Snimak stanja stare krovne konstrukcije i prijedlog sanacije

Boko, Rina

SVEUČILIŠTE U ZAGREBU

GRAĐEVINSKI FAKULTET ZAGREB

ZAVRŠNI RAD

SNIMAK STANJA STARE KROVNE KONSTRUKCIJE I PRIJEDLOG SANACIJE

Rina Boko

SVEUČILIŠTE U ZAGREBU

GRAĐEVINSKI FAKULTET ZAGREB

ZAVRŠNI RAD

SNIMAK STANJA STARE KROVNE KONSTRUKCIJE I PRIJEDLOG SANACIJE

Mentorica: Studentica:

prof. dr. sc. Vlatka Rajčić Rina Boko

Komentor:

dr. sc. Nikola Perković

Zagreb, 2023.

SAŽETAK:

U uvodnom dijelu rada prikazano je ponašanje drvenih konstrukcija u požaru kroz opis metoda požarnog proračuna konstrukcija. Nadalje, u drugom dijelu rada napravljen je vizualni pregled dijela krovišta Stare gradske vijećnice u Zagrebu, Ćirilometodska ul. 5, 10000, Zagreb, zona 5. Nakon vizualnog pregleda konstrukcije provedena je ocjena mehaničkih karakteristika elemenata krovišta nerazornim ispitivanjima pomoću vlagomjera i rezistografa. Na temelju prikupljenih mehaničkih i geometrijskih karakteristika krovišta te sagledavanja statičkog sustava krovišta, pristupilo se izradi statičkog modela krovišta u programu Dlubal RFEM 6 i izradi proračuna nosive konstrukcije. Proračun se sastoji od provjere graničnih stanja nosivosti i uporabljivosti prema Eurokodu 5: Projektiranje drvenih konstrukcija te prema hrvatskim nacionalnim dodacima za projektiranje drvenih konstrukcija.

KLJUČNE RIJEČI: drveno krovište, ocjena stanja, nerazorna ispitivanja, računski model, požar

SUMMARY:

In the introductory part of the paper, the behavior of wooden structures in a fire is presented through a description of the methods of fire calculation of structures. Furthermore, in the second part of the work a visual inspection of part of the roof Old Town Hall in Zagreb, Ćirilometodska St, 5, 10000, Zagreb, zone 5 was made. After a visual inspection of the structure, an evaluation of the mechanical characteristics of the roofing elements was carried out by non-destructive testing using a hygrometer and a resistograph. Based on the collected mechanical and geometrical characteristics of the roof and analyzing the static system of the roof, the creation of a static model of the roof in the Dlublal RFEM 6 program was made, as well as a static calculation of it. The calculation consists of checking the limit states of load capacity and serviceability according to Eurocode 5: Design of wooden structures and according to the Croatian national annexes for designing of the wooden structures.

KEY WORDS: wooden roof, Assessment, nondestructive testing, FEA model

SADRŽAJ

POPIS ILUSTRACIJA

Slike

Grafikoni

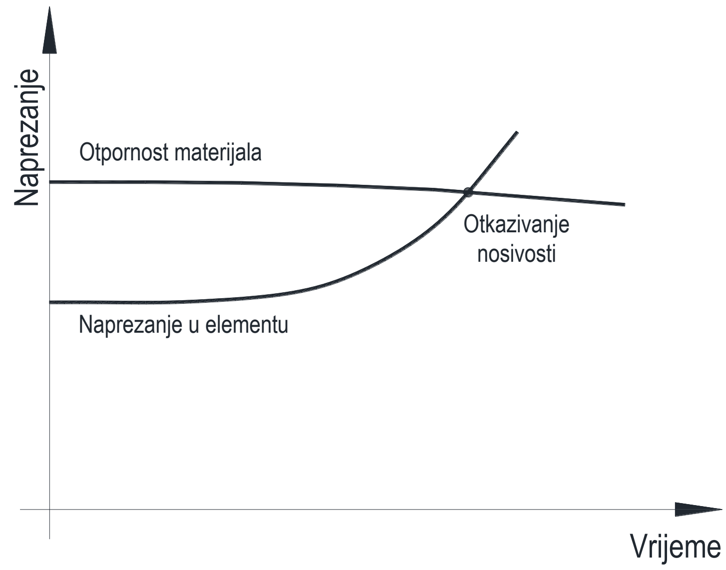
Tablice

1. UVOD

Ovaj rad se sastoji od dva ključna dijela. U prvom dijelu rada prikazat će se ponašanje drvenih konstrukcija u požaru kroz opis metoda požarnog proračuna konstrukcija. U drugom dijelu rada će se dati vizualni pregled dijela krovišta Stare gradske vijećnice u Zagrebu, ocjena mehaničkih karakteristika elemenata krovišta nerazornim ispitivanjima pomoću vlagomjera i rezistografa. Na kraju će se izraditi statički model i proračun krovišta dokazom graničnih stanja nosivosti i uporabljivosti.

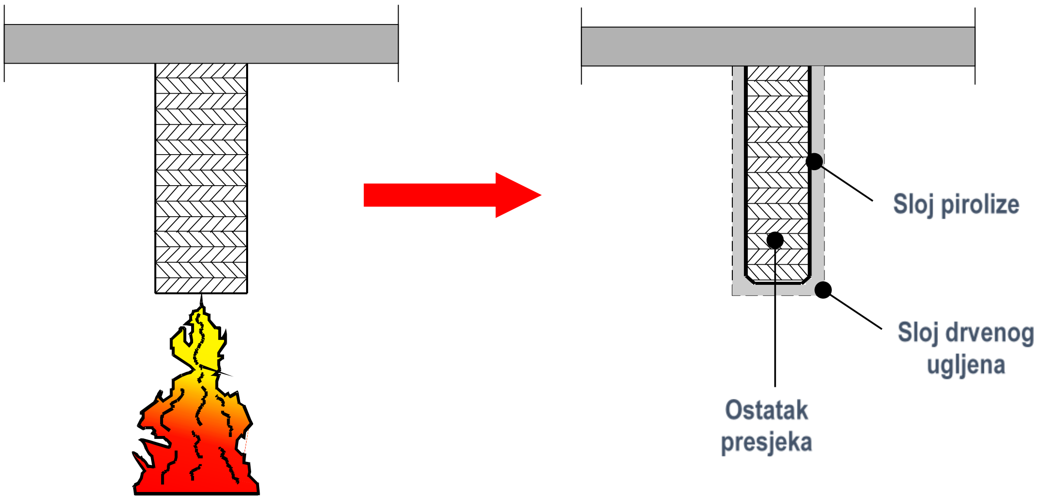
Drvene konstrukcije u građevinarstvu izvode se kao monolitne ili kao lijepljene lamelirane (složeni poprečni presjeci). Drvo je prirodan, ekološki visokovrijedan i tehnički svestran materijal koji posljednjih godina ponovo dobiva na značenju. Osnovne mehaničke, fizikalne i kemijske značajke drva od presudne su važnosti za njegovu raznovrsnu primjenu u graditeljstvu [1]. Ujedno je organski i anizotropni materijal kao i zapaljiv materijal.

Vrijeme do zapaljenja drvene konstrukcije, karakteristike procesa izgaranja i otpornost protiv požara drvenog elementa ovise o nizu faktora: vrsti presjeka, dimenzijama presjeka, stupnju vlažnosti. Razaranje drvenih elemenata vatrom je pravilno i može se unaprijed odrediti. Granična linija između izgorjelog i još zdravog dijela drvenog elementa je jasna. Neoštećeni dio presjeka, odnosno elementa kao cjeline, ima ista mehanička svojstva kao i prije požara. Prema tome, kod drvenih elemenata treba uzeti u obzir samo činjenicu da je došlo do degradacije poprečnog presjeka, bez degradacije mehaničkih svojstava u preostalom dijelu presjeka, kako je prikazano na slici 1.



Slika 1. Mehanizam otkazivanja nosivosti drvenih elemenata u požaru [2]

Degradacija poprečnog presjeka drvenog elementa prikazana je na sljedećoj slici:



Slika 2. Degradacija poprečnog presjeka drvenog elementa

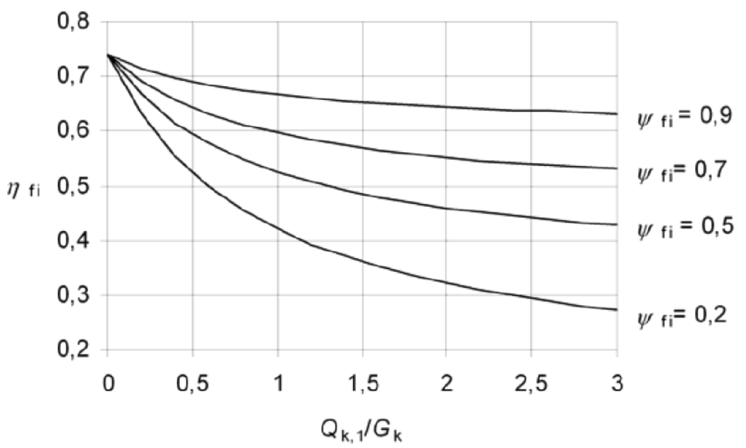
Pri proračunu drvenih elemenata u požarnim situacijama promatramo samo nepromijenjeni dio ispod pougljenog sloja koji ima početne vrijednosti temperature i mehaničkih svojstava. Poznavanje ovog fenomena može u određenim scenarijima omogućiti određivanje vremena od trenutka zapaljenja do samog sloma. U realnoj požarnoj situaciji ispod pougljenog sloja nalazit će se sloj pirolize koji nije pougljen ali mehanička svojstva drva su izmijenjena uslijed djelovanja visoke temperature. Upravo na temelju ove dvije konstatacije postoje dvije metode proračuna drvenih elemenata [3, 4]:

- metoda smanjenja poprečnog presjeka,
- metoda smanjenja mehaničkih svojstava.

Prilikom određivanja sigurnosti drvenih elemenata za zahtijevano vrijeme otpornosti na požara (R30, R60, R90, …) potrebno je dokazati da proračunska vrijednost djelovanja $E_{\mathrm{d,fi}}$ je manja ili jednaka proračunskoj otpornosti konstrukcijskog elementa i konstrukcije u cjelini $R_{\mathrm{d,fi}}$:

$$E_{\mathrm{d,fi}} \leq R_{\mathrm{d,fi}}.$$

$E_{\mathrm{d,fi}}$ predstavlja proračunsku vrijednost djelovanja za izvanrednu (požarnu) proračunsku situaciju i može se odrediti redukcijom djelovanja za atmosfersku temperaturu uz pomoć faktora redukcije η_{fi}:



Grafikon 1. Faktori redukcije proračunske vrijednosti djelovanja E_d

gdje je:

- ψ_{fi} kombinacijski faktor za česte vrijednosti promjenjivih djelovanja u požarnoj situaciji ($\psi_{1,1}$ ili $\psi_{2,1}$)

Učinak djelovanja $E_{d,fi}$ dobije se iz izraza:

$$E_{d,fi} \leq \eta E_d$$

Kod određivanja učinaka djelovanja na nosivu konstrukciju potrebno je u obzir uzeti toplinske karakteristike materijala drva:

- specifični toplinski kapacitet,
- koeficijent toplinske vodljivosti.

Vrijednosti specifičnog toplinskog kapaciteta u ovisnosti od temperature θ dani su u tablici [2]:

Temperatura [°C]	Specifični toplinski kapacitet [kJ/kgK]
20	1.53
99	1.77
99	13.60
120	13.50
120	2.12
200	2.00
250	1.62
300	0.71
350	0.85
400	1.00
600	1.40
800	1.65
1200	1.65

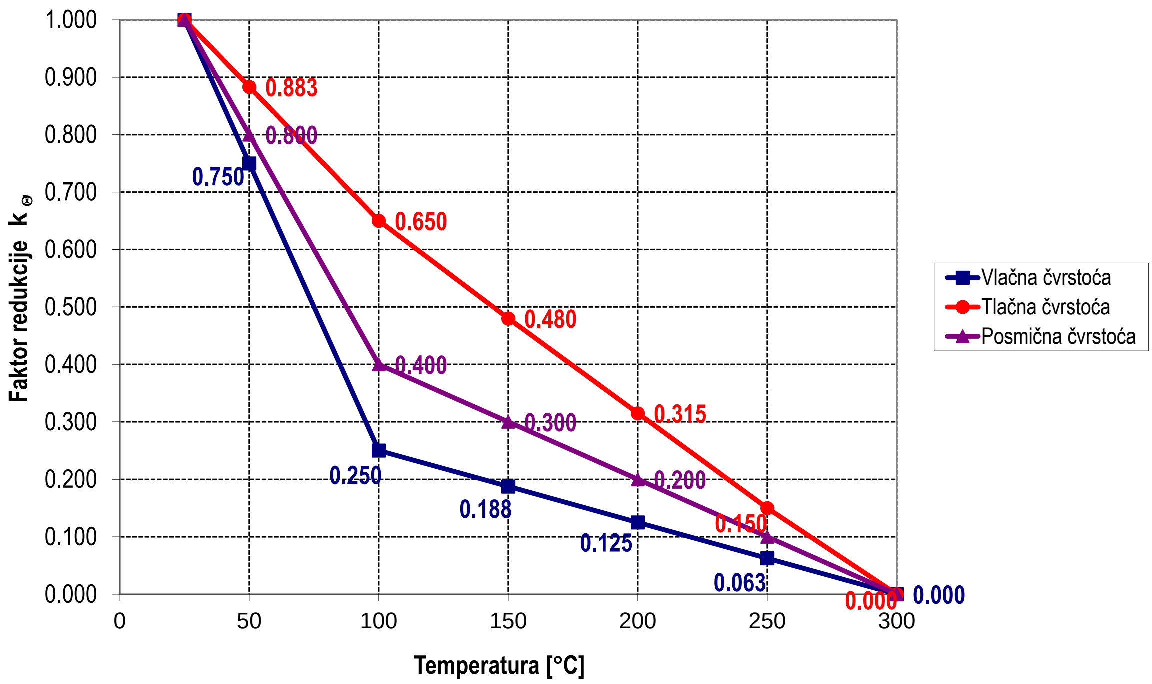
Tablica 1. Specifični toplinski kapacitet u ovisnosti od temperature θ

Koeficijent toplinske vodljivosti drva u ovisnosti od temperature θ dan je u tablici [3]:

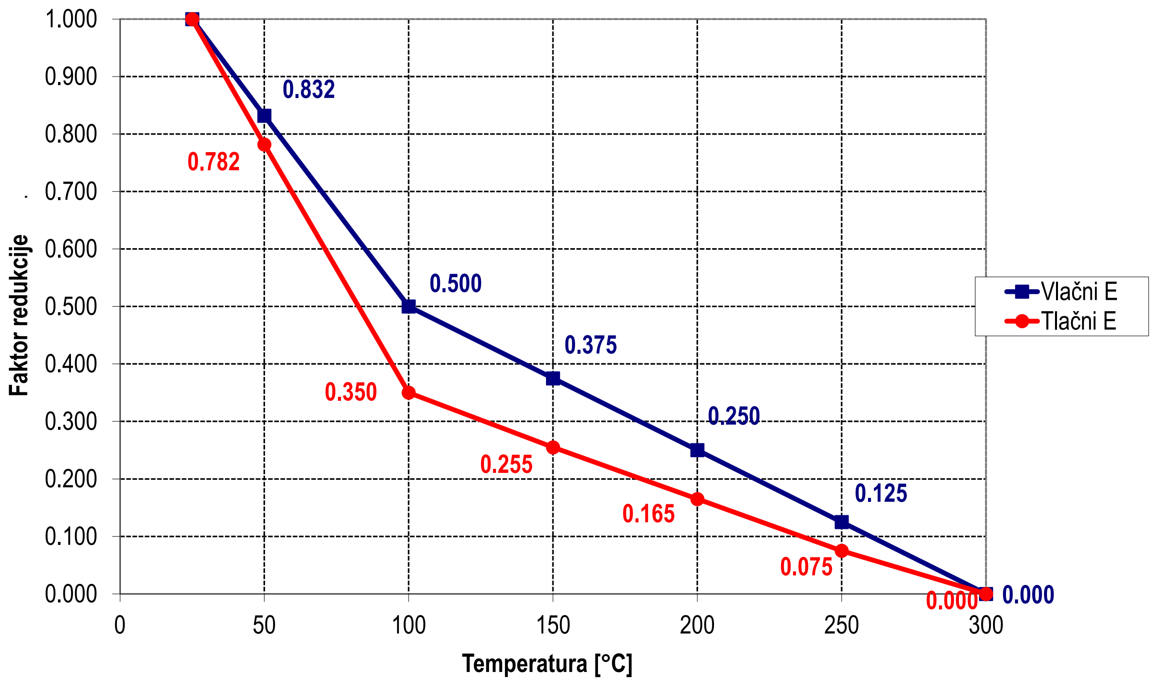
Temperatura [°C]	Koeficijent toplinske vodljivosti [W/mK]
20	0.12
200	0.15
350	0.07
500	0.09
500	0.35
800	1.50

Tablica 2. Koeficijent toplinske vodljivosti drva u ovisnosti od temperature θ

Redukcija mehaničkih karakteristika drva na visokim – požarnim temperaturama dana je na sljedećim slikama [3]:



Slika 3. Redukcija mehaničkih karakteristika – čvrstoća drva na određenim razinama temperature



Slika 4. Redukcija mehaničkih karakteristika – modula elastičnosti (posmika) drva na određenim razinama temperature

Za određivanje mehaničke otpornosti potrebno je prvo odrediti proračunske vrijednosti čvrstoće $f_{d,fi}$ i krutosti materijala $S_{d,fi}$ prema definiranim izrazima:

$$f_{d,fi} = k_{mod,fi} \frac{f_{20}}{\gamma_{M,fi}}$$

$$S_{d,fi} = k_{mod,fi} \frac{S_{20}}{\gamma_{M,fi}}$$

gdje je:

- $f_{d,fi}$ proračunska čvrstoća u požaru,
- $S_{d,fi}$ proračunsko svojstvo krutosti (modul elastičnosti $E_{d,fi}$ ili modul posmika $G_{d,fi}$) u požaru,
- f_{20} 20 postotna fraktila svojstva čvrstoće pri uobičajenoj temperaturi,
- S_{20} 20 postotna fraktila svojstva krutosti pri uobičajenoj temperaturi,
- $k_{mod,fi}$ faktor izmjene za požar,
- $\gamma_{M,fi}$ parcijalni koeficijent sigurnosti za drvo u požaru (vrijednost 1.0).

