULS ULS (STR/GEO) - Permanent and transient	All
2	S Ch SLS - Characteristic	☒	☒	S Ch SLS - Characteristic	All
3	S Qp SLS - Quasi-permanent	☒	☒	S Qp1 SLS - Quasi-permanent 1	All

9.3 MATERIALS

Legend
Stiffness modification

Material No.	Name	To Design	Material Type	Options	Comment
1	D50	☒	Timber		

9.4 SECTIONS

Legend
Warping stiffness deactivated

Section No.	Name	Material	To Design	Section Type	Use Other Section for Design	Options
1	R_M1 160/220	1	☒	Parametric - Massive I	--	
2	R_M1 160/160	1	☒	Parametric - Massive I	--	
3	R_M1 150/150	1	☒	Parametric - Massive I	--	
4	R_M1 120/150	1	☒	Parametric - Massive I	--	
5	2R_M2 120/80/100/1	1	☒	Parametric - Massive II	--	
6	R_M1 150/180	1	☒	Parametric - Massive I	--	
7	R_M1 160/120	1	☒	Parametric - Massive I	--	
8	R_M1 270/200	1	☒	Parametric - Massive I	--	
9	R_M1 170/150	1	☒	Parametric - Massive I	--	
10	R_M1 200/270	1	☒	Parametric - Massive I	--	
11	R_M1 150/170	1	☒	Parametric - Massive I	--	
12	R_M1 120/160	1	☒	Parametric - Massive I	--	

9.5 ULTIMATE CONFIGURATIONS

Config. No.	Name	Assigned to: Members	Member Sets	Surfaces	Surface Sets
1	Default	All	All	All	All

9.5.1 ULTIMATE CONFIGURATIONS - SETTINGS - MEMBERS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	General			
	☒ Perform stability design			
	Limit Values for Special Cases			
	Tension ($\sigma_{t,0,d}$ / $f_{t,0,d}$)	$\eta_{t,lim}$	0.001	--
	Compression ($\sigma_{c,0,d}$ / $f_{c,0,d}$)	$\eta_{c,lim}$	0.001	--
	Shear ($\tau_{y,d}$ / $f_{v,d}$)	$\eta_{v,y,lim}$	0.001	--
	Shear ($\tau_{z,d}$ / $f_{v,d}$)	$\eta_{v,z,lim}$	0.001	--
	Torsion ($\tau_{tor,d}$ / $f_{v,d}$)	$\eta_{tor,lim}$	0.010	--
	Bending ($\sigma_{m,y,d}$ / $f_{m,d}$)	$\eta_{m,y,lim}$	0.001	--
	Bending ($\sigma_{m,z,d}$ / $f_{m,d}$)	$\eta_{m,z,lim}$	0.001	--
	Curved and Saddle Members			
	☒ Perpendicular tension design of curved members			
	☒ Perpendicular tension design of saddle members			

9.5.1 ULTIMATE CONFIGURATIONS - SETTINGS - MEMBERS

Config. No.	Description	Symbol	Value	Unit
	Cut-to-Grain Angle Limit			
	Allow further design if angle does not exceed limit	$\lvert\alpha\rvert \le$	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)			

9.6 SERVICEABILITY CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets
1	Default	All	All	All	All

9.6.1 SERVICEABILITY CONFIGURATIONS - SETTINGS - MEMBERS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	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_{lim}	5.0	mm

9.7 FIRE RESISTANCE CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Surfaces	Surface Sets
1	Default	All	All	All	All

9.7.1 FIRE RESISTANCE CONFIGURATIONS - SETTINGS - MEMBERS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Fire Design Settings			
	Required time of fire resistance	t	15	min
	Fire exposure (not for circular sections)			
	☒ Top (-z)			
	☒ Left (-y)			
	☒ Right (+y)			
	☒ Bottom (+z)			

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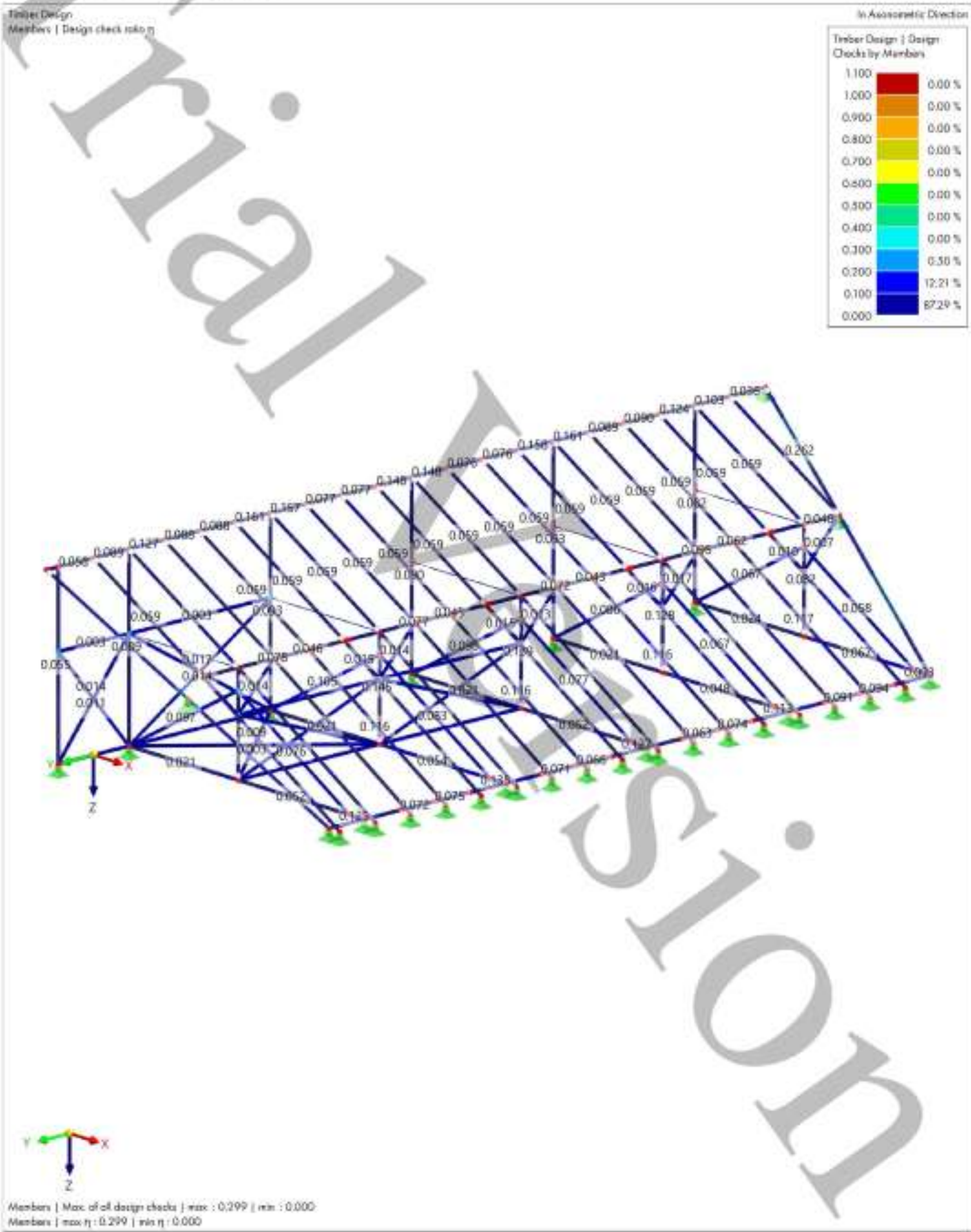
MODEL

9.8.1 TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, MAX. OF ALL DESIGN CHECKS, IN AXONOMETRIC DIRECTION

Timber Design



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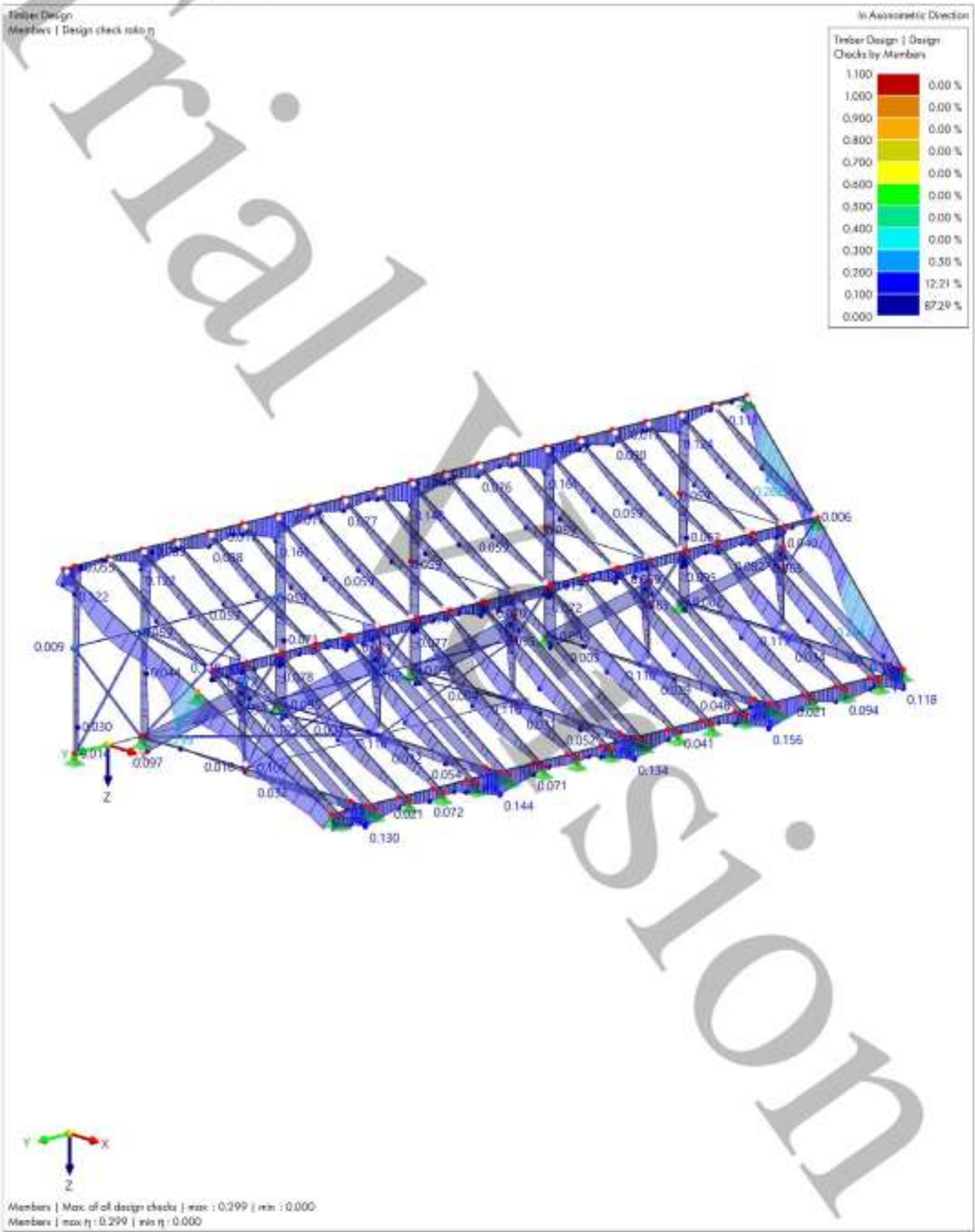
Model: Enia Klanac_1.zona krovišta - kopija (2)

9.8.2 TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, MAX. OF ALL DESIGN CHECKS, IN AXONOMETRIC DIRECTION

Timber Design



9.8.3 **TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, MAX. OF ALL DESIGN CHECKS, IN AXONOMETRIC DIRECTION** **Timber Design**

Timber Design
Members | Design check ratio η

In Axonometric Direction

Members | Max. of all design checks | max : 0.299 | min : 0.000
Members | max η : 0.299 | min η : 0.000

9.9 **MEMBER NO. 203 | DS3 | CO12 | 5.926 M | SE1200.02** **Timber Design**

Design Check SE1200.02 | EN 1995 | CEN | 2014-05

Serviceability
Combination of actions 'Quasi-permanent 1' | z-direction acc. to 7.2

Segment type in z-axis: Beam

$$w_{net,fin,z} = w_{fin,z} - w_{c,x,z} = 4.1\,\text{mm} - 0.0\,\text{mm} = 4.1\,\text{mm}$$

$$w_{net,fin,limit,z} = \frac{l}{l/w_{net,fin,limit,z}} = \frac{8.205\,\text{m}}{250.00} = 32.8\,\text{mm}$$

$$\eta = \frac{|w_{net,fin,z}|}{w_{net,fin,limit,z}} = \frac{|4.1\,\text{mm}|}{32.8\,\text{mm}} = 0.126$$ 7.2

$\eta = 0.126 \leq 1$ ✓

$w_{net,fin,z}$	Net final deflection
$w_{fin,z}$	Deflection
$w_{c,x,z}$	Precamber at x-location
$w_{net,fin,limit,z}$	Limit value of deflection
l	Reference length
$l / w_{net,fin,limit,z}$	Limit value criterion

9.10 MEMBER NO. 7 | DS3 | CO12 | 2.337 M | SE1100.02

Timber Design

Design Check SE1100.02 | EN 1995 | CEN | 2014-05

Serviceability
Combination of actions 'Quasi-permanent 1' | y-direction acc. to 7.2