Proračunska vrijednost mehaničke otpornosti $R_{d,t,fi}$ (sposobnost nosivosti) proračunava se po izrazu:

$$R_{d,fi} = \eta \frac{R_{20}}{\gamma_{M,fi}}$$

gdje je:

- $R_{d,fi}$ proračunska vrijednost mehaničke otpornosti u požarnoj situaciji u vremenu t,
- R_{20} 20 postotna fraktila vrijednosti mehaničke otpornosti pri uobičajenoj temperaturi bez učinaka trajanja opterećenja i sadržaja vlage (k_{mod}=1),
- η faktor pretvorbe,
- $\gamma_{M,fi}$ parcijalni koeficijent sigurnosti za drvo u požaru.

20 postotna fraktila čvrstoće ili svojstva krutosti proračunava se kao:

$$f_{20} = k_{fi} \cdot f_k$$

gdje je:

- S_{05} 5 postotna fraktila svojstva kruutosti (modul elastičnosti ili modul posmika) pri uobičajenoj temperaturi.

Vrijednosti k_{fi} dane su u sljedećoj tablici [2]:

Materijal	k_{fi}
Cjelovito drvo	1.25
Lijepljeno lamelirano drvo	1.15
Ploče na osnovi drva	1.15
Lamelirana furnirska građa	1.10
Spojevi s bočnim elementima od drva i ploča na osnovi drva i bočno opterećenim spajalima	1.15
Spojevi s vanjskim čeličnim elementima i bočno opterećenim spajalima	1.05
Spojevi s osno opterećenim spajalima	1.05

Tablica 3. Vrijednosti k_{fi}

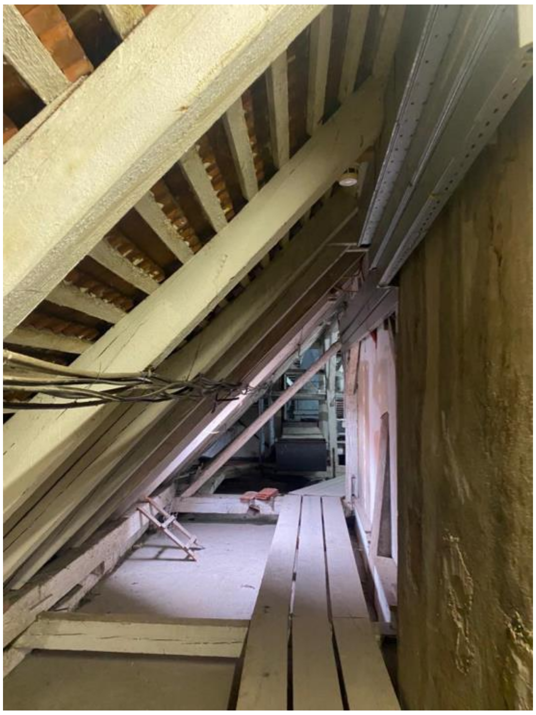
2. PROJEKTNI DIO

Pregled i provjera drvenog krovišta Stare gradske vijećnice u Zagrebu

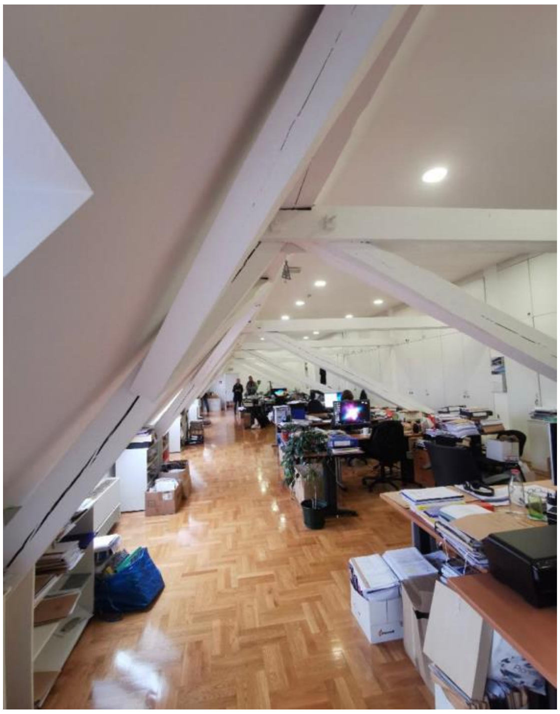
Projektni dio završnog rada sastoji se od pregleda krovišta zagrebačke Stare gradske vijećnice i provođenja nekoliko nerazornih ispitivanja s ciljem utvrđivanja stanja u kojem se krovište nalazi. Ispitivanja su provedena vlagomjerom kojim je utvrđeno da je drvo u 2. razredu uporabljivosti. Osim toga, provedena su ispitivanja rezistografom.

Krovište vijećnice podijeljeno je u pet zona, a u sklopu ovog rada bilo je važno proračunati provjere po graničnim stanjima nosivosti i uporabljivosti prema Eurokodu 5 za proračun drvenih konstrukcija za 5. zonu samog krovišta. Model krovišta nacrtan je u programu Dlublal RFEM 6. Cilj ovih provjera bio je utvrditi zadovoljava li trenutno stanje krovišta uvjete sigurnosti nosivih konstrukcija (GSN i GSU) [5, 6]. U proračunu nosive konstrukcije uzeta su sva relevantna djelovanja na konstrukciju. Riječ je o vlastitoj težini konstrukcije, dodatnom stalnom opterećenju, opterećenju vjetrom i opterećenju snijegom.

U nastavku su prikazane slike krovišta i rezultata mjerenja.



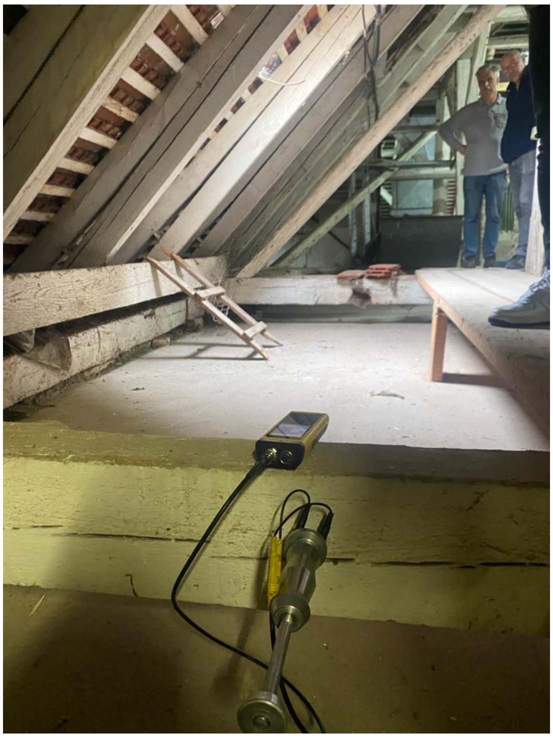
Slika 5. Krovište 1



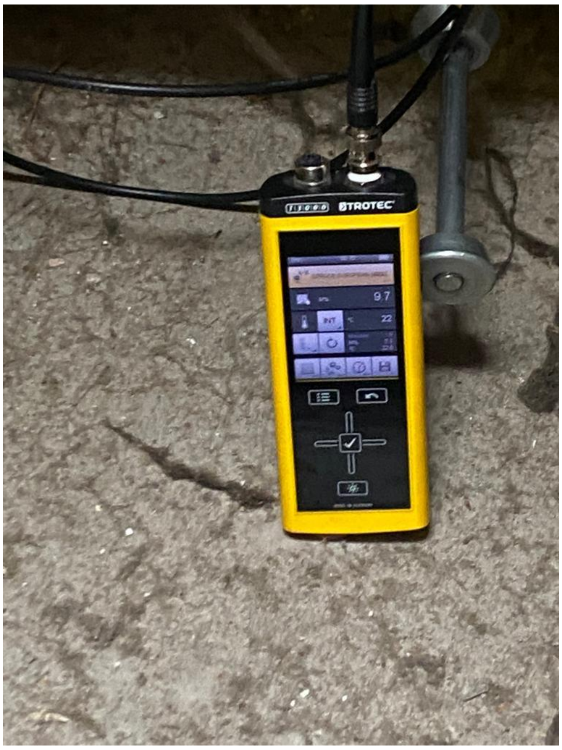
Slika 6. Krovište 2

Slika 7. Detalj krovišta 1

Slika 8. Detalj krovišta 2



Slika 9. i Slika 10. Prvo mjerenje vlagomjerom



Slika 11. Drugo mjerenje vlagomjerom

Slika 12. Drugo mjerenje vlagomjerom

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

Structural Analysis

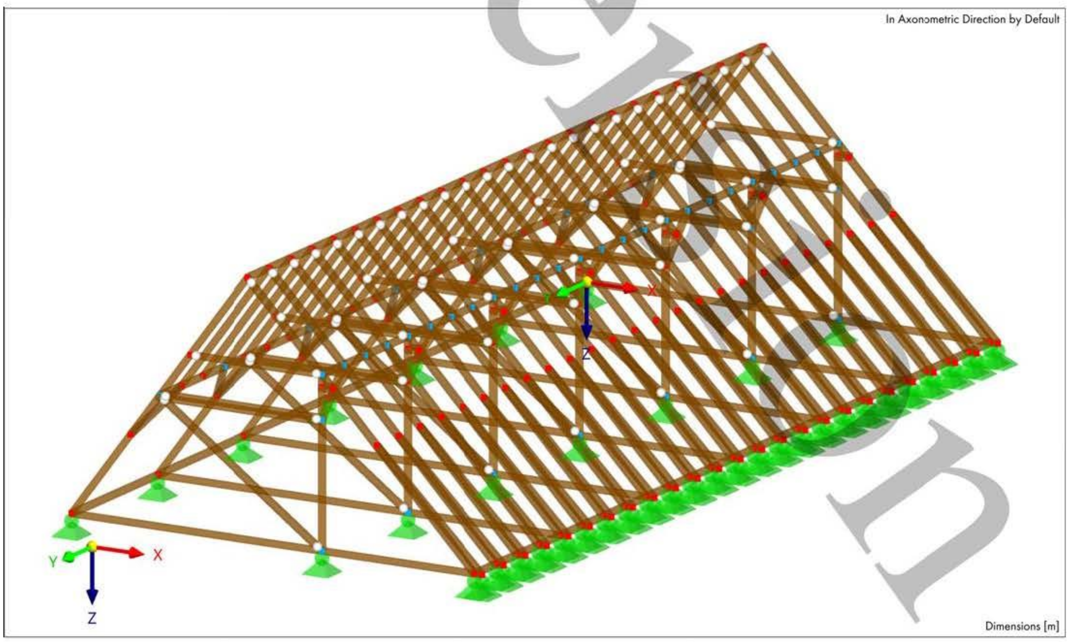
Chapters

CLIENT

CREATED BY

PROJECT

MODEL



CONTENTS

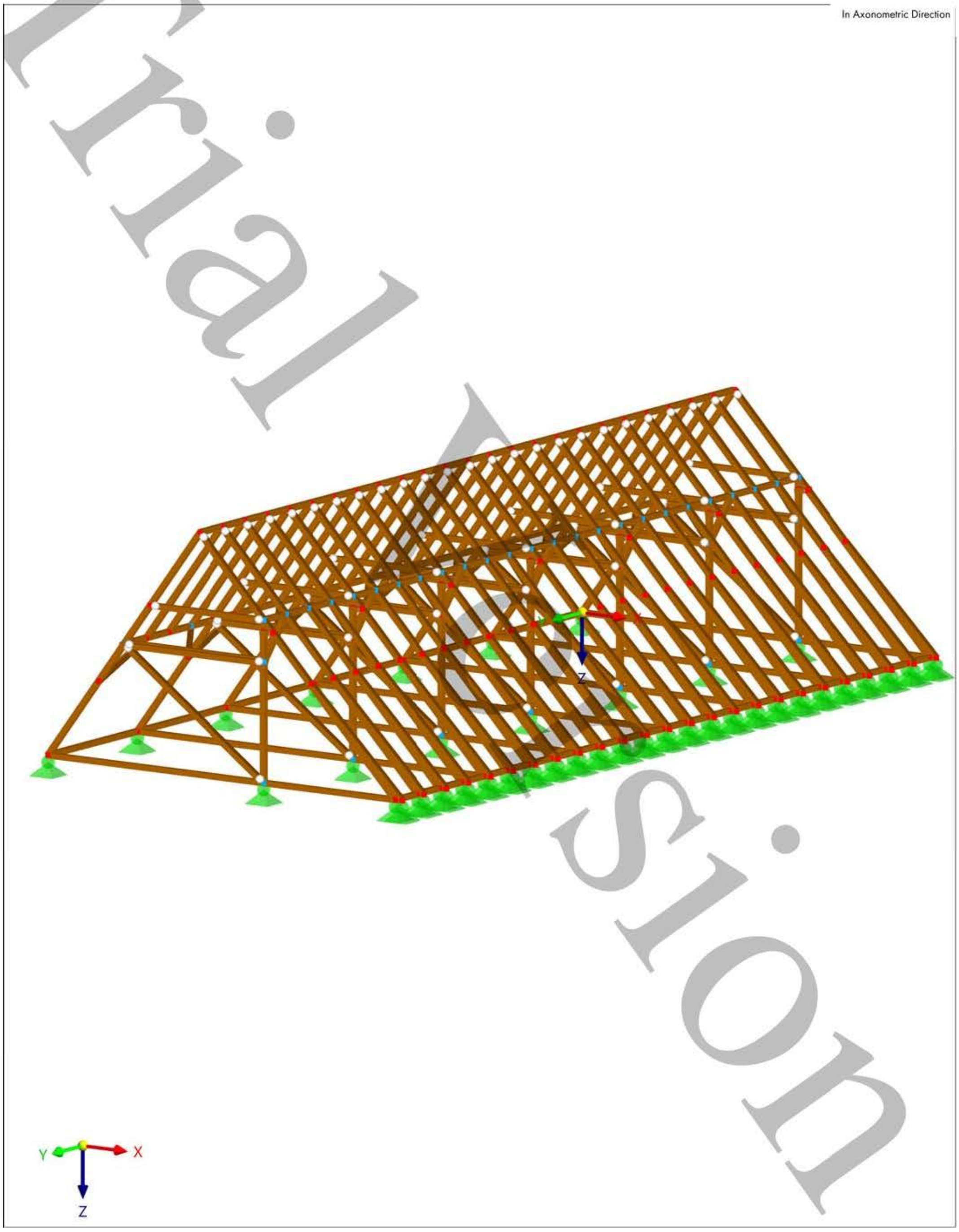
CONTENTS

A MODEL - LOCATION

Location			
	Country	:	--
	Street	:	
	Zip / Postal code	:	
	City	:	
	State	:	
	Latitude	:	deg
	Longitude	:	deg
	Altitude	:	m

1 Basic Objects

1.1 **MODEL, IN AXONOMETRIC DIRECTION**



1.2

MATERIALS

Legend
Stiffness modification

Material No.	Material Name	Material Type	Analysis Model	Options
1	C24 | Isotropic | Linear Elastic	Timber	Isotropic | Linear Elastic	

1.3

SECTIONS

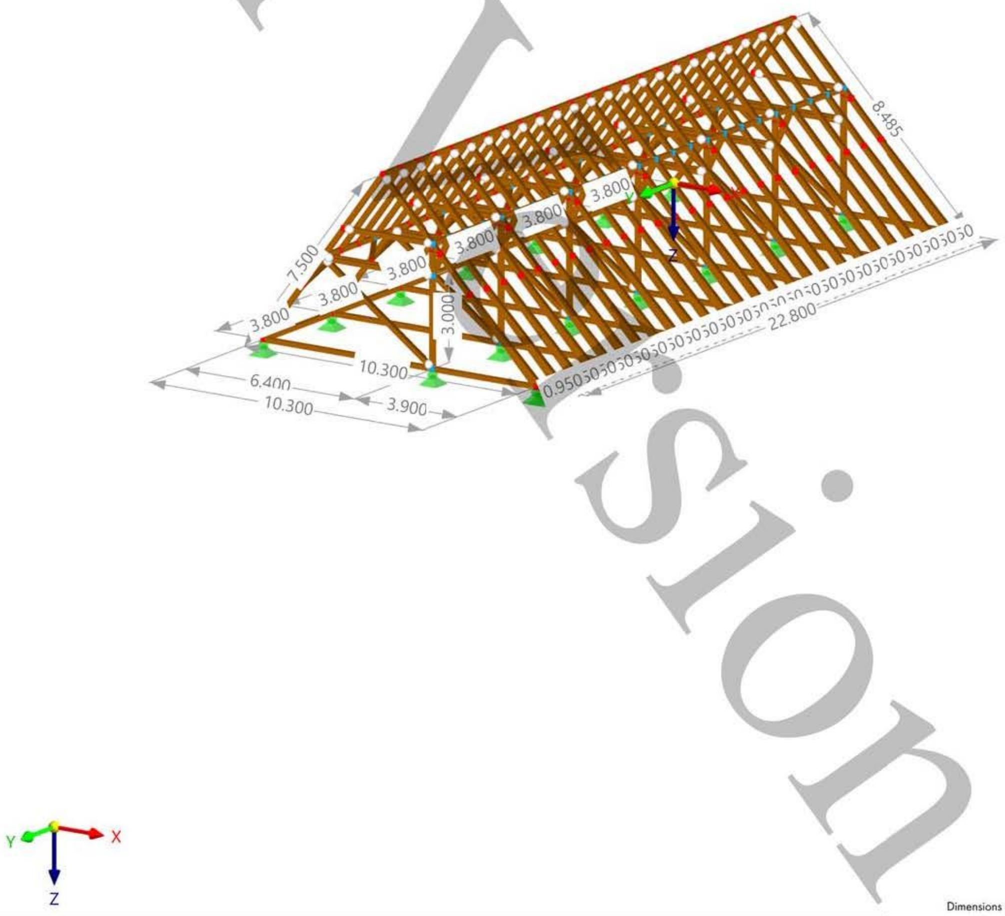
R_M1 120/120 R_M1 140/140

2R_M2 140/140/140/1 2R_M2 120/120/140/1

Section No.	Material No.	Section Type	Manufacturing Type	I_t [cm^4] / A [cm^2]	I_y [cm^4] / A_y [cm^2]	I_z [cm^4] / A_z [cm^2]	Overall Dimensions b [mm]	h [mm]
1	R_M1 120/120 | 1 - C24							
	1	Parametric - Massive I		2920.32	1728.00	1728.00	120.0	120.0
				144.00	120.00	120.00		
2	R_M1 140/140 | 1 - C24							
	1	Parametric - Massive I		5410.25	3201.33	3201.33	140.0	140.0
				196.00	163.33	163.33		
3	2R_M2 140/140/140/1 | 1 - C24							
	1	Parametric - Massive II		10894.93	6402.68	83234.71	420.0	140.0
				392.00	0.00	329.39		
4	2R_M2 120/120/140/1 | 1 - C24							
	1	Parametric - Massive II		5880.81	3456.01	52128.03	380.0	120.0
				288.00	0.00	242.00		