Segment type in y-axis: Beam

$$w_{net,fin,y} = w_{fin,y} - w_{c,x,y} = -0.5\text{ mm} - 0.0\text{ mm} = -0.5\text{ mm}$$

$$w_{net,fin,limit,y} = \frac{l}{1/w_{net,fin,limit,y}} = \frac{4.000\text{ m}}{250.00} = 16.4\text{ mm}$$

$$\eta = \frac{|w_{net,fin,y}|}{w_{net,fin,limit,y}} = \frac{|-0.5\text{ mm}|}{16.4\text{ mm}} = 0.028$$

7.2

$\eta = 0.028 \leq 1$ ✓

$w_{net,fin,y}$	Net final deflection
$w_{fin,y}$	Deflection
$w_{c,x,y}$	Precamber at x-location
$w_{net,fin,limit,y}$	Limit value of deflection
l	Reference length
$1 / w_{net,fin,limit,y}$	Limit value criterion

Enia Klanac
Obala kralja P. Krešimira IV., 23450 Obrovac

Model: Enia Klanac_1.zona krovišta – kopija (2)

9.11 MEMBER NO. 203 | D52 | CO7 | 5.926 M | SE1200.01

Timber Design

Design Check SE1200.01 | EN 1995 | CEN | 2014-05

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

Segment type in z-axis: Beam

$$w_{inst,limit,z} = \frac{l}{l/w_{inst,limit,z}} = \frac{8.205\ \text{m}}{300.00} = 27.3\ \text{mm}$$

$$\eta = \frac{|w_{inst,z}|}{w_{inst,limit,z}} = \frac{|3.2\ \text{mm}|}{27.3\ \text{mm}} = 0.118 \quad 7.2$$

$$\eta = 0.118 \leq 1 \ ✓$$

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

9.12 MEMBER NO. 7 | DS2 | CO7 | 2.337 M | SE1100.01

Timber Design

Design Check SE1100.01 | EN 1995 | CEN | 2014-05

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

Segment type in y-axis: Beam

$$w_{inst,limit,y} = \frac{l}{l/w_{inst,limit,y}} = \frac{4.080\ \text{m}}{300.00} = 13.6\ \text{mm}$$

$$\eta = \frac{|w_{inst,y}|}{w_{inst,limit,y}} = \frac{|-0.3\ \text{mm}|}{13.6\ \text{mm}} = 0.025 \qquad 7.2$$

$$\eta = 0.025 \le 1 ✓$$

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

9.13 MEMBER NO. 203 | DS1 | CO2 | 4.102 M | STRESS POINT NO. 1 | ST3100 — Timber Design

Design Check ST3100 | EN 1995 | CEN | 2014-05

Stability
Bending about y-axis and compression acc. to 6.3.3

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\,N/mm^2}{1.30} = 20.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\,N/mm^2}{1.30} = 34.615\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{8.205\,m}{34.6\,mm} = 236.85$$

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{236.85}{\pi} \cdot \sqrt{\frac{30.000\,N/mm^2}{11800.0\,N/mm^2}} = 3.80$$ 6.3.2, Eq. 6.22

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot (\lambda_{rel,z} - 0.3) + (\lambda_{rel,z})^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (3.80 - 0.3) + (3.80)^2\right) = 8.08$$ 6.3.2, Eq. 6.28

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - (\lambda_{rel,z})^2}} = \frac{1}{8.08 + \sqrt{(8.08)^2 - (3.80)^2}} = 0.07$$ 6.3.2, Eq. 6.26

$$\sigma_{m,crit} = \frac{\pi \cdot \sqrt{E_{0,05,z} \cdot I_z \cdot G_{05} \cdot I_t}}{L_{cr} \cdot W_y} = \frac{\pi \cdot \sqrt{11800.0\,N/mm^2 \cdot 2304.00\,cm^4 \cdot 741.8\,N/mm^2 \cdot 4976.26\,cm^4}}{8.525\,m \cdot 512.00\,cm^3} = 72.108\,N/mm^2$$ 6.3.3, Eq. 6.31

$$\lambda_{rel,m} = \sqrt{\frac{f_{m,y,k}}{\sigma_{m,crit}}} = \sqrt{\frac{50.000\,N/mm^2}{72.108\,N/mm^2}} = 0.83$$ 6.3.3, Eq. 6.30

$0.75 < \lambda_{rel,m} <= 1.4$

$$k_{crit} = 1.56 - 0.75 \cdot \lambda_{rel,m} = 1.56 - 0.75 \cdot 0.83 = 0.94$$ 6.3.3, Eq. 6.34

$$\eta = \left| -\left(\frac{\sigma_{m,y,d}}{k_{crit} \cdot f_{m,y,d}}\right)^2 + \frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} \right| = \left| -\left(\frac{-28.309\,N/mm^2}{0.94 \cdot 34.615\,N/mm^2}\right)^2 + \frac{-0.029\,N/mm^2}{0.07 \cdot 20.769\,N/mm^2} \right| = 0.785$$ 6.3.3, Eq. 6.35

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Model: Enia Klanac_1.zona krovišta – kopija (2)

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MODEL

9.13 **MEMBER NO. 203 | DS1 | CO2 | 4.102 M | STRESS POINT NO. 1 | ST3100** **Timber Design**

η = 0.985 ≤ 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_z	Slenderness ratio
$L_{cr,z}$	Equivalent member length
i_z	Radius of gyration
$\lambda_{rel,z}$	Relative slenderness ratio
$E_{0,05,z}$	Modulus of elasticity
k_z	Instability factor
β_c	Straightness factor
$k_{c,z}$	Instability factor
$\sigma_{m,crit}$	Critical bending stress
I_z	Moment of inertia
G_{05}	Shear modulus
I_t	Torsional constant
L_{cr}	Equivalent member length
W_y	Elastic section modulus to more compressed edge
$\lambda_{rel,m}$	Relative slenderness ratio
k_{crit}	Lateral buckling coefficient
$\sigma_{m,y,d}$	Design bending stress
$\sigma_{c,0,d}$	Design compressive stress

9.14 **MEMBER NO. 203 | D51 | CO2 | 3.861 M | LEFT SIDE | STRESS POINT NO. 1 | ST2100** **Timber Design**

Design Check ST2100 | EN 1995 | CEN | 2014-05

Stability
Flexural member without compression force | Bending about y-axis acc. to 6.3.3

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\,N/mm^2}{1.30} = 34.615\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\sigma_{m,crit} = \frac{\pi \cdot \sqrt{E_{0,05,z} \cdot I_z \cdot G_{05} \cdot I_t}}{L_{cr} \cdot W_y} = \frac{\pi \cdot \sqrt{11800.0\,N/mm^2 \cdot 2304.00\,cm^4 \cdot 741.8\,N/mm^2 \cdot 4976.26\,cm^4}}{8.525\,m \cdot 512.00\,cm^3} = 72.108\,N/mm^2$$ 6.3.3, Eq. 6.31

$$\lambda_{rel,m} = \sqrt{\frac{f_{m,y,k}}{\sigma_{m,crit}}} = \sqrt{\frac{50.000\,N/mm^2}{72.108\,N/mm^2}} = 0.83$$ 6.3.3, Eq. 6.30

$0.75 < \lambda_{rel,m} <= 1.4$

$$k_{crit} = 1.56 - 0.75 \cdot \lambda_{rel,m} = 1.56 - 0.75 \cdot 0.83 = 0.94$$ 6.3.3, Eq. 6.34

$$\eta = \frac{|\sigma_{m,y,d}|}{k_{crit} \cdot f_{m,y,d}} = \frac{|-28.398\,N/mm^2|}{0.94 \cdot 34.615\,N/mm^2} = 0.877$$ 6.3.3, Eq. 6.33

$$\eta = 0.877 \leq 1 \checkmark$$

$f_{m,y,d}$	Design bending strength
k_{mod}	Modification factor
$f_{m,y,k}$	Characteristic bending strength
γ_M	Partial factor
$\sigma_{m,crit}$	Critical bending stress
$E_{0,05,z}$	Modulus of elasticity
I_z	Moment of inertia
G_{05}	Shear modulus
I_t	Torsional constant
L_{cr}	Equivalent member length
W_y	Elastic section modulus to more compressed edge
$\lambda_{rel,m}$	Relative slenderness ratio
k_{crit}	Lateral buckling coefficient
$\sigma_{m,y,d}$	Design bending stress

Enia Klanac
Obala kralja P. Krešimira IV., 23450 Obrovac

9.15 MEMBER NO. 203 | DS1 | CO2 | 4.102 M | STRESS POINT NO. 3 | ST1600.03 — Timber Design

Design Check ST1600.03 | EN 1995 | CEN | 2014-05

Stability
Biaxial bending and compression with buckling about both axes acc. to 6.3.2

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\ \mathrm{N/mm^2}}{1.30} = 20.769\ \mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\ \mathrm{N/mm^2}}{1.30} = 34.615\ \mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\ \mathrm{N/mm^2}}{1.30} = 34.615\ \mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{8.205\ \mathrm{m}}{46.2\ \mathrm{mm}} = 177.64$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{8.205\ \mathrm{m}}{34.6\ \mathrm{mm}} = 236.85$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0.05,y}}} = \frac{177.64}{\pi} \cdot \sqrt{\frac{30.000\ \mathrm{N/mm^2}}{11800.0\ \mathrm{N/mm^2}}} = 2.85$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0.05,z}}} = \frac{236.85}{\pi} \cdot \sqrt{\frac{30.000\ \mathrm{N/mm^2}}{11800.0\ \mathrm{N/mm^2}}} = 3.80$$ 6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,y} - 0.3\right) + \left(\lambda_{rel,y}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (2.85 - 0.3) + (2.85)^2\right) = 4.82$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,z} - 0.3\right) + \left(\lambda_{rel,z}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (3.80 - 0.3) + (3.80)^2\right) = 8.08$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - \left(\lambda_{rel,y}\right)^2}} = \frac{1}{4.82 + \sqrt{(4.82)^2 - (2.85)^2}} = 0.11$$ 6.3.2, Eq. 6.25

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9.15 MEMBER NO. 203 | DS1 | CO2 | 4.102 M | STRESS POINT NO. 3 | ST1600.03

Timber Design

6.3.2, Eq. 6.26

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - (\lambda_{rel,z})^2}} = \frac{1}{8.08 + \sqrt{(8.08)^2 - (3.80)^2}} = 0.07$$

Eq. 6.23

$$\eta_1 = \left| \frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| \frac{-0.029\,N/mm^2}{0.11 \cdot 20.769\,N/mm^2} + \frac{-28.309\,N/mm^2}{34.615\,N/mm^2} + 0.70 \cdot \frac{-0.912\,N/mm^2}{34.615\,N/mm^2} \right| = 0.848$$

Eq. 6.24

$$\eta_2 = \left| \frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| \frac{-0.029\,N/mm^2}{0.07 \cdot 20.769\,N/mm^2} + 0.70 \cdot \frac{-28.309\,N/mm^2}{34.615\,N/mm^2} + \frac{-0.912\,N/mm^2}{34.615\,N/mm^2} \right| = 0.620$$

6.3.2

$$\eta = \max(\eta_1, \eta_2) = \max(0.848, 0.620) = 0.848$$

$$\eta = 0.848 \leq 1 \checkmark$$

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

9.16 MEMBER NO. 7 | DS1 | CO2 | 1.398 M | STRESS POINT NO. 1 | ST1600.02 — Timber Design

Design Check ST1600.02 | EN 1995 | CEN | 2014-05

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\ N/mm^2}{1.30} = 20.769\ N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\ N/mm^2}{1.30} = 34.615\ N/mm^2$$ 2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{4.090\ m}{43.3\ mm} = 94.45$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{4.090\ m}{43.3\ mm} = 94.45$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}} = \frac{94.45}{\pi} \cdot \sqrt{\frac{30.000\ N/mm^2}{11800.0\ N/mm^2}} = 1.52$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{94.45}{\pi} \cdot \sqrt{\frac{30.000\ N/mm^2}{11800.0\ N/mm^2}} = 1.52$$ 6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,y} - 0.3\right) + \left(\lambda_{rel,y}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (1.52 - 0.3) + (1.52)^2\right) = 1.77$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot (\lambda_{rel,z} - 0.3) + (\lambda_{rel,z})^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (1.52 - 0.3) + (1.52)^2\right) = 1.77$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - \left(\lambda_{rel,y}\right)^2}} = \frac{1}{1.77 + \sqrt{(1.77)^2 - (1.52)^2}} = 0.37$$ 6.3.2, Eq. 6.25

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - (\lambda_{rel,z})^2}} = \frac{1}{1.77 + \sqrt{(1.77)^2 - (1.52)^2}} = 0.37$$ 6.3.2, Eq. 6.26