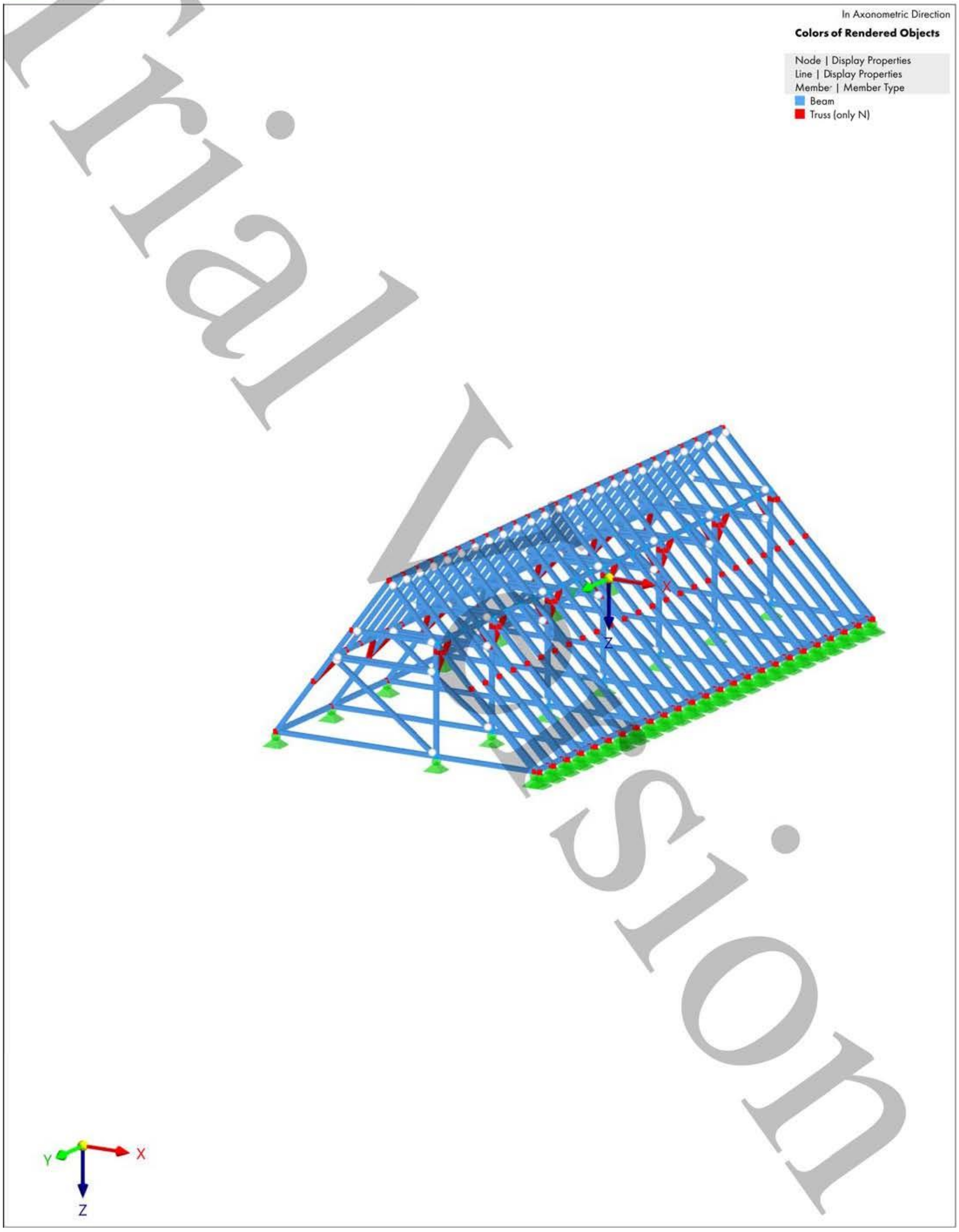
1.4 **DIMENZIJE**

In Axonometric Direction



Dimensions [m]

1.5 **POPREČNI PRESJECI**



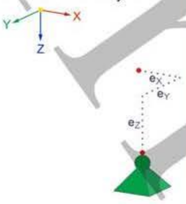
1.6 **MEMBER SETS - NUMBERING**

In direction +Z

2 Types for Nodes

2.1 NODAL SUPPORTS

Global Coordinate System



Support No.	Nodes No.	Coordinate System	Translation Spring [kN/m] $C_{u,X}$	$C_{u,Y}$	$C_{u,Z}$	Rotation Spring [kNm/rad] $C_{φ,X}$	$C_{φ,Y}$	$C_{φ,Z}$
7	☑☑☑ ☐☐☑							
	1, 3,4,9,13,18,22,27,40,45, 47,49,50,54,59,62,66,67 ,71,73,75,78,82,90,93,9 7,98,102,104,106,109,11 3,116,121,124,128,129,1 33,135,137,140,144,147 ,152,155,159,160,164,1 66,168,171,175,178,183 ,186,190,191,195,197,1 99,201,202,206,209	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] $C_{φ,x}$	$C_{φ,y}$	$C_{φ,z}$
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 : 1-4,6-11,16-19,24,25,34,35,40-50,52-272)					
	1-4,6-11,16-19,24,25, 34,35,40-50,52-272				1 - Dry	

5 Load Cases & Combinations

5.1 LOAD CASES

LC No.	Settings	Value	Unit	To Solve
1	G Self-weight			
	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 - Finland, Iceland, ...		
	Load duration	Medium-term		
3	Qw Vjetar			
	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 - Finland, Iceland, ...		
	Action Category	Qs Snow/Ice loads - Finland, Iceland, ...	☒
	Action Type	Alternatively	
3	Qw Wind		
	Action Category	Qw Wind	☒
	Action Type	Alternatively	

5.3

DESIGN SITUATIONS

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

5.4

ACTION COMBINATIONS

AC No.	Settings	Value	Active
1	ULS 1.35 * A1		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	1	
	Generated by	Design Situation No. 1	
2	ULS 1.35 * A1 + 1.50 * A2		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	2	
	Generated by	Design Situation No. 1	
3	ULS 1.35 * A1 + 1.50 * A2 + 0.90 * A3		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	3	
	Generated by	Design Situation No. 1	
4	ULS 1.35 * A1 + 1.50 * A3		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒
	Generated load combinations	4	
	Generated by	Design Situation No. 1	
5	ULS 1.35 * A1 + 1.05 * A2 + 1.50 * A3		
	Design Situation	ULS 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 + 0.70 * 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 + 1.12 * 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 + 1.12 * 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 + 0.82 * 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	ULS 1.35 * LC1			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Load duration	Permanent		
2	ULS 1.35 * LC1 + 1.50 * LC2			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Load duration	Medium-term		
3	ULS 1.35 * LC1 + 1.50 * LC2 + 0.90 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Load duration	Short-term		
4	ULS 1.35 * LC1 + 1.50 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Load duration	Short-term		
5	ULS 1.35 * LC1 + 1.05 * LC2 + 1.50 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10		
	Load duration	Short-term		
6	S Ch LC1			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Permanent		
7	S Ch LC1 + LC2			

5.5 **LOAD COMBINATIONS**

CO No.	Settings	Value	Unit	To Solve
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Medium-term		
8	S Ch LC1 + LC2 + 0.60 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Short-term		
9	S Ch LC1 + LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Short-term		
10	S Ch LC1 + 0.70 * LC2 + LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Ch DS2 - SLS - Characteristic		
	Load duration	Short-term		
11	S Qp 1.60 * LC1			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent		
	Load duration	Permanent		
12	S Qp 1.60 * LC1 + 1.12 * LC2			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent		
	Load duration	Medium-term		
13	S Qp 1.60 * LC1 + 1.12 * LC2 + 0.60 * LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent		
	Load duration	Short-term		
14	S Qp 1.60 * LC1 + LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Qp DS3 - SLS - Quasi-permanent		
	Load duration	Short-term		
15	S Qp 1.60 * LC1 + 0.82 * LC2 + LC3			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	S Qp 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)	
	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		☐	

5.6 **STATIC ANALYSIS SETTINGS**

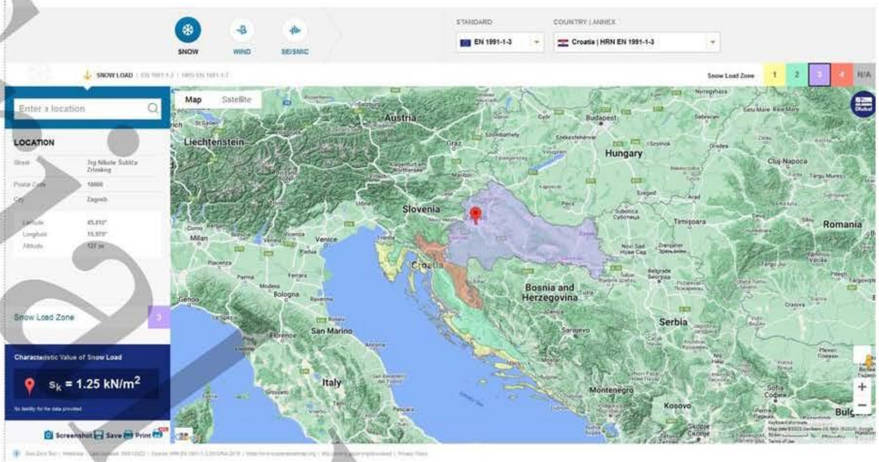
Settings No.	Description	Symbol	Value	Unit
	Modify loading by multiplier factor		☐	
	Consider favorable effect due to tension in members		☒	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Refer internal forces to deformed structure		☒	
	Refer internal forces to deformed structure for 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**

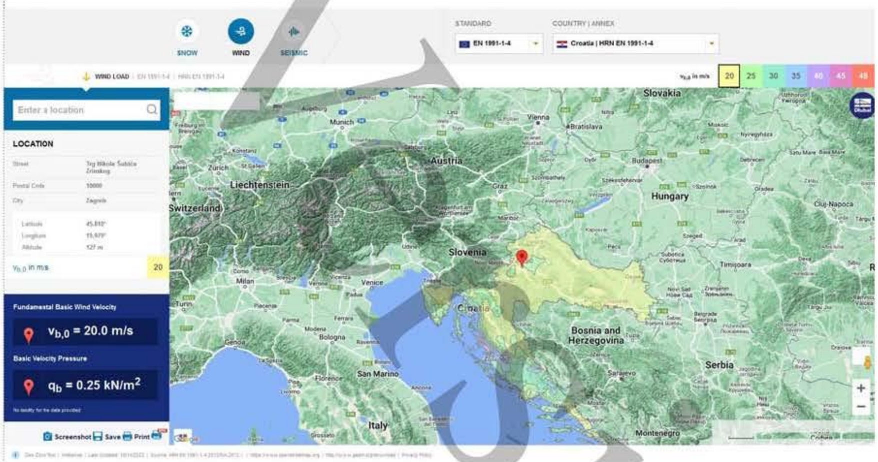
Wizard No.	Settings	Value
1	Load combinations | SA2 - Second-order (P-Δ) | Picard | 100 | 1	
	Assigned to	DS 2,3
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1
	Consider imperfection case	☒
	Consider initial state	☐
	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	DS 1
	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

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.]	
$\alpha=$	32	°	
$s_k=$	1,25	[kN/m²]	karakteristična vrijednost opterećenja snijegom na tlu
$\mu 1(\alpha)=$	0,8		koeficijent oblika opterećenja snijegom
$C_e=$	1		koeficijent izloženosti
$C_t=$	1		toplinski koeficijent
$s_d=$	$\mu_{1(\alpha 1)} \cdot C_e \cdot C_t \cdot s_k$		
$s_d=$	**1,00**	[kN/m²]	

Vjetar (w)

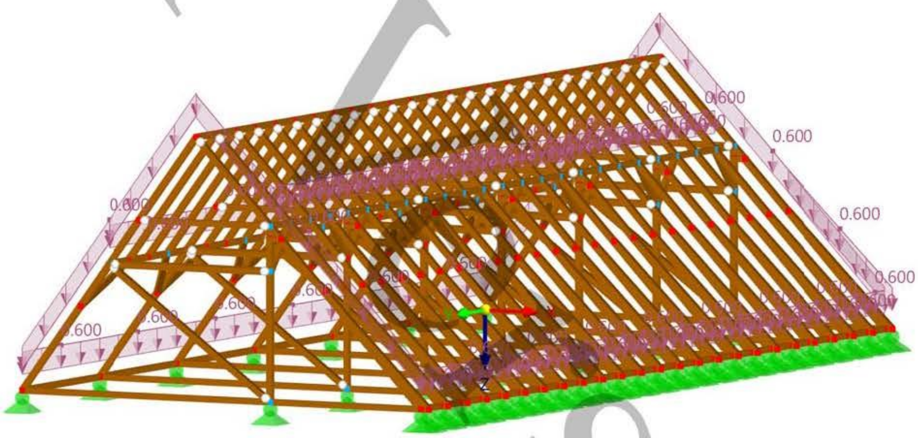
$c_{dir}=$	1		koeficijent smjera vjetra
$c_{season}=$	1		koeficijent godišnjeg doba
$v_{b,0}=$	20	[m/s]	fundamentalna vrijednost osnovne brzine vjetra
$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$		[m/s]	osnovna brzina vjetra
$v_b=$	**20**	[m/s]	
$\rho=$	1,25	[kg/m³]	gustoća zraka
*kategorija terena: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

USVOJENE VRIJEDNOSTI ZA SVE PLOHE (POJEDNOSTAVLJENO)

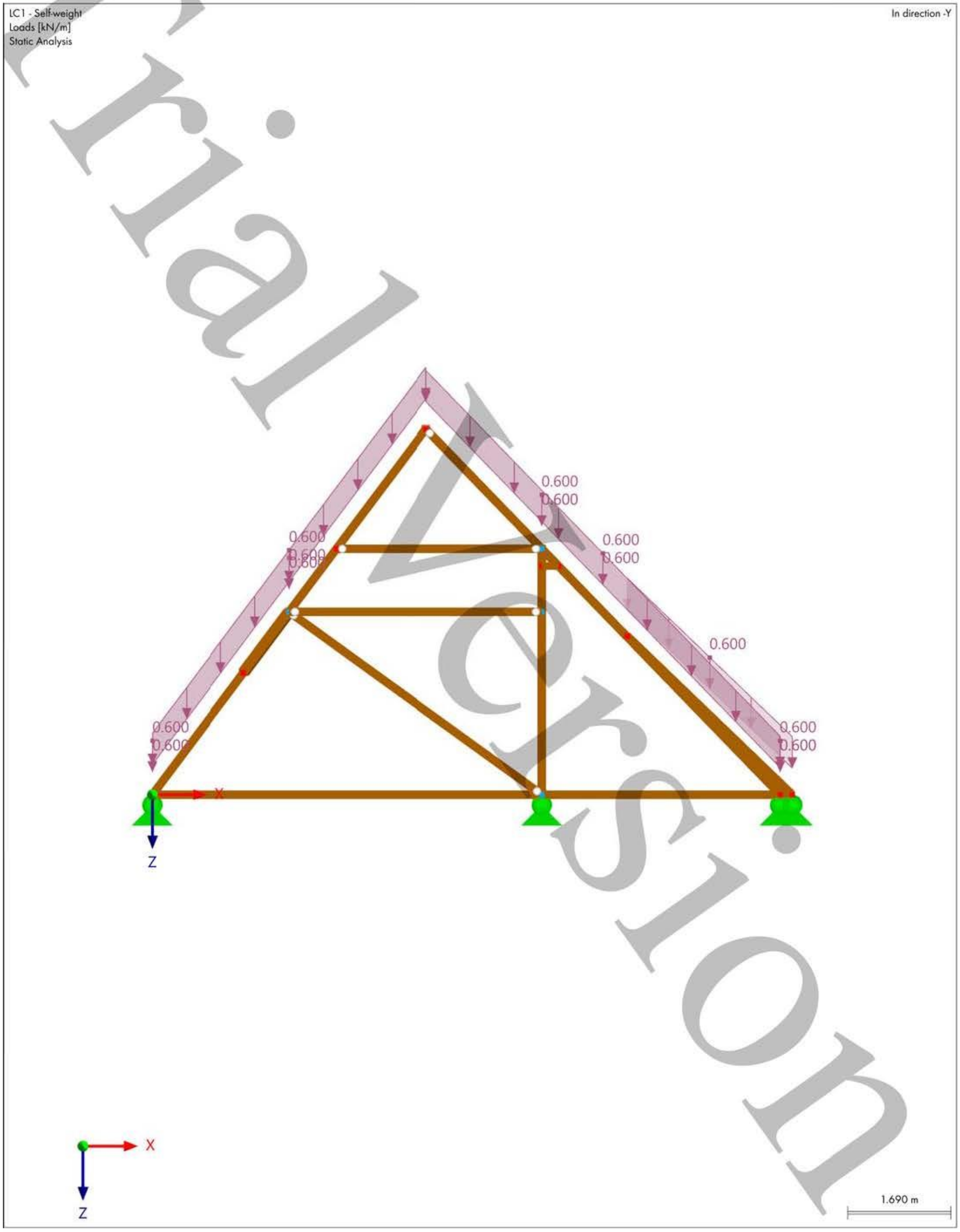
6.4.1 **LC1-STALNO** **Static Analysis**