9.16 **MEMBER NO. 7 | DS1 | CO2 | 1.398 M | STRESS POINT NO. 1 | ST1600.02** **Timber Design**

$$\eta_1 = \left| \frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right|$$ Eq. 6.23

$$= \left| \frac{-0.459\,N/mm^2}{0.37 \cdot 20.789\,N/mm^2} + 0.70 \cdot \frac{0.085\,N/mm^2}{34.615\,N/mm^2} \right|$$

$$= 0.058$$

$$\eta_2 = \left| \frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right|$$ Eq. 6.24

$$= \left| \frac{-0.459\,N/mm^2}{0.37 \cdot 20.789\,N/mm^2} + \frac{0.085\,N/mm^2}{34.615\,N/mm^2} \right|$$

$$= 0.057$$

$$\eta = \max\{\eta_1, \eta_2\}$$ 6.3.2

$$= \max\{0.058, 0.057\}$$

$$= 0.058$$

$$\eta = 0.058 \leq 1$$ ✓

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

9.17 **MEMBER NO. 203 | DS1 | CO3 | 4.102 M | STRESS POINT NO. 1 | 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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\ N/mm^2}{1.30} = 20.769\ N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\ N/mm^2}{1.30} = 34.615\ N/mm^2$$ 2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{8.205\ m}{46.2\ mm} = 177.64$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{8.205\ m}{34.6\ mm} = 236.85$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}} = \frac{177.64}{\pi} \cdot \sqrt{\frac{30.000\ N/mm^2}{11800.0\ N/mm^2}} = 2.85$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{236.85}{\pi} \cdot \sqrt{\frac{30.000\ N/mm^2}{11800.0\ N/mm^2}} = 3.80$$ 6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,y} - 0.3\right) + \left(\lambda_{rel,y}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (2.85 - 0.3) + (2.85)^2\right) = 4.82$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,z} - 0.3\right) + \left(\lambda_{rel,z}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (3.80 - 0.3) + (3.80)^2\right) = 8.08$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - \left(\lambda_{rel,y}\right)^2}} = \frac{1}{4.82 + \sqrt{(4.82)^2 - (2.85)^2}} = 0.11$$ 6.3.2, Eq. 6.25

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - \left(\lambda_{rel,z}\right)^2}} = \frac{1}{8.08 + \sqrt{(8.08)^2 - (3.80)^2}} = 0.07$$ 6.3.2, Eq. 6.26

9.17 **MEMBER NO. 203 | DS1 | CO3 | 4.102 M | STRESS POINT NO. 1 | ST1600.01** **Timber Design**

$$\eta_1 = \left| \frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right|$$ Eq. 6.23

$$= \left| \frac{-0.075\,N/mm^2}{0.11 \cdot 20.769\,N/mm^2} + \frac{-19.736\,N/mm^2}{34.615\,N/mm^2} \right|$$

$$= 0.601$$

$$\eta_2 = \left| \frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right|$$ Eq. 6.24

$$= \left| \frac{-0.075\,N/mm^2}{0.07 \cdot 20.769\,N/mm^2} + 0.70 \cdot \frac{-19.736\,N/mm^2}{34.615\,N/mm^2} \right|$$

$$= 0.454$$

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

$$= \max(0.601,\ 0.454)$$

$$= 0.601$$

$$\eta = 0.601 \leq 1$$ ✓

$f_{c,0,d}$	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

9.18 **MEMBER NO. 29 | D51 | CO2 | 0.000 M | STRESS POINT NO. 1 | ST1300** **Timber Design**

Design Check ST1300 | EN 1995 | CEN | 2014-05

Stability
Axial compression with buckling about both axes acc. to 6.3.2

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\,N/mm^2}{1.30} = 20.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{3.745\,m}{52.0\,mm} = 72.07$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{3.745\,m}{43.3\,mm} = 86.48$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}} = \frac{72.07}{\pi} \cdot \sqrt{\frac{30.000\,N/mm^2}{11800.0\,N/mm^2}} = 1.16$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{86.48}{\pi} \cdot \sqrt{\frac{30.000\,N/mm^2}{11800.0\,N/mm^2}} = 1.39$$ 6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot (\lambda_{rel,y} - 0.3) + (\lambda_{rel,y})^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (1.16 - 0.3) + (1.16)^2\right) = 1.25$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot (\lambda_{rel,z} - 0.3) + (\lambda_{rel,z})^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (1.39 - 0.3) + (1.39)^2\right) = 1.57$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - (\lambda_{rel,y})^2}} = \frac{1}{1.25 + \sqrt{(1.25)^2 - (1.16)^2}} = 0.57$$ 6.3.2, Eq. 6.25

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - (\lambda_{rel,z})^2}} = \frac{1}{1.57 + \sqrt{(1.57)^2 - (1.39)^2}} = 0.43$$ 6.3.2, Eq. 6.26

$$\eta_1 = \frac{|\sigma_{c,0,d}|}{k_{c,y} \cdot f_{c,0,d}} = \frac{|-0.604\,N/mm^2|}{0.57 \cdot 20.769\,N/mm^2} = 0.051$$ Eq. 6.23

9.18 **MEMBER NO. 29 | D51 | CO2 | 0.000 M | STRESS POINT NO. 1 | ST1300** **Timber Design**

$$\eta_2 = \frac{|\sigma_{c,0,d}|}{k_{c,z} \cdot f_{c,0,d}} = \frac{|-0.604\,\mathrm{N/mm^2}|}{0.43 \cdot 20.769\,\mathrm{N/mm^2}} = 0.067$$ Eq. 6.24

$$\eta = \max\{\eta_1, \eta_2\} = \max\{0.051, 0.067\} = 0.067$$ 6.3.2

$$\eta = 0.067 \leq 1 ✓$$

$f_{c,0,d}$	Design compressive strength
k_{mod}	Modification factor
$f_{c,0,k}$	Characteristic compressive strength
γ_M	Partial factor
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
η_2	Design ratio 2

9.19 MEMBER NO. 203 | DS1 | CO2 | 4.102 M | STRESS POINT NO. 3 | SP6300

Timber Design

Design Check SP6300 | EN 1995 | CEN | 2014-05

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\,\text{N/mm}^2}{1.30} = 20.769\,\text{N/mm}^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\,\text{N/mm}^2}{1.30} = 34.615\,\text{N/mm}^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\,\text{N/mm}^2}{1.30} = 34.615\,\text{N/mm}^2$$ 2.4.1, Eq. 2.14

$$\eta_1 = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-0.029\,\text{N/mm}^2}{20.769\,\text{N/mm}^2}\right)^2 + \frac{-28.309\,\text{N/mm}^2}{34.615\,\text{N/mm}^2} + 0.70 \cdot \frac{-0.912\,\text{N/mm}^2}{34.615\,\text{N/mm}^2} \right| = 0.836$$ 6.2.4, Eq. 6.19

$$\eta_2 = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-0.029\,\text{N/mm}^2}{20.769\,\text{N/mm}^2}\right)^2 + 0.70 \cdot \frac{-28.309\,\text{N/mm}^2}{34.615\,\text{N/mm}^2} + \frac{-0.912\,\text{N/mm}^2}{34.615\,\text{N/mm}^2} \right| = 0.599$$ 6.2.4, Eq. 6.20

$$\eta = \max(\eta_1, \eta_2) = \max(0.836, 0.599) = 0.836$$ 6.2.4

$$\eta = 0.836 \leq 1 \checkmark$$

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

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9.20 **MEMBER NO. 2 | DS1 | CO2 | 4.090 M | STRESS POINT NO. 3 | SP6200** **Timber Design**