LC1 - Self-weight
Loads [kN/m]
Static Analysis

In Axonometric Direction



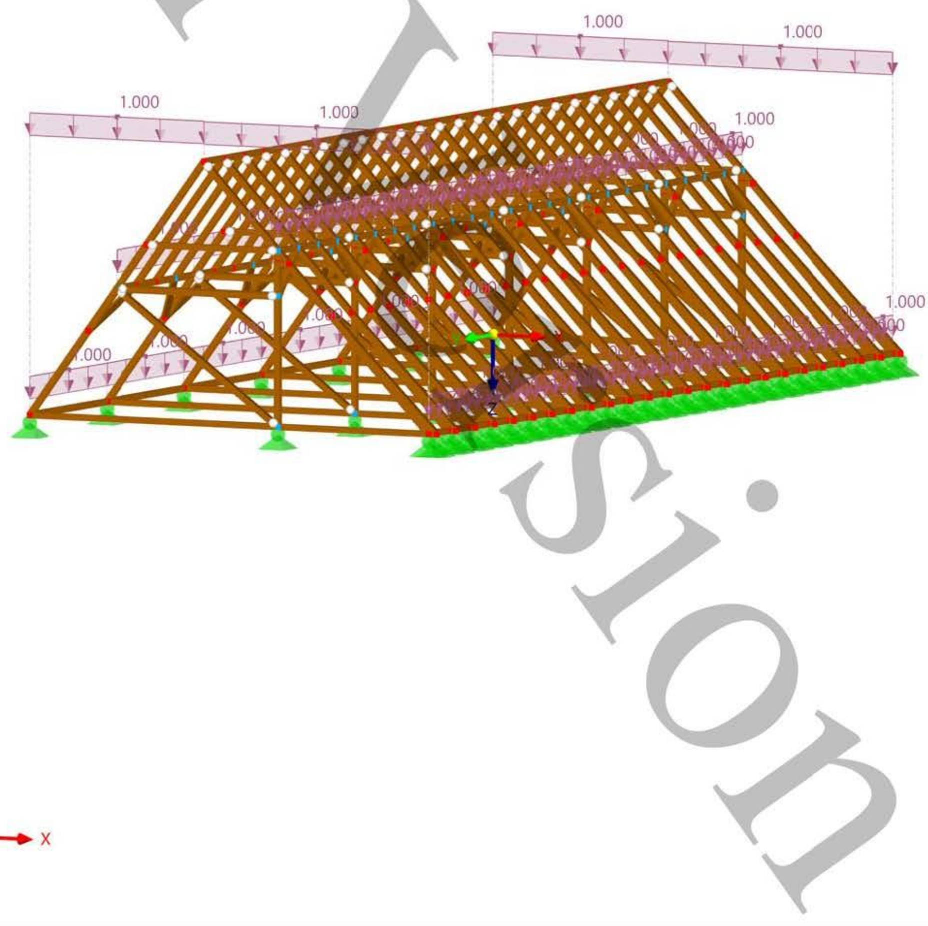
6.4.2 **LC1: , LOADING, IN DIRECTION -Y** **Static Analysis**



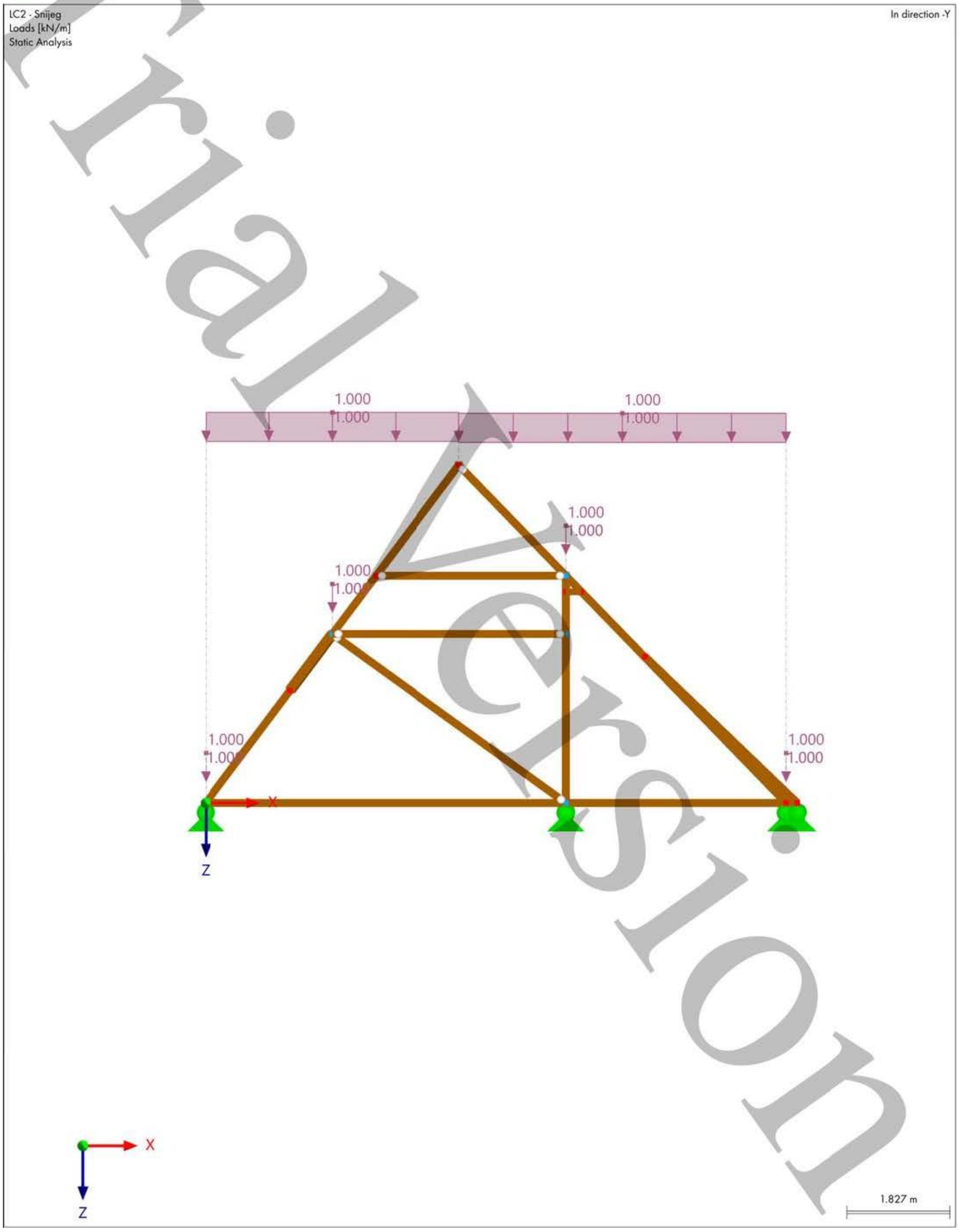
6.5.1 **LC2-SNIJEG** **Static Analysis**

LC2 - Snijeg
Loads [kN/m]
Static Analysis

In Axonometric Direction



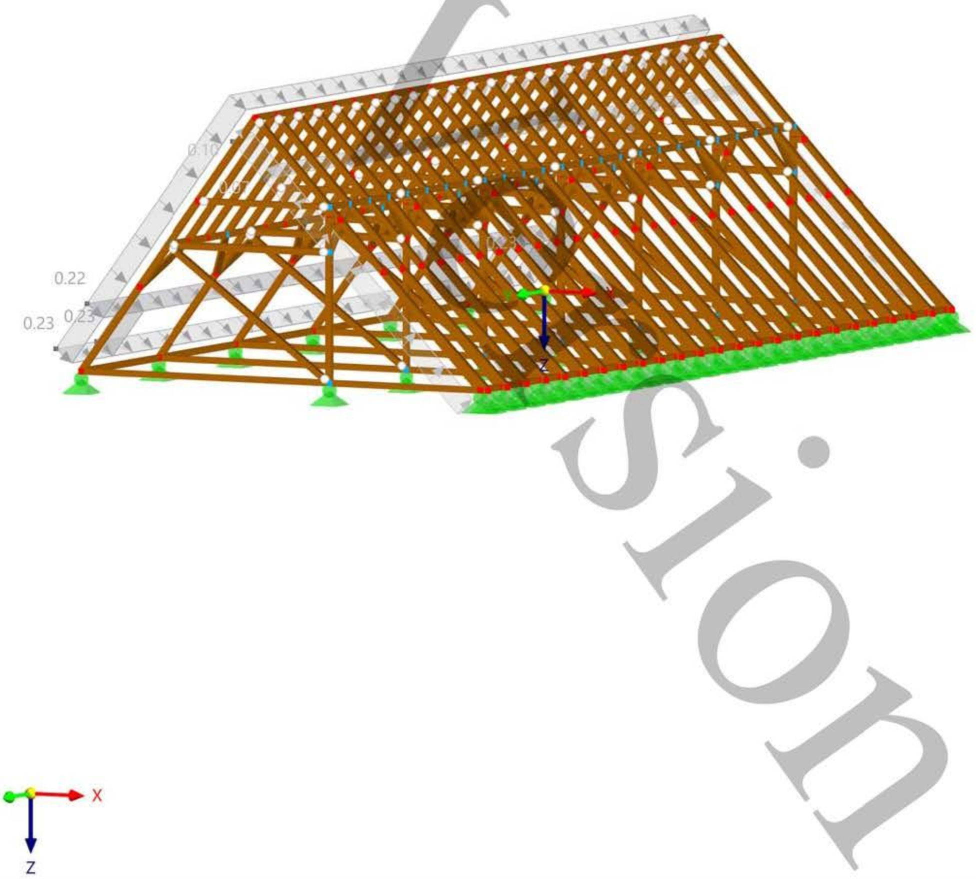
6.5.2 **LC2: , LOADING, IN DIRECTION -Y** **Static Analysis**



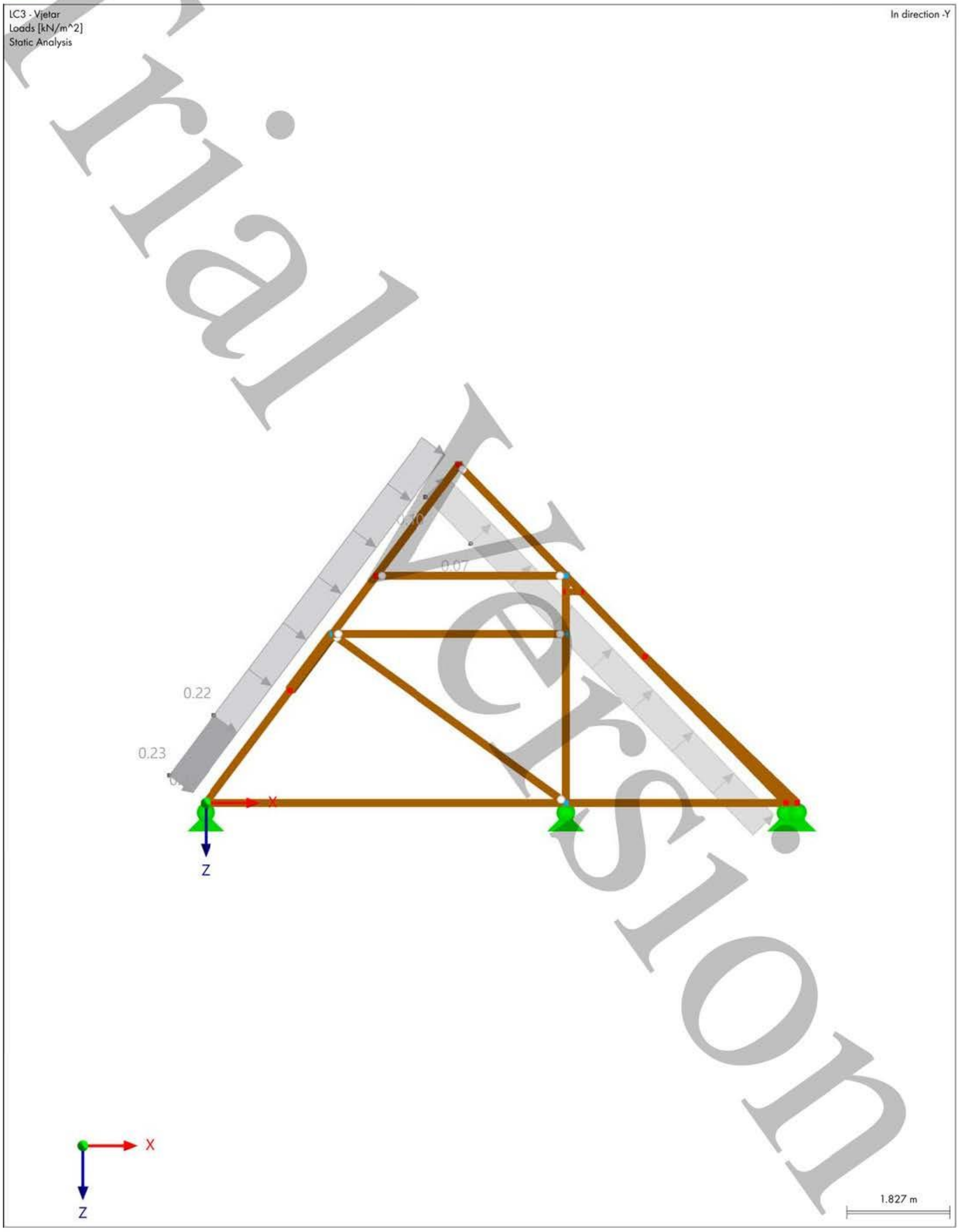
6.6.1 **LC3-VJETAR** **Static Analysis**

LC3 - Vjetar
Loads [kN/m^2]
Static Analysis

In Axonometric Direction



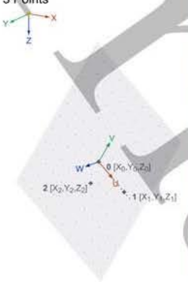
6.6.2 **LC3: , LOADING, IN DIRECTION -Y** **Static Analysis**



7 Guide Objects

7.1 COORDINATE SYSTEMS

3 Points



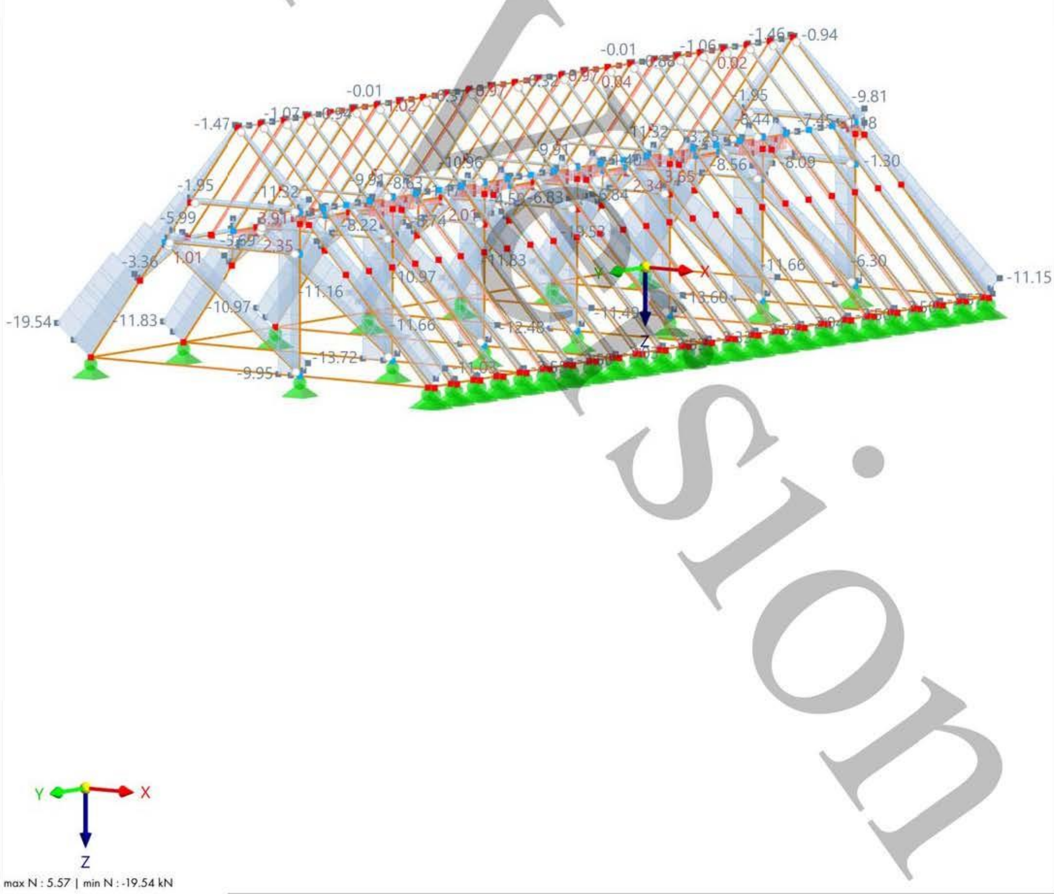
System No.	Type	Coordinates Symbol	Coordinates Value	Coordinates Unit	Rotation Sequence	Rotation Symbol	Rotation Value	Rotation Unit	Comment
1	Global XYZ								
2	3 Points | Load Wizard | Wind Load No. 1 | 4.500, 22.800, -6.000 m | 4.535, 21.801, -5.964 m | 3.781, 22.800, -5.305 m								
	3 Points	X_0	4.500	m					
		Y_0	22.800	m					
		Z_0	-6.000	m					
		X_1	4.535	m					
		Y_1	21.801	m					
		Z_1	-5.964	m					
		X_2	3.781	m					
		Y_2	22.800	m					
		Z_2	-5.305	m					
3	3 Points | Load Wizard | Wind Load No. 1 | 0.000, 22.800, 0.000 m | 0.333, 21.968, -0.444 m | 0.800, 22.800, 0.600 m								
	3 Points	X_0	0.000	m					
		Y_0	22.800	m					
		Z_0	0.000	m					
		X_1	0.333	m					
		Y_1	21.968	m					
		Z_1	-0.444	m					
		X_2	0.800	m					
		Y_2	22.800	m					
		Z_2	0.600	m					

8 Static Analysis Results

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

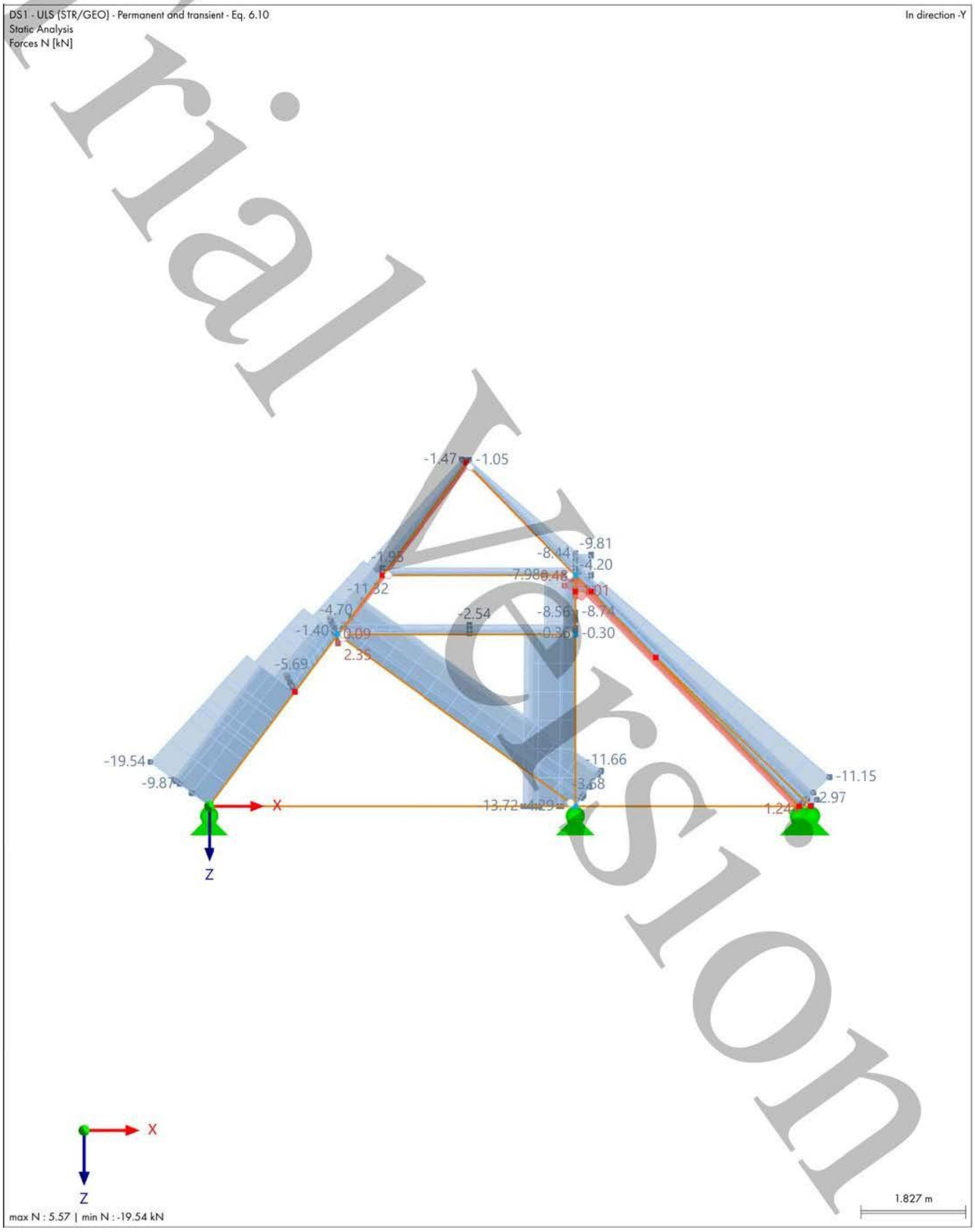
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Forces N [kN]

In Axonometric Direction



max N : 5.57 | min N : -19.54 kN

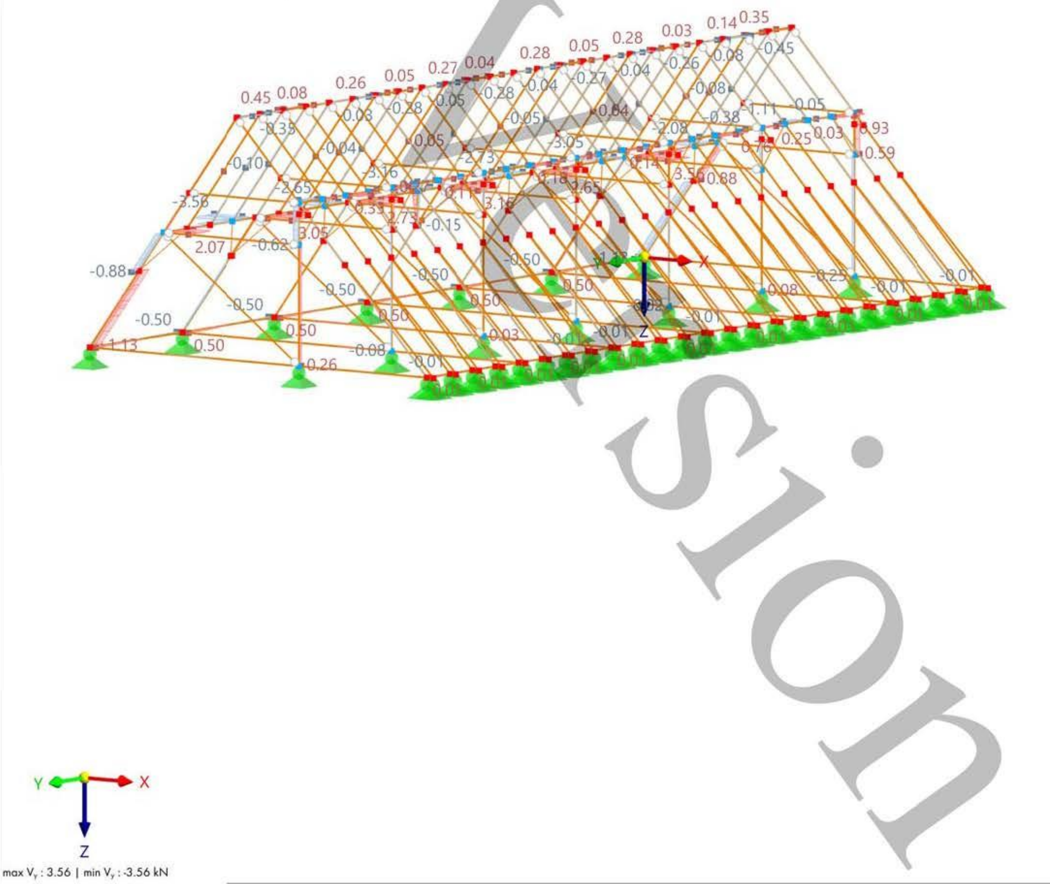
8.2 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES N, LOADING, IN DIRECTION -Y** **Static Analysis**



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

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

In Axonometric Direction

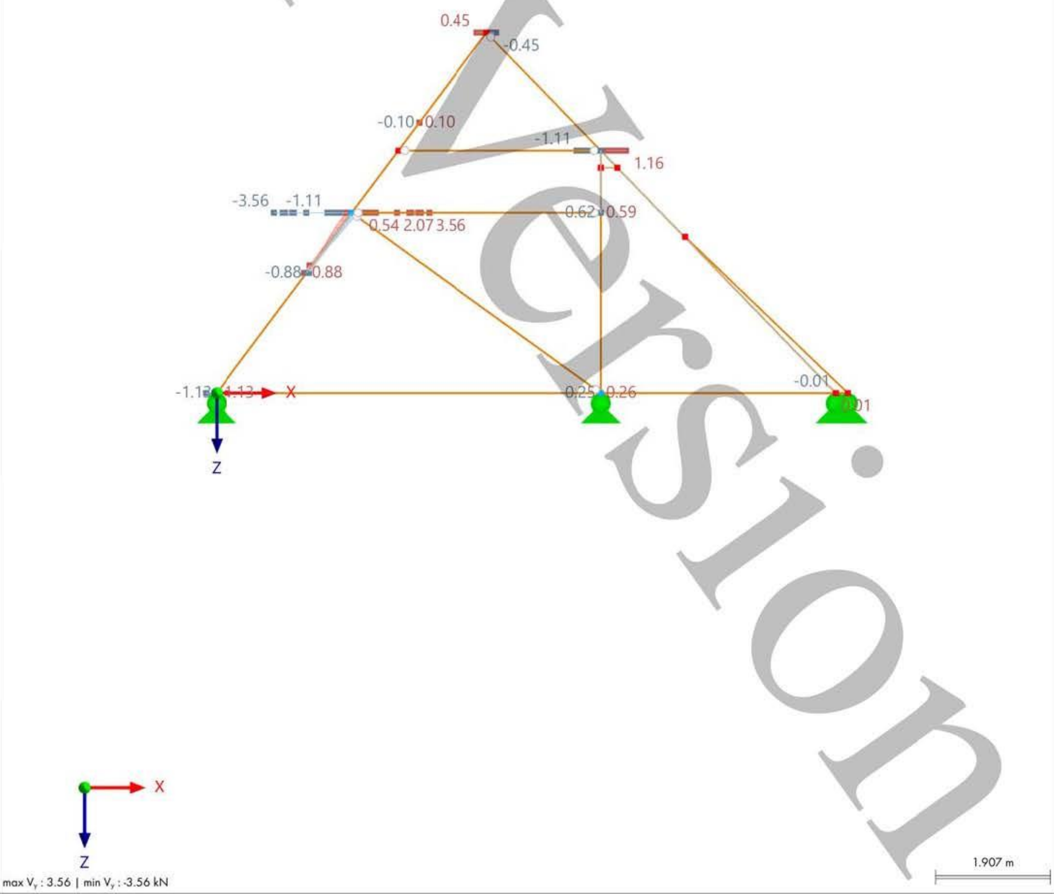


max V_y : 3.56 | min V_y : -3.56 kN

8.4 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES V_y, LOADING, IN DIRECTION -Y** **Static Analysis**

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

In direction -Y

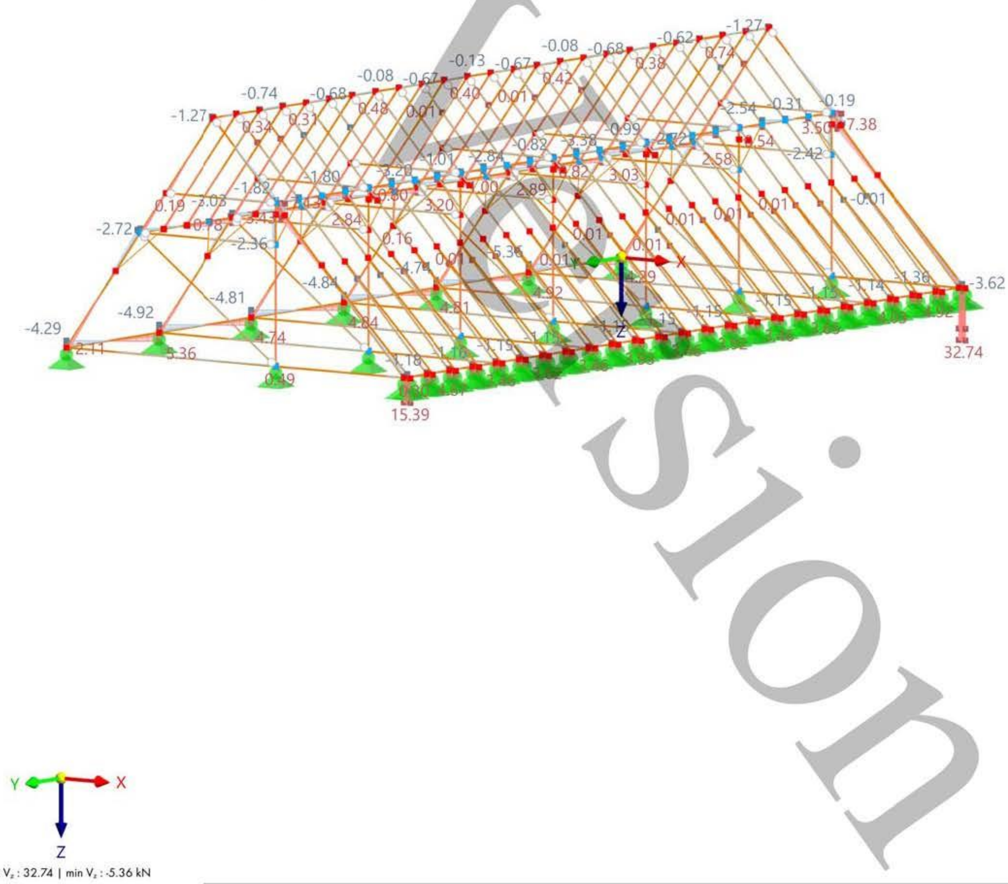


max V_y : 3.56 | min V_y : -3.56 kN

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

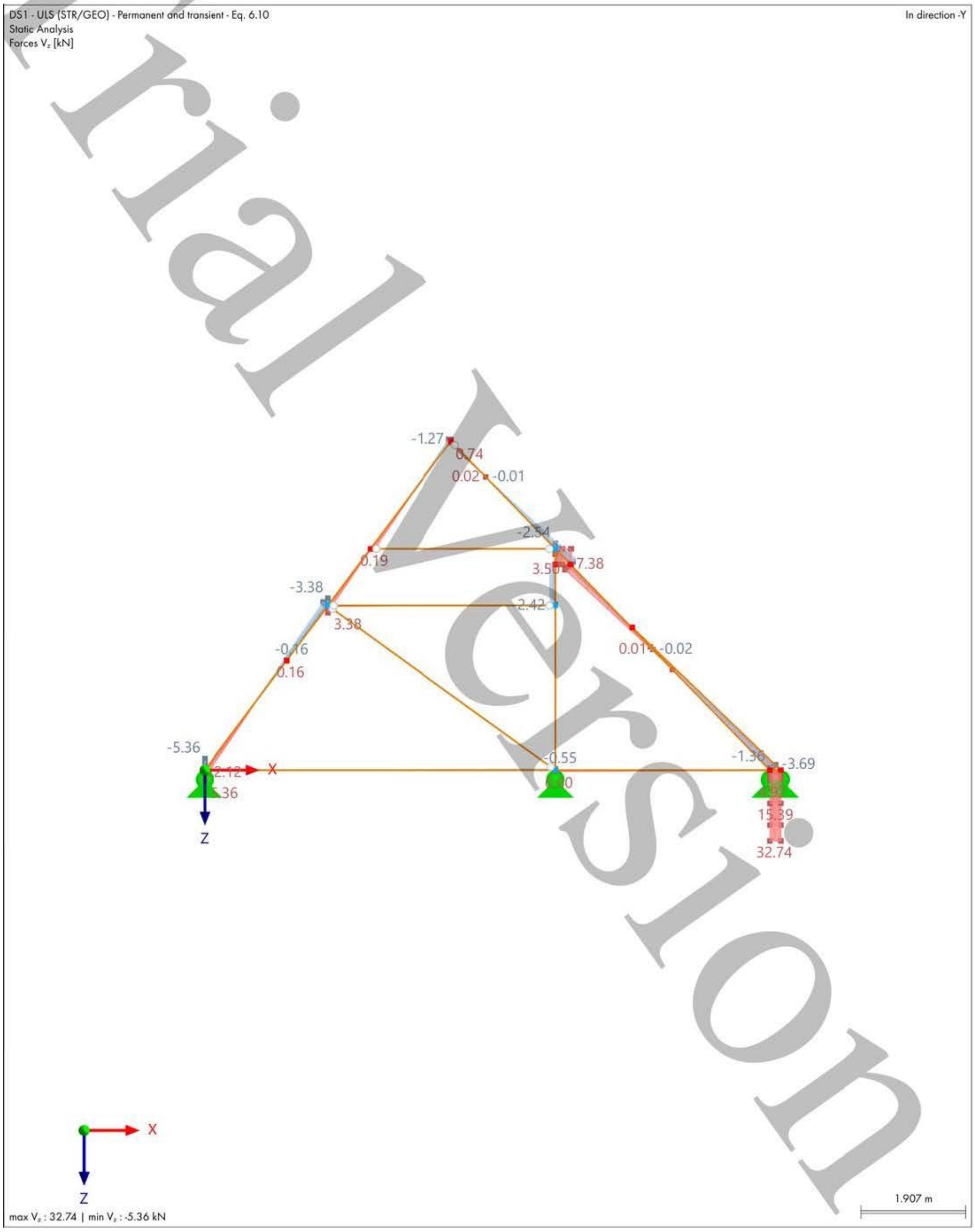
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Forces V_z [kN]