Design Check SP6200 | EN 1995 | CEN | 2014-05

Section Proof
Bending about z-axis and compressive axial force acc. to 6.2.4

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\,N/mm^2}{1.30} = 20.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\,N/mm^2}{1.30} = 34.615\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-0.282\,N/mm^2}{20.769\,N/mm^2}\right)^2 + \frac{-0.658\,N/mm^2}{34.615\,N/mm^2} \right| = 0.019$$ 6.2.4, Eq. 6.20

$\eta = 0.019 \leq 1$ ✓

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

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Model: Enia Klanac_1.zona krovišta – kopija (2)

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MODEL

9.21 **MEMBER NO. 203 | DS1 | CO3 | 4.102 M | STRESS POINT NO. 1 | SP6100** **Timber Design**

Design Check SP6100 | EN 1995 | CEN | 2014-05

Section Proof
Bending about y-axis and compressive axial force acc. to 6.2.4

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\ N/mm^2}{1.30} = 20.769\ N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\ N/mm^2}{1.30} = 34.615\ N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right| = \left| -\left(\frac{-0.075\ N/mm^2}{20.769\ N/mm^2}\right)^2 + \frac{-19.730\ N/mm^2}{34.615\ N/mm^2} \right| = 0.570$$ 6.2.4, Eq. 6.19

$\eta = 0.570 \leq 1$ ✓

$f_{c,0,d}$	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
$\sigma_{c,0,d}$	Design compressive stress
$\sigma_{m,y,d}$	Design bending stress

9.22 **MEMBER NO. 203 | DS1 | CO2 | 3.861 M | LEFT SIDE | STRESS POINT NO. 3 | SP4300** **Timber Design**

Design Check SP4300 | EN 1995 | CEN | 2014-05

Section Proof
Biaxial bending acc. to 6.1.6

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\,N/mm^2}{1.30} = 34.615\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\,N/mm^2}{1.30} = 34.615\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta_1 = \left|\frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|\frac{-28.398\,N/mm^2}{34.615\,N/mm^2} + 0.70 \cdot \frac{-0.853\,N/mm^2}{34.615\,N/mm^2}\right| = 0.838$$ 6.1.6, Eq. 6.11

$$\eta_2 = \left|k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|0.70 \cdot \frac{-28.398\,N/mm^2}{34.615\,N/mm^2} + \frac{-0.853\,N/mm^2}{34.615\,N/mm^2}\right| = 0.599$$ 6.1.6, Eq. 6.12

$$\eta = \max(\eta_1, \eta_2) = \max(0.838, 0.599) = 0.838$$ 6.1.6

$\eta = 0.838 \leq 1$ ✓

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

9.23 **MEMBER NO. 170 | DS1 | CO5 | 0.777 M | STRESS POINT NO. 1 | SP4200** — **Timber Design**

Design Check SP4200 | EN 1995 | CEN | 2014-05

Section Proof
Bending about z-axis acc. to 6.1.6

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\ \mathrm{N/mm^2}}{1.30} = 34.615\ \mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$\eta = \frac{|\sigma_{m,z,d}|}{f_{m,z,d}} = \frac{|1.174\ \mathrm{N/mm^2}|}{34.615\ \mathrm{N/mm^2}} = 0.034$$ 6.1.6, Eq. 6.12

$$\eta = 0.034 \leq 1 ✓$$

$f_{m,z,d}$	Design bending strength
k_{mod}	Modification factor
$f_{m,z,k}$	Characteristic bending strength
γ_M	Partial factor
$\sigma_{m,z,d}$	Design bending stress

9.24 **MEMBER NO. 171 | DS1 | CO2 | 0.000 M | STRESS POINT NO. 1 | SP4100** **Timber Design**

Design Check SP4100 | EN 1995 | CEN | 2014-05

Section Proof
Bending about y-axis acc. to 6.1.6

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M}$$
$$= 0.90 \cdot \frac{30.000\ N/mm^2}{1.30}$$
$$= 34.615\ N/mm^2$$

2.4.1, Eq. 2.14

$$\eta = \frac{|\sigma_{m,y,d}|}{f_{m,y,d}}$$
$$= \frac{|5.029\ N/mm^2|}{34.615\ N/mm^2}$$
$$= 0.145$$

6.1.6, Eq. 6.11

$\eta = 0.145 \leq 1$ ✓

$f_{m,y,d}$	Design bending strength
k_{mod}	Modification factor
$f_{m,y,k}$	Characteristic bending strength
γ_M	Partial factor
$\sigma_{m,y,d}$	Design bending stress

9.25 MEMBER NO. 24 | DS1 | CO2 | 0.000 M | STRESS POINT NO. 2 | SP3200

Timber Design

Design Check SP3200 | EN 1995 | CEN | 2014-05

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

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M} = 0.90 \cdot \frac{4.500\ \text{N/mm}^2}{1.30} = 3.115\ \text{N/mm}^2$$

2.4.1, Eq. 2.14

$$\tau_{xy,d} = \frac{\tau_{xy}}{k_{cr}} = \frac{-0.058\ \text{N/mm}^2}{0.67} = -0.086\ \text{N/mm}^2$$

$$\eta = \frac{|\tau_{xy,d}|}{f_{v,y,d}} = \frac{|-0.086\ \text{N/mm}^2|}{3.115\ \text{N/mm}^2} = 0.028$$

6.1.7, Eq. 6.13

$$\eta = 0.028 \le 1 \checkmark$$

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

9.26 **MEMBER NO. 203 | DS1 | CO2 | 8.205 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

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M} = 0.90 \cdot \frac{4.500\ N/mm^2}{1.30} = 3.115\ N/mm^2$$ 2.4.1, Eq. 2.14

$$\tau_{xz,d} = \frac{\tau_{xz}}{k_{cr}} = \frac{-0.701\ N/mm^2}{0.67} = -1.046\ N/mm^2$$

$$\eta = \frac{|\tau_{xz,d}|}{f_{v,z,d}} = \frac{|-1.046\ N/mm^2|}{3.115\ N/mm^2} = 0.336$$ 6.1.7, Eq. 6.13

$\eta = 0.336 \leq 1$ ✓

$f_{v,z,d}$	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

9.27 MEMBER NO. 175 | DS1 | CO2 | 0.475 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

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M} = 0.90 \cdot \frac{4.500\,N/mm^2}{1.30} = 3.115\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M} = 0.90 \cdot \frac{4.500\,N/mm^2}{1.30} = 3.115\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \frac{\tau_{tor,d}}{k_{shape} \cdot f_{v,d}} = \frac{0.332\,N/mm^2}{1.06 \cdot 3.115\,N/mm^2} = 0.101$$ 6.1.8, Eq. 6.14

$$\eta = 0.101 \leq 1$$ ✓

$f_{v,z,d}$	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

9.28 MEMBER NO. 29 | DS1 | CO2 | 0.000 M | STRESS POINT NO. 1 | SP1200

Timber Design

Design Check SP1200 | EN 1995 | CEN | 2014-05

Section Proof
Compression along grain acc. to 6.1.4

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\ \mathrm{N/mm^2}}{1.30} = 20.769\ \mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} = \frac{|-0.604\ \mathrm{N/mm^2}|}{20.769\ \mathrm{N/mm^2}} = 0.029$$ 6.1.4, Eq. 6.2

$$\eta = 0.029 \leq 1 \checkmark$$

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

9.29 **MEMBER NO. 24 | DS1 | CO2 | 0.470 M | RIGHT SIDE | STRESS POINT NO. 1 | SP1100** **Timber Design**