In Axonometric Direction



max V_z : 32.74 | min V_z : -5.36 kN

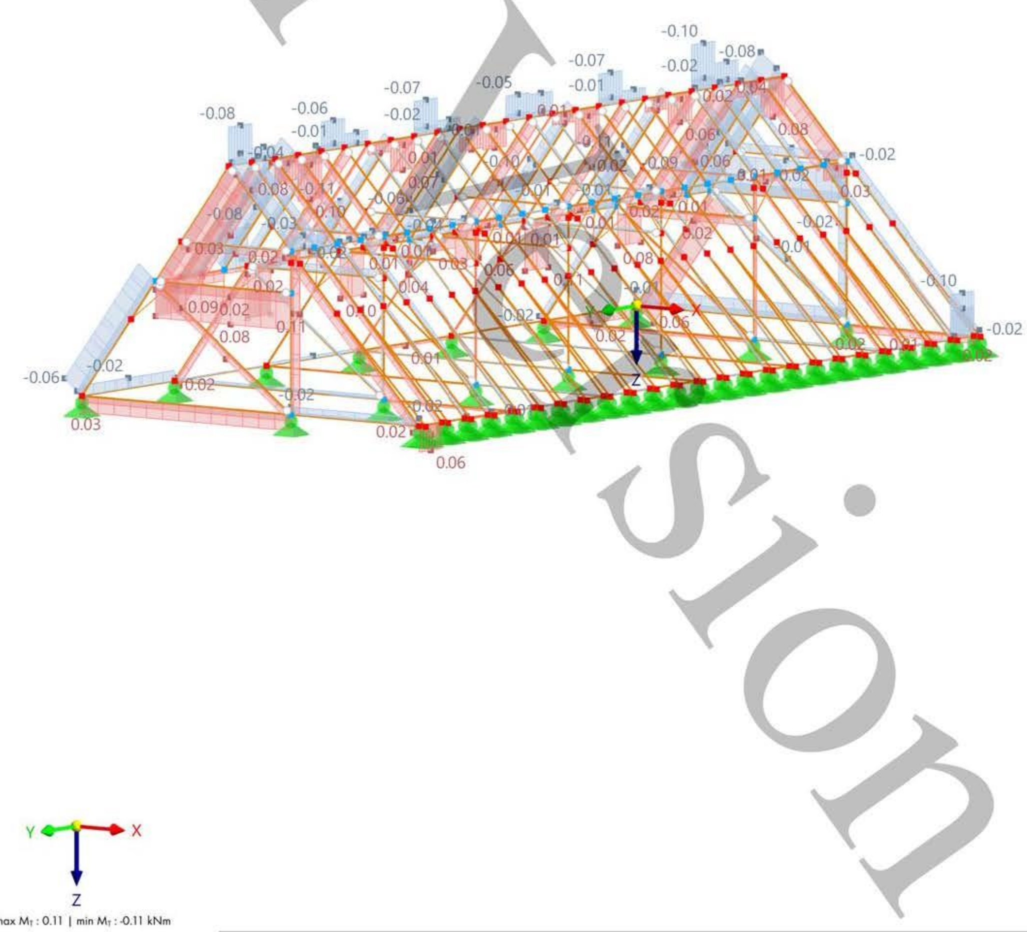
8.6 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES V_z, LOADING, IN DIRECTION -Y** **Static Analysis**



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

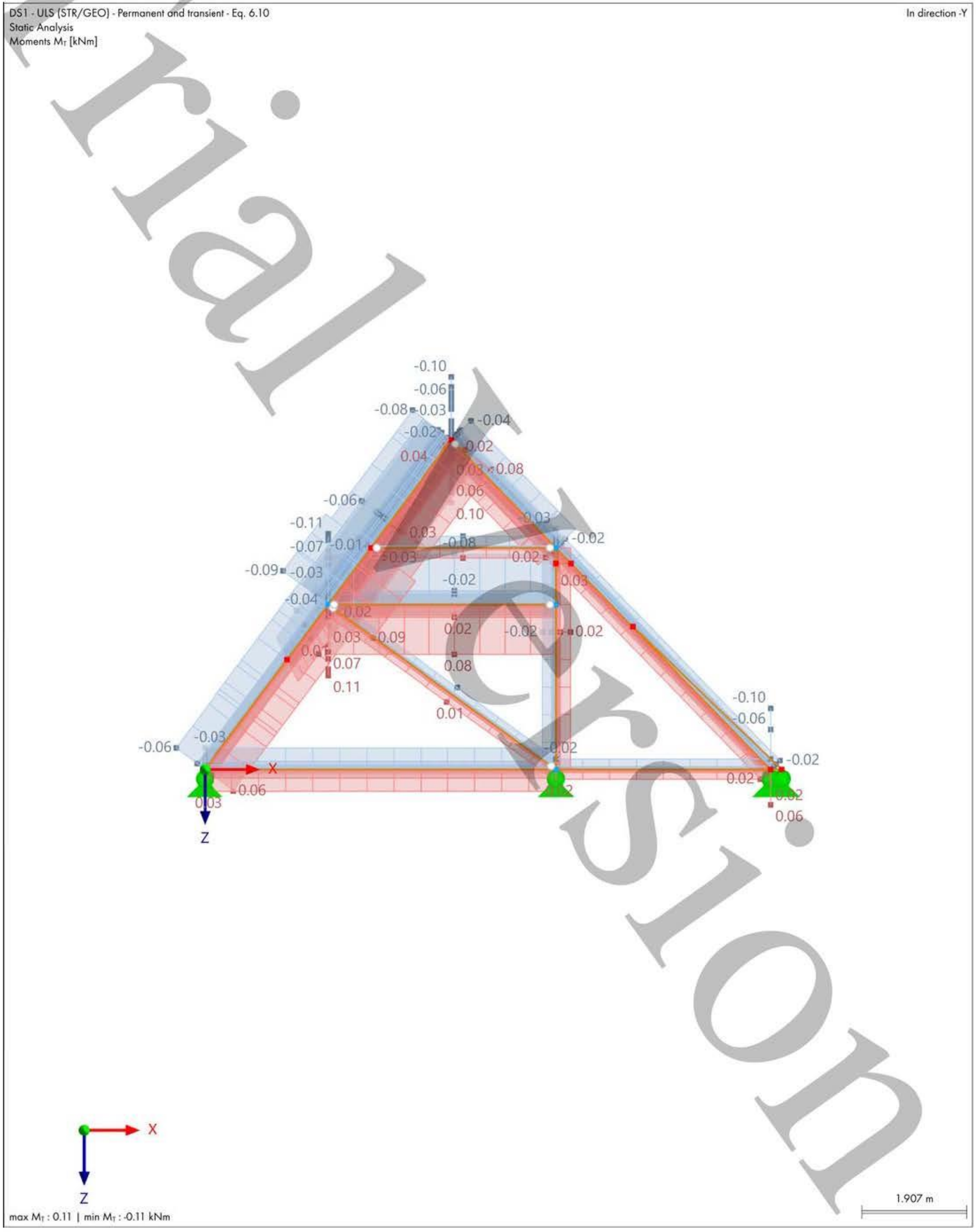
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Moments M_T [kNm]

In Axonometric Direction



max M_T : 0.11 | min M_T : -0.11 kNm

8.8 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES M_T, LOADING, IN DIRECTION -Y** **Static Analysis**

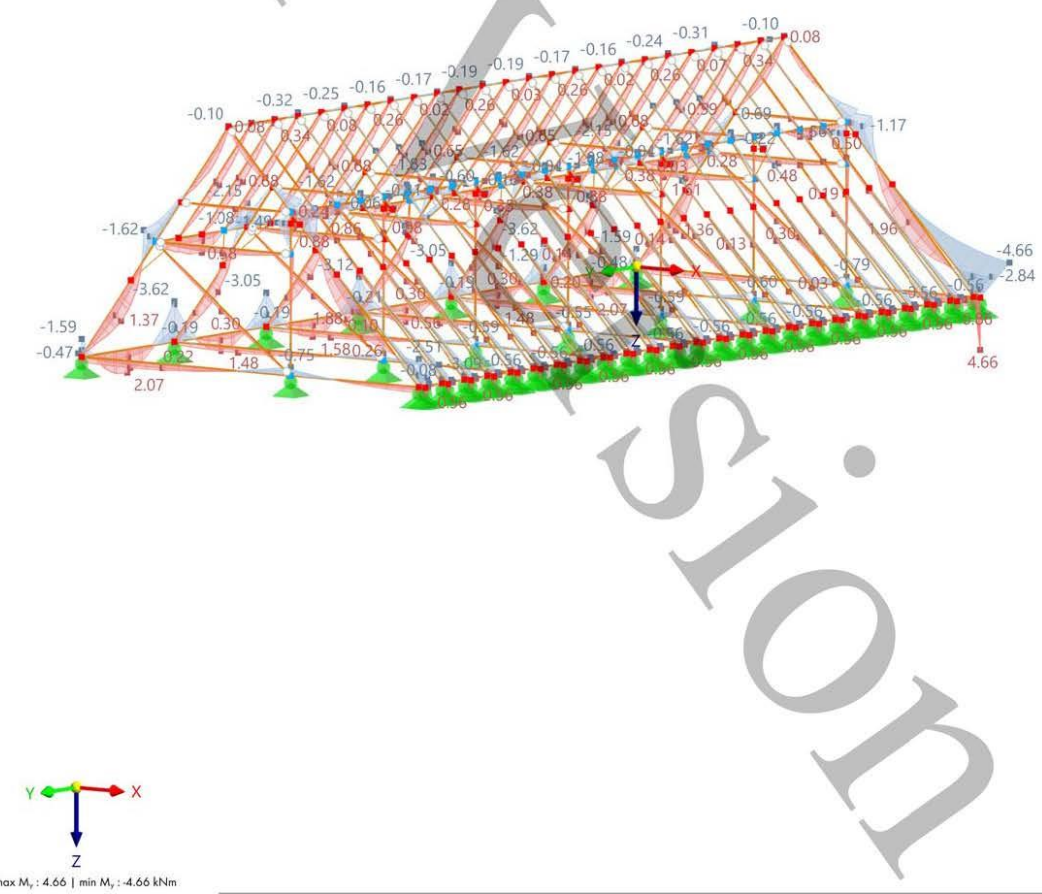


8.9 DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES M_y, IN AXONOMETRIC DIRECTION

Static Analysis

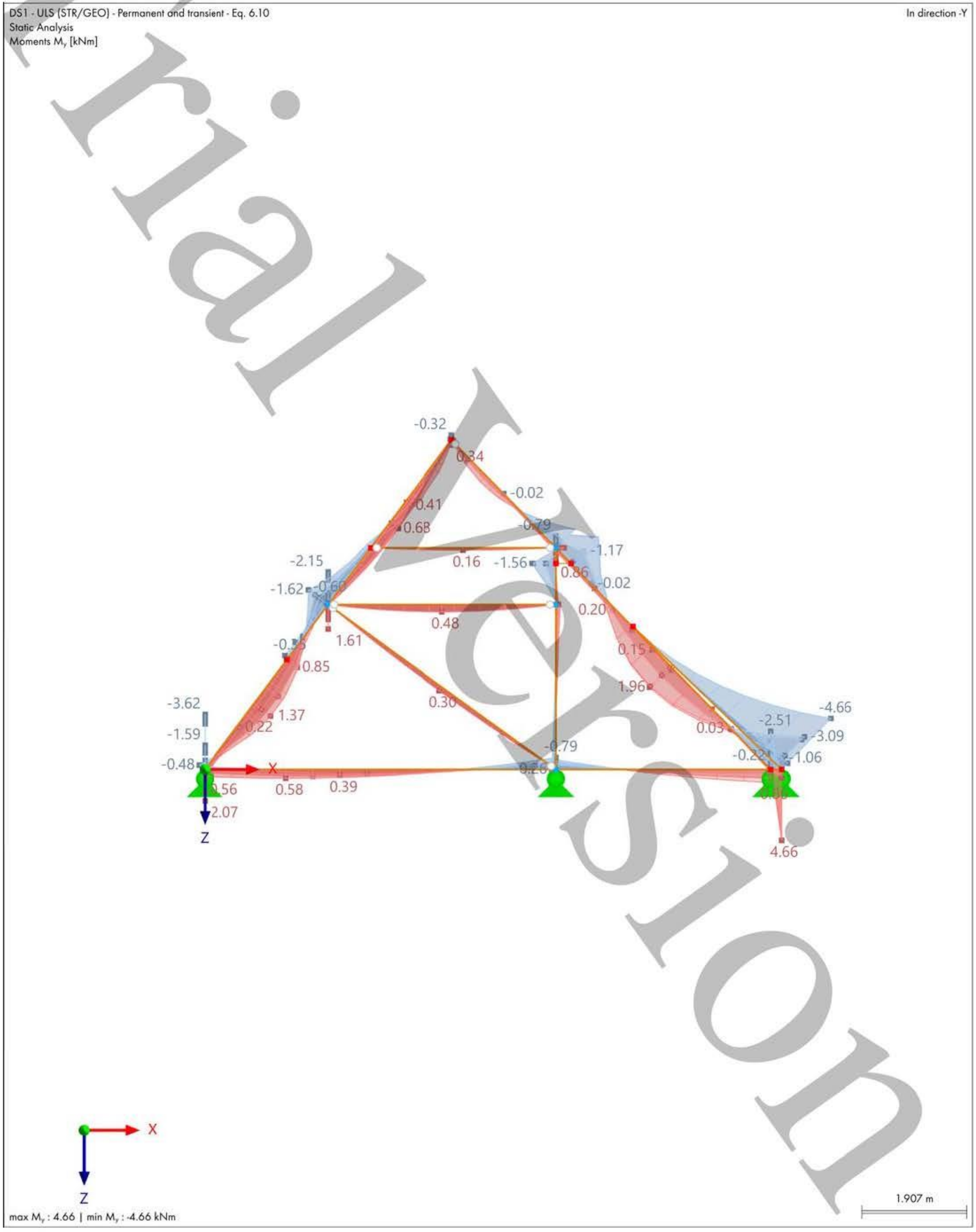
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Moments M_y [kNm]

In Axonometric Direction



max M_y : 4.66 | min M_y : -4.66 kNm

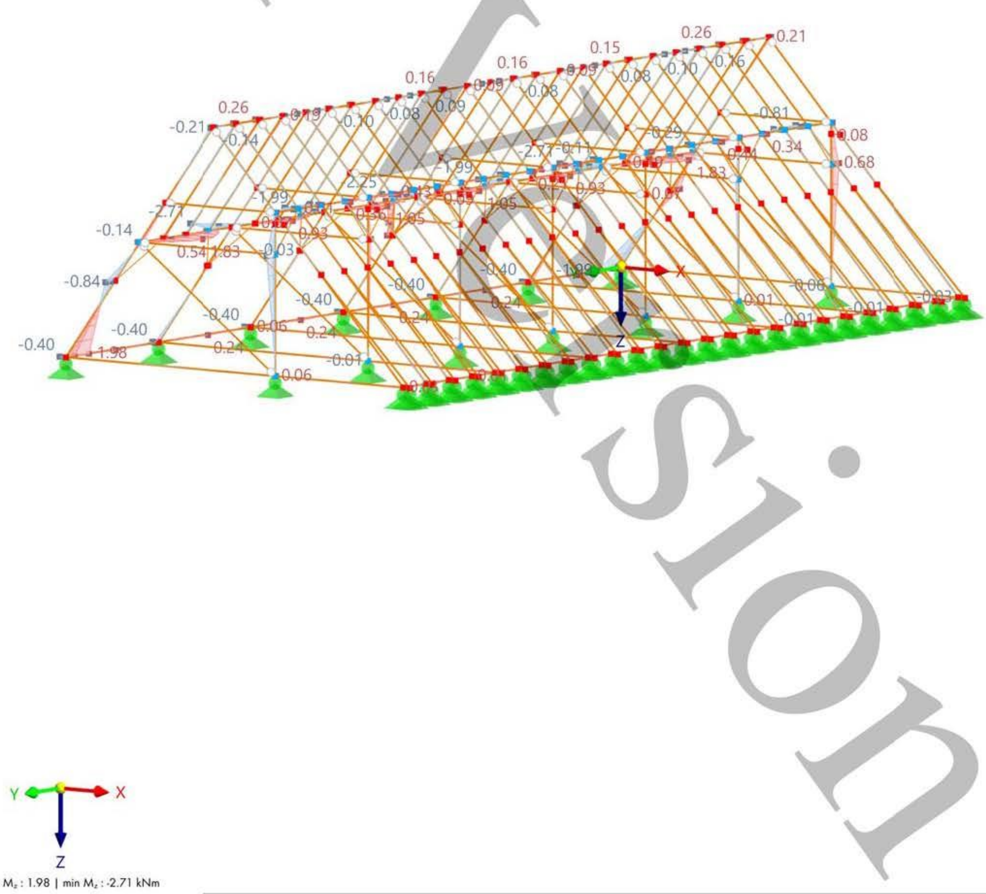
8.10 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES M_y, LOADING, IN DIRECTION -Y** **Static Analysis**



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

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

In Axonometric Direction

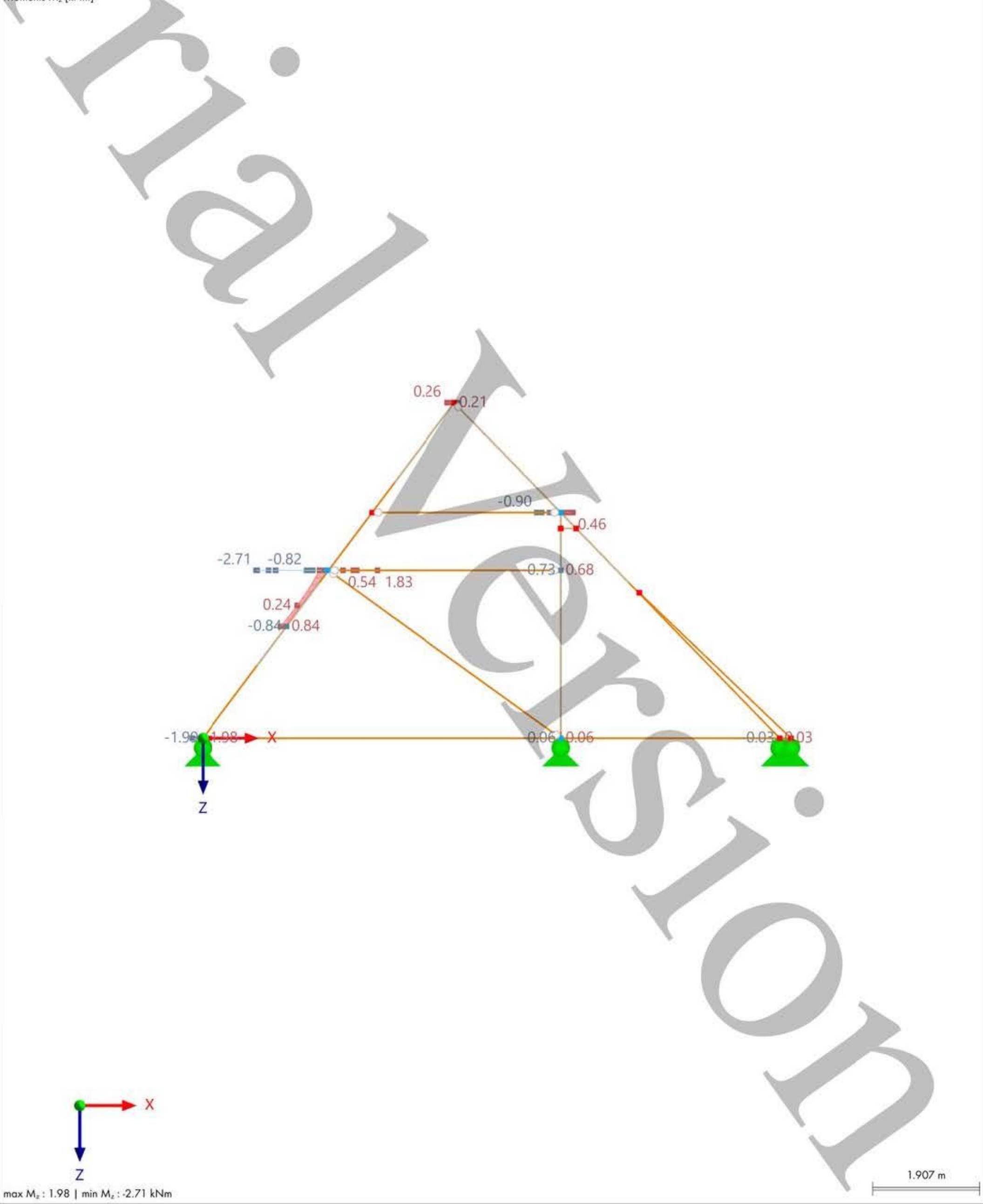


max M_z : 1.98 | min M_z : -2.71 kNm

8.12 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES M_z, LOADING, IN DIRECTION -Y** **Static Analysis**

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

In direction -Y

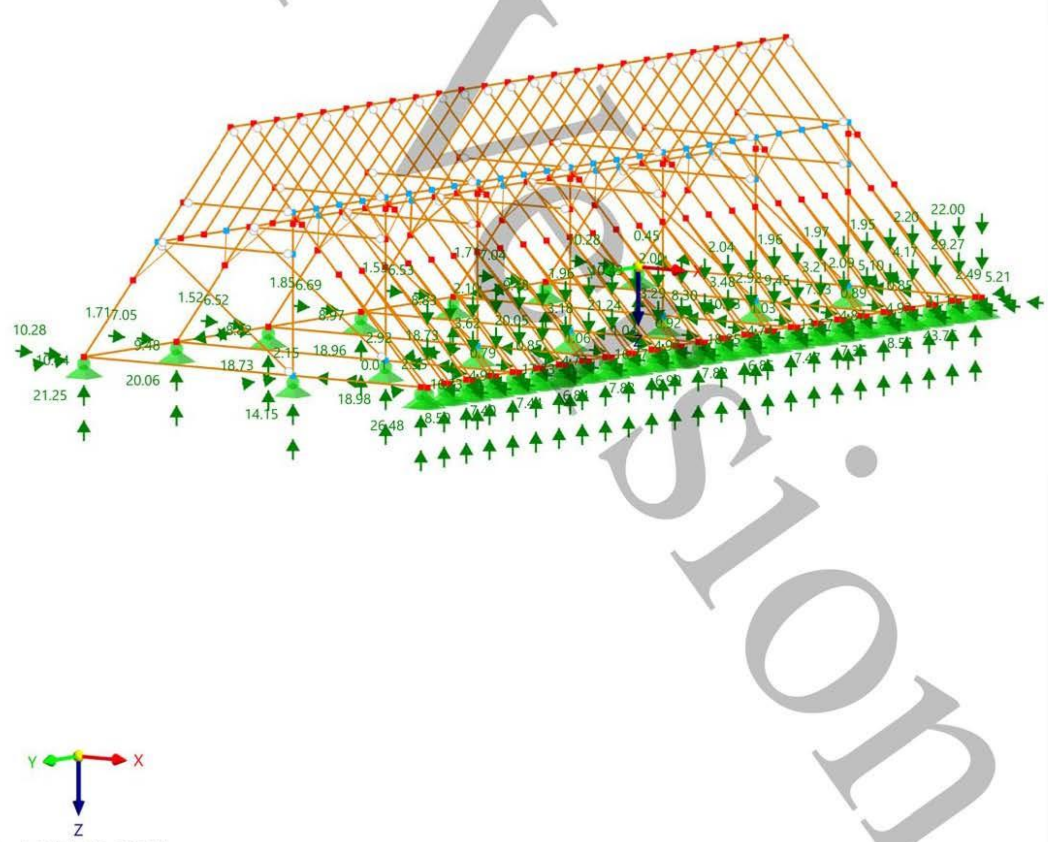


max M_z : 1.98 | min M_z : -2.71 kNm

8.13 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, NODAL SUPPORTS P_x, NODAL SUPPORTS P_y, NODAL SUPPORTS P_z, 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

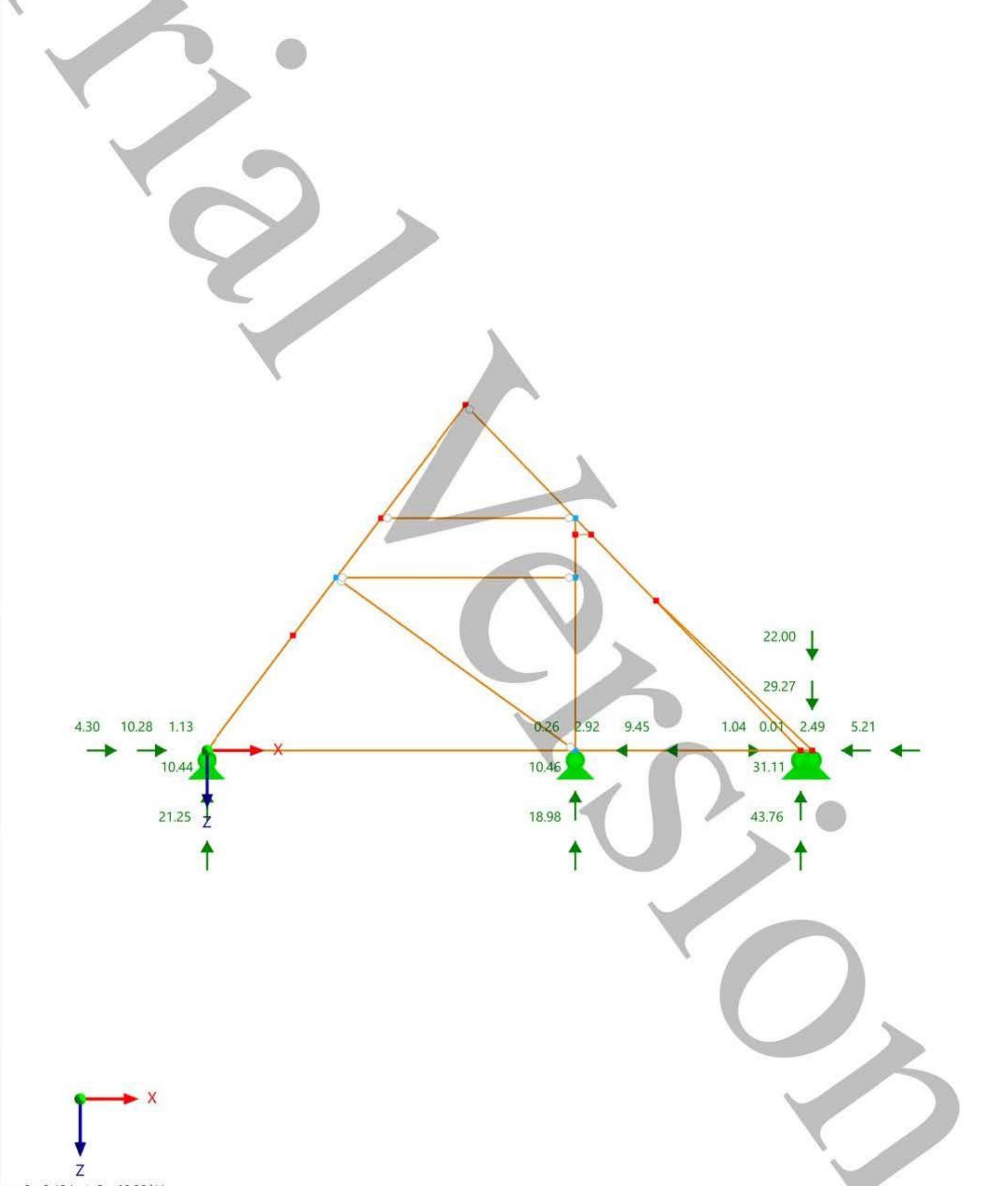


max P_x : 9.45 | min P_x : -10.28 kN
max P_y : 1.13 | min P_y : -1.13 kN
max P_z : 43.76 | min P_z : -29.27 kN

8.14 **DS1: ENVELOPE VALUES - MAX AND MIN VALUES, NODAL SUPPORTS P_x, NODAL SUPPORTS P_y, NODAL SUPPORTS P_z, LOADING, IN DIRECTION -Y** **Static Analysis**

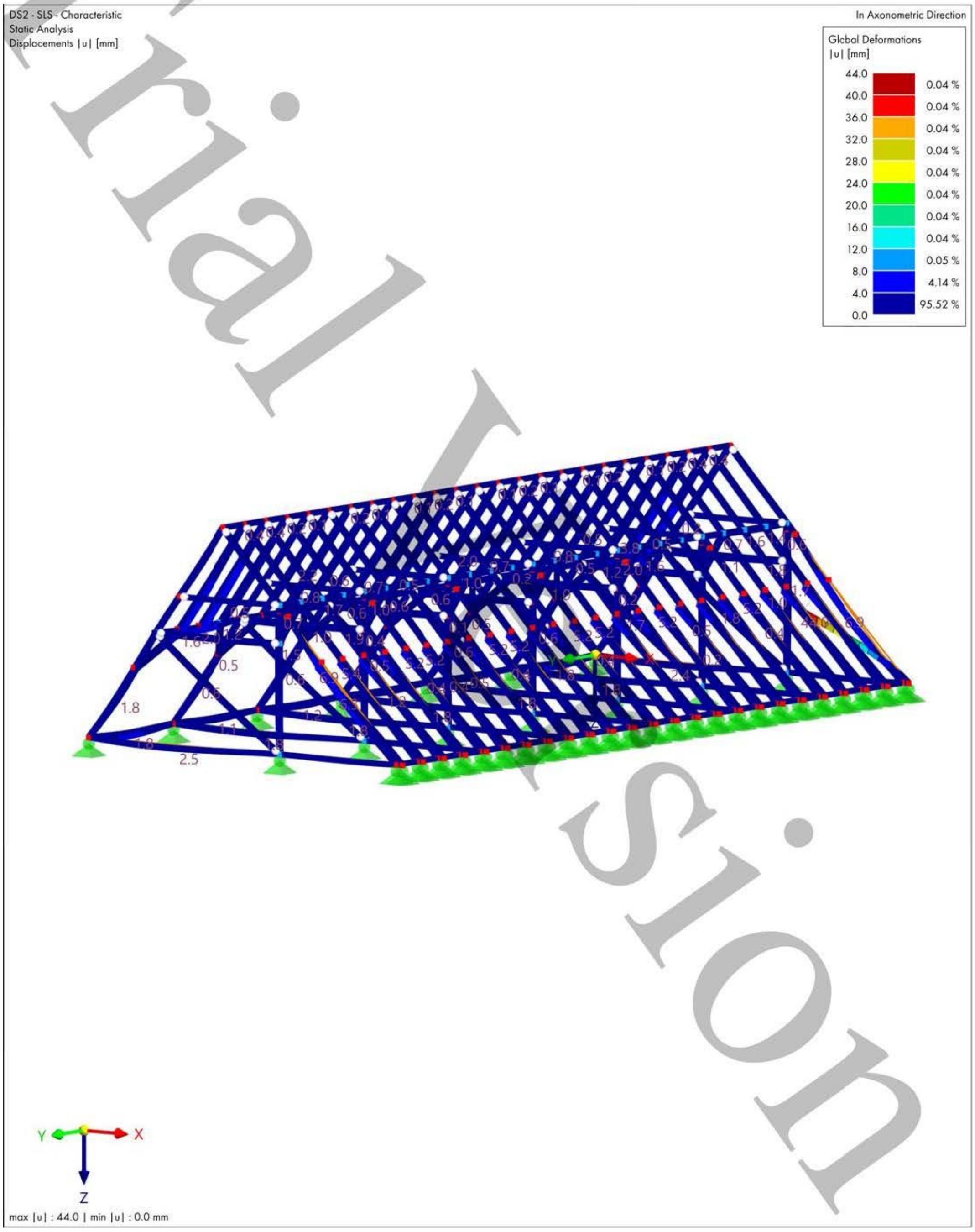
DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10
Static Analysis
Local Reaction Forces P_x, P_y, P_z [kN]

In direction -Y

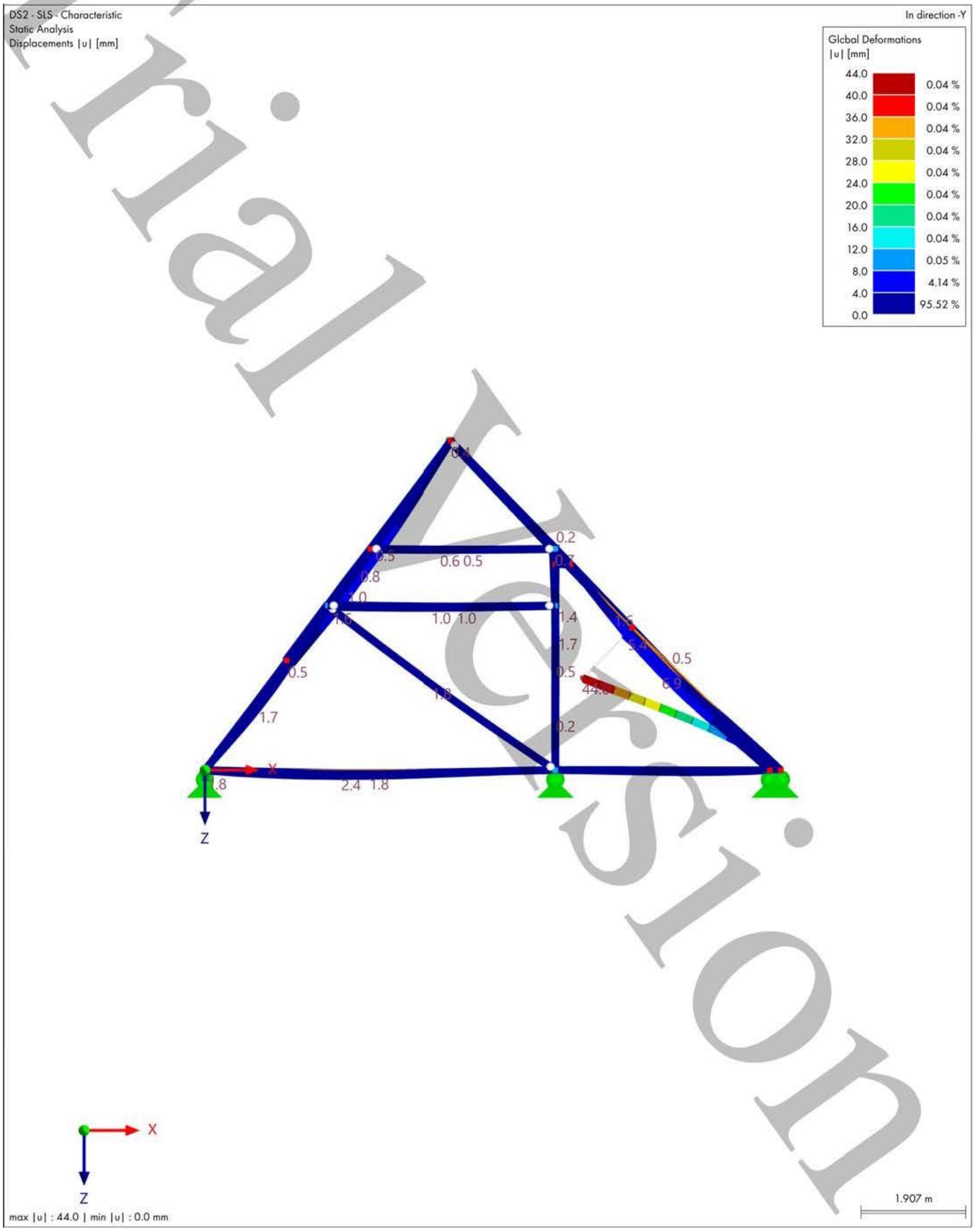


max P_x : 9.45 | min P_x : -10.28 kN
max P_y : 1.13 | min P_y : -1.13 kN
max P_z : 43.76 | min P_z : -29.27 kN