Design Check SP1100 | EN 1995 | CEN | 2014-05

Section Proof
Tension along grain acc. to 6.1.2

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\ N/mm^2}{1.30} = 20.769\ N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \frac{\sigma_{t,0,d}}{f_{t,0,d}} = \frac{0.500\ N/mm^2}{20.769\ N/mm^2} = 0.024$$ 6.1.2(1), Eq. 6.1

$\eta = 0.024 \leq 1$ ✓

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

9.30 **MEMBER NO. 152 | DS1 | CO5 | 1.219 M | SP0100** **Timber Design**

Design Check SP0100 | EN 1995 | CEN | 2014-05

Section Proof
Negligible internal forces

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M} = 0.90 \cdot \frac{30.000\ N/mm^2}{1.30} = 20.769\ N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M} = 0.90 \cdot \frac{4.500\ N/mm^2}{1.30} = 3.115\ N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M} = 0.90 \cdot \frac{4.500\ N/mm^2}{1.30} = 3.115\ N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\ N/mm^2}{1.30} = 34.615\ N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.90 \cdot \frac{50.000\ N/mm^2}{1.30} = 34.615\ N/mm^2$$ 2.4.1, Eq. 2.14

Tension:

$$\eta_{\sigma_t} = \frac{\sigma_{t,0,d}}{f_{t,0,d}} = \frac{0.020\ N/mm^2}{20.769\ N/mm^2} = 0.001$$

$\eta_{\sigma_t} \leq \eta_{\sigma_t,lim}$

N_t is negligible.

Shear in y-axis:

$$\eta_{\tau_{xy}} = \frac{|\tau_{xy}|}{f_{v,y,d}} = \frac{|0.000\ N/mm^2|}{3.115\ N/mm^2} = 0.000$$

$\eta_{\tau_{xy}} \leq \eta_{\tau_{xy},lim}$

τ_{xy} is negligible.

Shear in z-axis:

$$\eta_{\tau_{xz}} = \frac{|\tau_{xz}|}{f_{v,z,d}} = \frac{|0.000\ N/mm^2|}{3.115\ N/mm^2} = 0.000$$

$\eta_{\tau_{xz}} \leq \eta_{\tau_{xz},lim}$

9.30 **MEMBER NO. 152 | DS1 | CO5 | 1.219 M | SP0100** — **Timber Design**

$\tau_{V,z}$ is negligible.

Torsion:

$$\eta_{\tau_{tor}} = \frac{|\tau_{tor,d}|}{f_{v,d}} = \frac{|-0.007\ \text{N/mm}^2|}{3.115\ \text{N/mm}^2} = 0.002$$

$\eta_{\tau_{tor}} \leq \eta_{\tau_{tor,lim}}$

M_t is negligible.

Bending about y-axis:

$$\eta_{\sigma_y} = \frac{|\sigma_{m,y,d}|}{f_{m,y,d}} = \frac{|-0.027\ \text{N/mm}^2|}{34.615\ \text{N/mm}^2} = 0.001$$

$\eta_{\sigma_y} \leq \eta_{\sigma_{y,lim}}$

$M_{Ed,y}$ is negligible.

Bending about z-axis:

$$\eta_{\sigma_z} = \frac{|\sigma_{m,z,d}|}{f_{m,z,d}} = \frac{|-0.003\ \text{N/mm}^2|}{34.615\ \text{N/mm}^2} = 0.000$$

$\eta_{\sigma_z} \leq \eta_{\sigma_{z,lim}}$

$M_{Ed,z}$ is negligible.

All internal forces are negligible.

$\eta = 0.000 \leq 1$ ✓

$f_{t,0,d}$	Design tensile strength
k_{mod}	Modification factor
$f_{t,0,k}$	Characteristic tensile strength
γ_M	Partial factor
$f_{v,z,d}$	Design shear strength
$f_{v,z,k}$	Characteristic shear strength
$f_{v,y,d}$	Design shear strength
$f_{v,y,k}$	Characteristic shear strength
$f_{m,y,d}$	Design bending strength
$f_{m,y,k}$	Characteristic bending strength
$f_{m,z,d}$	Design bending strength
$f_{m,z,k}$	Characteristic bending strength
η_{σ_t}	Design component for tension
$\sigma_{t,0,d}$	Design tensile stress
$\eta_{\sigma_{t,lim}}$	Limit value of design ratio for tension
η_{τ_y}	Design component for shear
τ_y	Shear stress
$\eta_{\tau_{y,lim}}$	Limit value of design ratio for shear
η_{τ_z}	Design component for shear
τ_z	Shear stress
$\eta_{\tau_{z,lim}}$	Limit value of design ratio for shear
$\eta_{\tau_{tor}}$	Design component for torsional moment

9.30 MEMBER NO. 152 | DS1 | CO5 | 1.219 M | SP0100

Timber Design

$\tau_{tor,d}$	Design torsional stress
$f_{v,d}$	Design shear strength
$\eta_{tor,lim}$	Limit value of design ratio for torsional moment
η_{σ_y}	Design component for bending moment
$\sigma_{m,y,d}$	Design bending stress
$\eta_{\sigma_y,lim}$	Limit value of design ratio for bending moment
η_{σ_z}	Design component for bending moment
$\sigma_{m,z,d}$	Design bending stress
$\eta_{\sigma_z,lim}$	Limit value of design ratio for bending moment

10 Design Overview

10.1 DESIGN OVERVIEW

Design Overview

Addon	Objects Type	No.	Location [m]	Design Situation	Loading No.	Design Check Ratio η [–]	Type	Description
Timber Design	Member	203	x: 4.102	DS1	CO2	0.299	ST1600.03	Stability | Biaxial bending and compression with buckling about both axes acc. to 6.3.2
Timber Design	Member	209	x: 2.181	DS3	CO12	0.262	SE1200.02	Serviceability | Combination of actions 'Quasi-permanent 1' | z-direction acc. to 7.2
Timber Design	Member	209	x: 2.181	DS2	CO7	0.248	SE1200.01	Serviceability | Combination of actions 'Characteristic' | z-direction acc. to 7.2
Timber Design	Member	203	x: 4.102	DS1	CO2	0.248	ST2100.00	Stability | Flexural member without compression force | Bending about y-axis acc. to 6.3.3
Timber Design	Member	203	x: 4.102	DS1	CO2	0.239	SP5300.00	Section Proof | Biaxial bending and tensile axial force acc. to 6.2.3
Timber Design	Member	203	x: 4.102	DS1	CO2	0.233	SP6300.00	Section Proof | Biaxial bending and compressive axial force acc. to 6.2.4
Timber Design	Member	203	x: 4.102	DS1	CO1	0.194	ST1600.01	Stability | Bending about y-axis and compression with buckling about both axes acc. to 6.3.2
Timber Design	Member	209	x: 4.102	DS1	CO2	0.190	SP3100.00	Section Proof | Shear in z-axis acc. to 6.1.7 | Rectangular section
Timber Design	Member	203	x: 4.102	DS1	CO2	0.176	ST3100.00	Stability | Bending about y-axis and compression acc. to 6.3.3
Timber Design	Member	196	x: 0.000	DS1	CO2	0.161	SP4300.00	Section Proof | Biaxial bending acc. to 6.1.6
Timber Design	Member	203	x: 4.102	DS1	CO1	0.152	SP6100.00	Section Proof | Bending about y-axis and compressive axial force acc. to 6.2.4
Timber Design	Member	171	x: 0.000	DS1	CO2	0.145	SP4100.00	Section Proof | Bending about y-axis acc. to 6.1.6
Timber Design	Member	203	x: 1.026	DS1	CO2	0.121	SP5100.00	Section Proof | Bending about y-axis and tensile axial force acc. to 6.2.3
Timber Design	Member	26	x: 0.000	DS1	CO1	0.105	ST1300.00	Stability | Axial compression with buckling about both axes acc. to 6.3.2
Timber Design	Member	175	x: 0.475	DS1	CO2	0.101	SP2100.00	Section Proof | Shear due to torsion acc. to 6.1.8
Timber Design	Member	3	x: 4.090	DS1	CO2	0.089	ST1600.02	Stability | Bending about z-axis and compression with buckling about both axes acc. to 6.3.2
Timber Design	Member	174	x: 0.950	DS1	CO4	0.062	SP3200.00	Section Proof | Shear in y-axis acc. to 6.1.7 | Rectangular section
Timber Design	Member	24	x: 1.036	DS3	CO13	0.061	SE1100.02	Serviceability | Combination of actions 'Quasi-permanent 1' | y-direction acc. to 7.2
Timber Design	Member	24	x: 1.036	DS2	CO8	0.053	SE1100.01	Serviceability | Combination of actions 'Characteristic' | y-direction acc. to 7.2
Timber Design	Member	26	x: 0.000	DS1	CO1	0.046	SP1200.00	Section Proof | Compression along grain acc. to 6.1.4
Timber Design	Member	21	x: 0.470	DS1	CO3	0.043	SP1100.00	Section Proof | Tension along grain acc. to 6.1.2
Timber Design	Member	3	x: 4.090	DS1	CO2	0.038	SP6200.00	Section Proof | Bending about z-axis and compressive axial force acc. to 6.2.4
Timber Design	Member	170	x: 0.831	DS1	CO5	0.038	SP4200.00	Section Proof | Bending about z-axis acc. to 6.1.6
Timber Design	Member	150	x: 0.704	DS1	CO5	0.018	SP5200.00	Section Proof | Bending about z-axis and tensile axial force acc. to 6.2.3
Timber Design	Member	152,232-234,237,241,243,244,248,251,268,273,274	x: 1.219	DS1	CO2	0.000	SP0100.00	Section Proof | Negligible internal forces
Timber Design	Member	2-7,20-44,81,98-110,115,118-121,123-125,127-129,131-133,135-138,140-142,144-146,148-150,152-200,203-205,208-211,213-234,237,238,241-244,248,251,26	x: 0.000	DS2	CO6	0.000	SE0100.01	Serviceability | Negligible deflection | Combination of actions 'Characteristic'
Timber Design	Member	2-7,20-44,81,98-110,115,118-121,123-125,127-129,131-133,135-138,140-142,144-146,14	x: 0.000	DS3	CO11	0.000	SE0100.02	Serviceability | Negligible deflection | Combination of actions 'Quasi-permanent 1'

10.1 DESIGN OVERVIEW

Design Overview

	Addon	Objects Type	Objects No.	Location [m]	Design Situation	Loading No.	Design Check Ratio η [--]	Design Check Type	Description
			8-150,152-200,20 3-205,208-211,21 3-234,237,238,24 1-244,248,251,26						

Iz prethodno prikazanog proračuna, vidimo kako su rezultati pokazali da svi dijelovi nosivog sustava zadovoljavaju provjeru graničnih stanja nosivosti i uporabljivosti prema Eurokodu 5. Konstrukcijski elementi zadovoljavaju uvjet stabilnosti te nije potrebno vršiti ojačanje dodavanjem drvenih elemenata.

4. ZAKLJUČAK

U ovom radu prikazali smo postupak evaluacije stanja stare krovne konstrukcije na primjeru Stare gradske vijećnice u Zagrebu, Ćirilometodska ul. 5, 10000 Zagreb, s fokusom na prvu zonu krovišta. Prvi korak obuhvaća vizualni pregled krovišta i nedestruktivna ispitivanja pomoću vlagomjera i rezistografa. Ove metode omogućile su analizu stanja drvene konstrukcije, s posebnim naglaskom na vlažnost drva i ocjenu mehaničkih svojstava elemenata krovišta. Na temelju dobivenih rezultata provedeni su daljnji proračuni. Koristeći mehaničke i geometrijske karakteristike, izrađen je statički model krovišta uz pomoć softverskog alata Dlubal RFEM 6. Analizom prethodnih ispitivanja provjerena je usklađenost trenutnog stanja krovišta s sigurnosnim zahtjevima za nosive konstrukcije prema Eurokodu 5. Rezultati analize i proračuna pokazali su da konstrukcijski elementi udovoljavaju uvjetima graničnog stanja nosivosti i uporabljivosti te da nije potrebno dodatno ojačanje jer je stabilnost krovišta već osigurana.

POPIS LITERATURE

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[3] Rajčić V.: Svojstva drva kao materijala, predavanje, kolegij Drvene konstrukcije, Građevinski fakultet Sveučilišta u Zagrebu

[4] https://www.researchgate.net/publication/292858714_Inspection_of_timber_construction_by_measuring_drilling_resistance_using_Resistograph_F300-S

[5] HRN EN 1995-1-1:2013, Eurokod 5: Projektiranje drvenih konstrukcija -- Dio 1-1: Općenito -- Opća pravila i pravila za zgrade (EN 1995-1-1:2004+AC:2006+A1:2008), HZN, 2013.

[6] HRN EN 1995-1-1:2013/NA:2013, Eurokod 5: Projektiranje drvenih konstrukcija -- Dio 1-1: Općenito -- Opća pravila i pravila za zgrade -- Nacionalni dodatak, HZN, 2013.

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