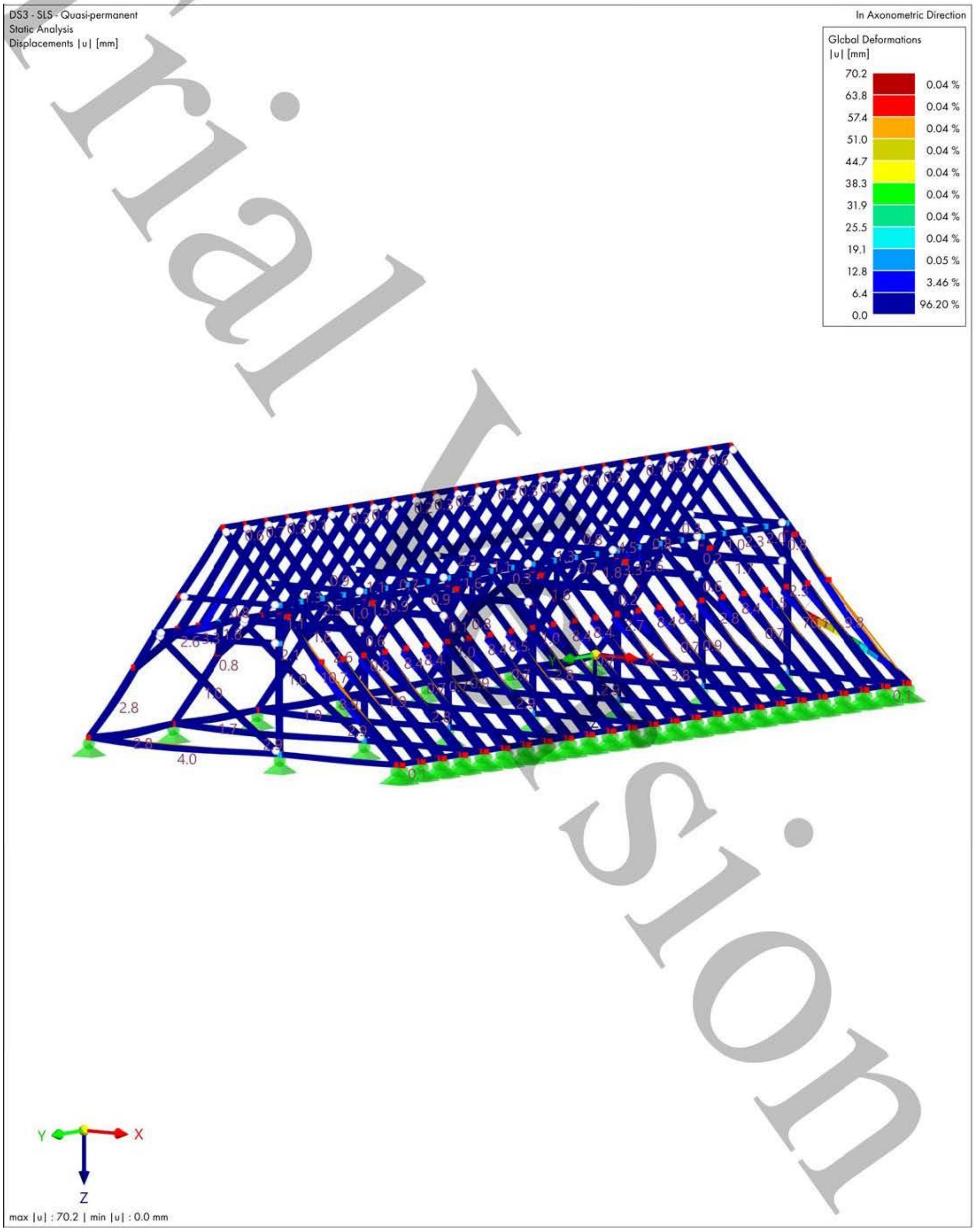
8.15 **DS2: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Static Analysis**



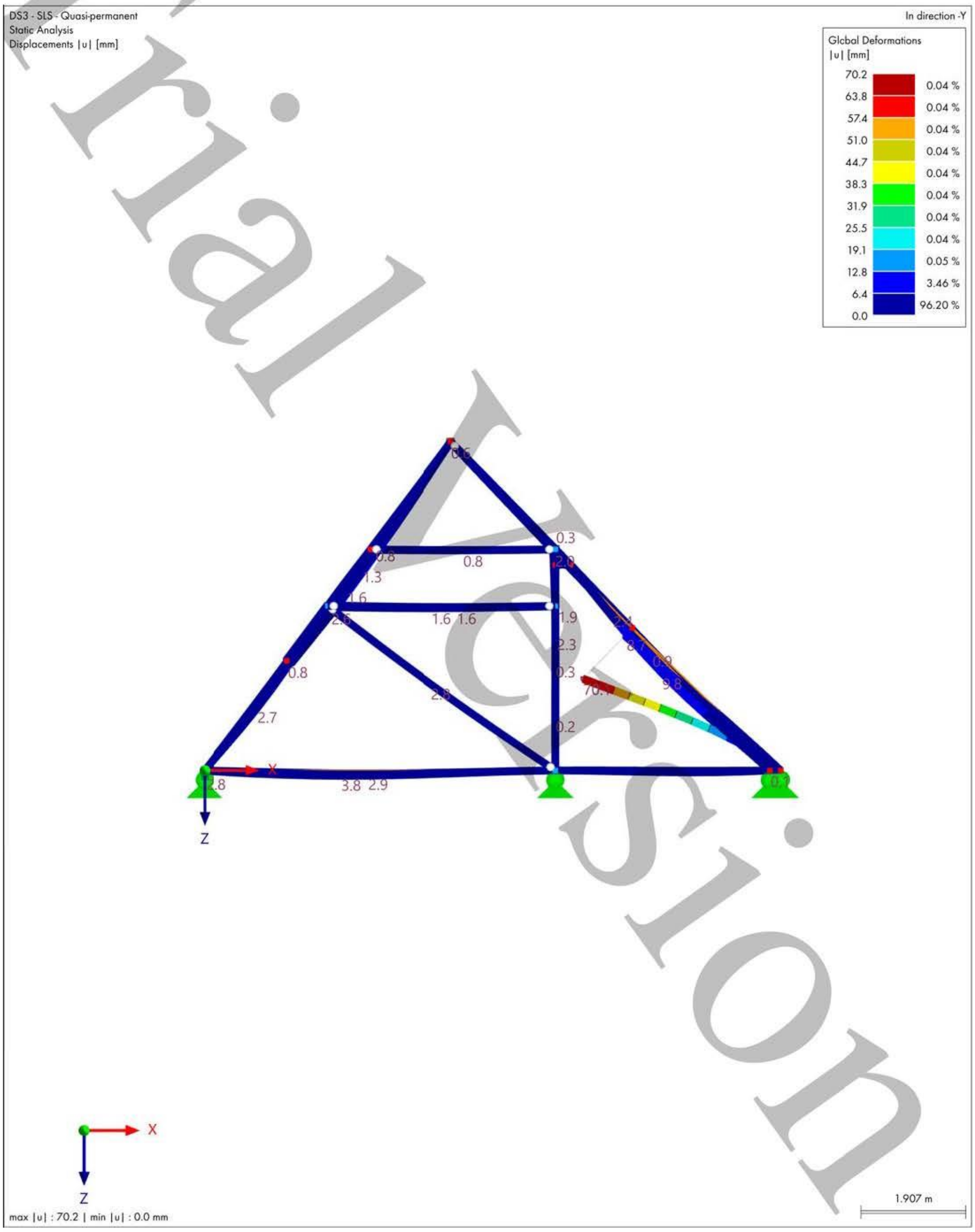
8.16 **DS2: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, LOADING, IN DIRECTION -Y** **Static Analysis**



8.17 **DS3: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, IN AXONOMETRIC DIRECTION** **Static Analysis**



8.18 **DS3: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, LOADING, IN DIRECTION -Y** **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	☐	1-4,6-8,10,11,16,18,19,24,34,35,40,42-48,55-62,64-66,68-70,72-78,84-91,93-95,97-99,101-107,113-120,122-124,126-128,130-136,142-149,151-153,155-157,159-165,171-178,180-182,184-186,188-194,200-242	1-4,7,8,10,11,16,18,19,24,34,35,40,42-45,47,48,55-62,64-66,68-70,72-75,77,78,84-91,93-95,97-99,101-104,106,107,113-120,122-124,126-128,130-133,135,136,142-149,151-153,155-157,159-162,164,165,171-178,180-182,184-186,188-191,193,194,200-211,219-242		6,46,76,105,134,163,192,212-218	

9.2 DESIGN SITUATIONS

DS No.	EN 1990 | Timber | CEN | 2010-04 Design Situation Type	To Design	Active	EN 1995 | HRN | 2015-03 Design Situation Type	Combinations to Design for Enumeration Method
1	ULS ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒	☒	ULS ULS (STR/GEO) - Permanent and transient	All
2	S Ch SLS - Characteristic	☒	☒	S Ch SLS - Characteristic	All
3	S Qp SLS - Quasi-permanent	☒	☒	S Qp1 SLS - Quasi-permanent 1	All

9.3 MATERIALS

Legend
Stiffness modification

Material No.	Name	To Design	Material Type	Options	Comment
1	C24	☒	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 120/120	1	☒	Parametric - Massive I	--	
2	R_M1 140/140	1	☒	Parametric - Massive I	--	
3	2R_M2 140/140/140/1	1	☒	Parametric - Massive II	--	
4	2R_M2 120/120/140/1	1	☒	Parametric - Massive II	--	

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 ($\sigma_{t,0,d}$ / $f_{t,0,d}$)	$\eta_{\sigma t,lim}$	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	$\|\alpha\| \leq$	24.00	deg

9.5.1 ULTIMATE CONFIGURATIONS - SETTINGS - MEMBERS

Config. No.	Description	Symbol	Value	Unit
	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)			

9.5.2 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			

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	$w_{inst,lim}$	5.0	mm

9.6.2 SERVICEABILITY CONFIGURATIONS - SETTINGS - SURFACES

Config. No.	Description	Symbol	Value	Unit
1	Default			
	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	--

9.6.2 SERVICEABILITY CONFIGURATIONS - SETTINGS - SURFACES

Config. No.	Description	Symbol	Value	Unit
	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

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)			

9.7.2 FIRE RESISTANCE CONFIGURATIONS - SETTINGS - SURFACES

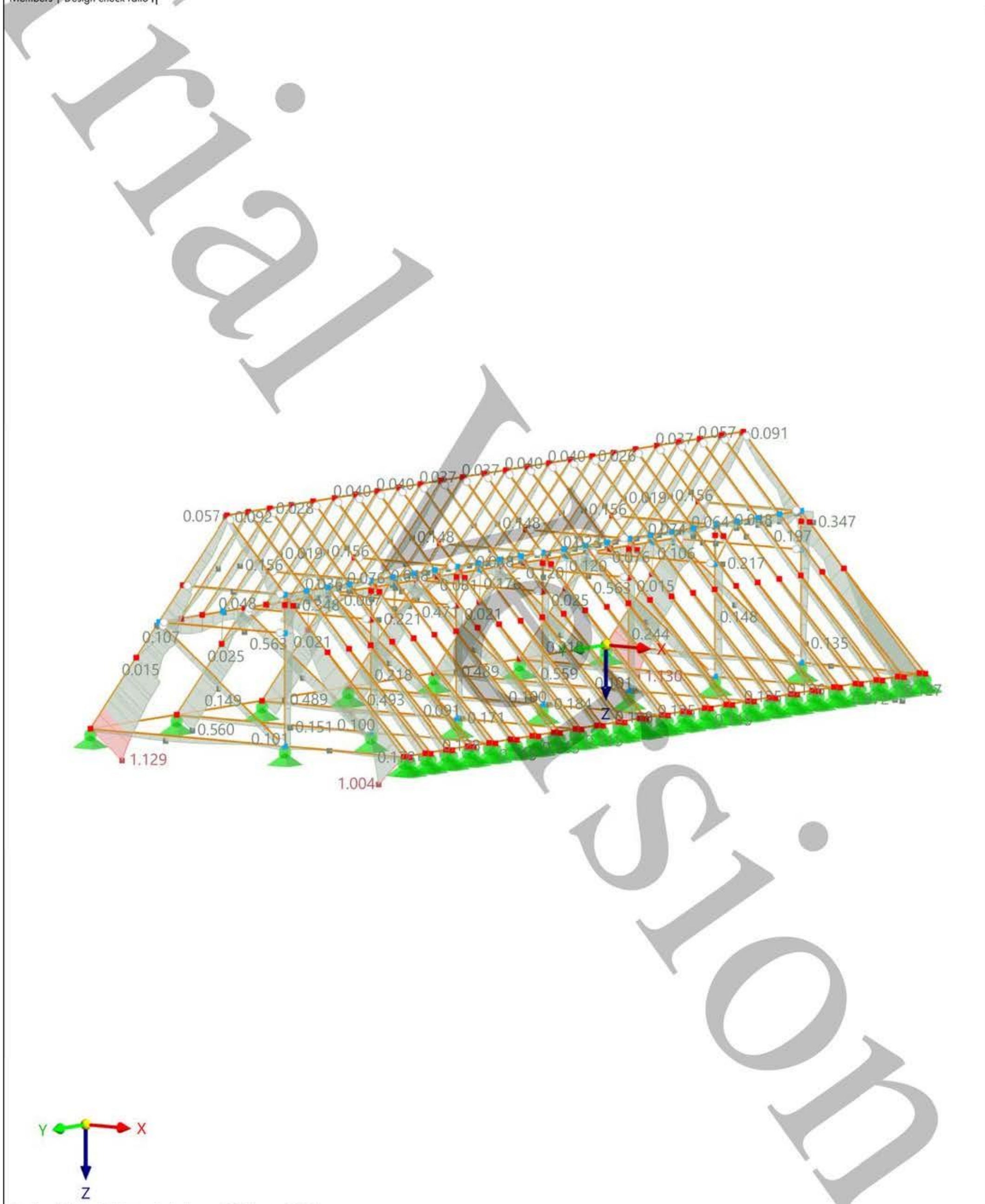
Config. No.	Description	Symbol	Value	Unit
1	Default			
	Fire Design Settings			
	Required time of fire resistance	t	15	min
	○ Heat-proof adhesion of cross-laminated timber layers			
	◉ Non-heat-proof adhesion of cross-laminated timber layers			
	Coefficient increasing charring rate of inner layers	k_β	2.00	--
	☐ User-defined coefficient of layer thickness with zero strength			
	Thickness to omit fire reduced layer		3.0	mm
	Fire exposure			
	☒ Top (-z)			
	☐ Initial fire protection from top (-z)			
	☒ Bottom (+z)			
	☐ Initial fire protection from bottom (+z)			

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

Timber Design

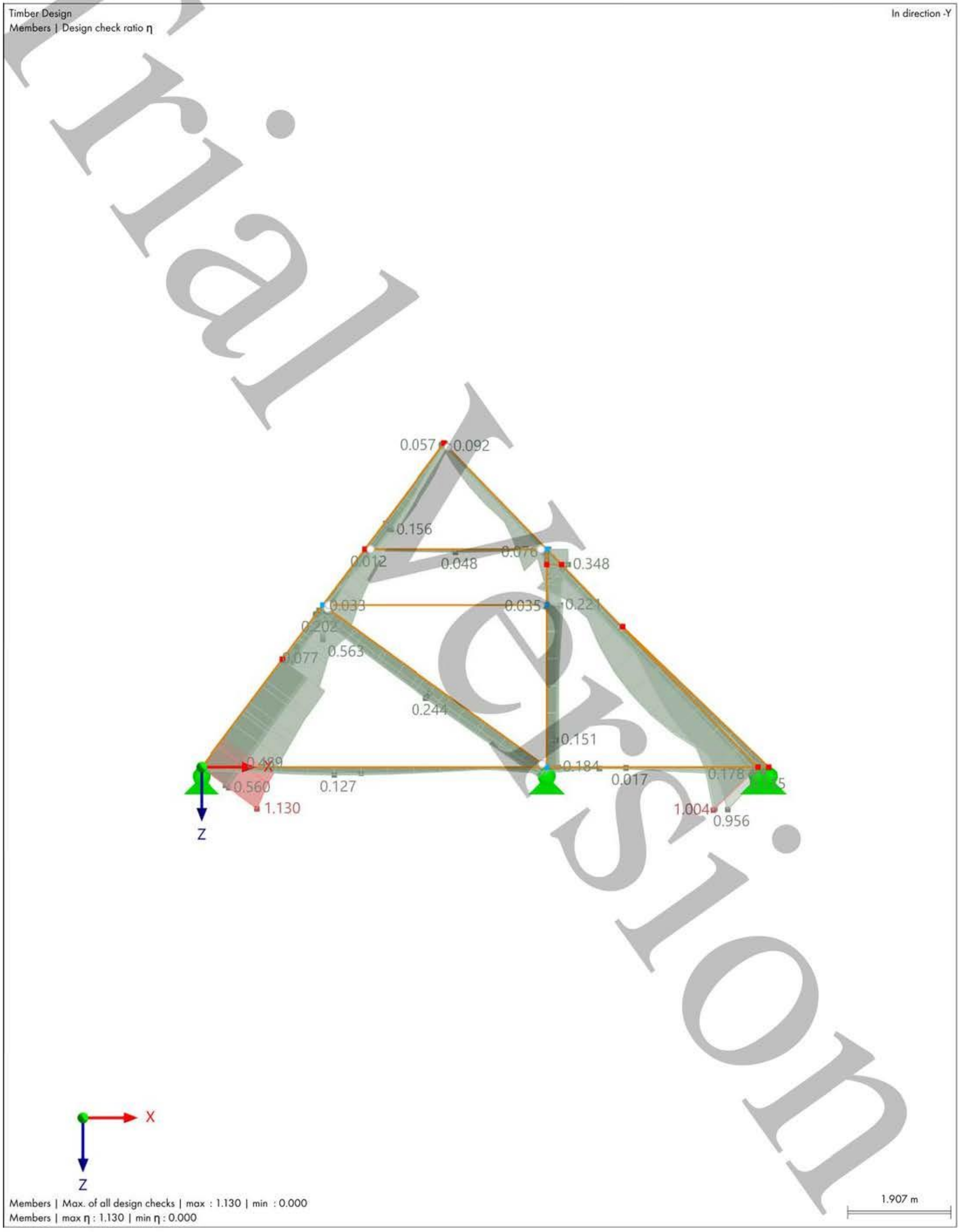
Timber Design
Members | Design check ratio η

In Axonometric Direction



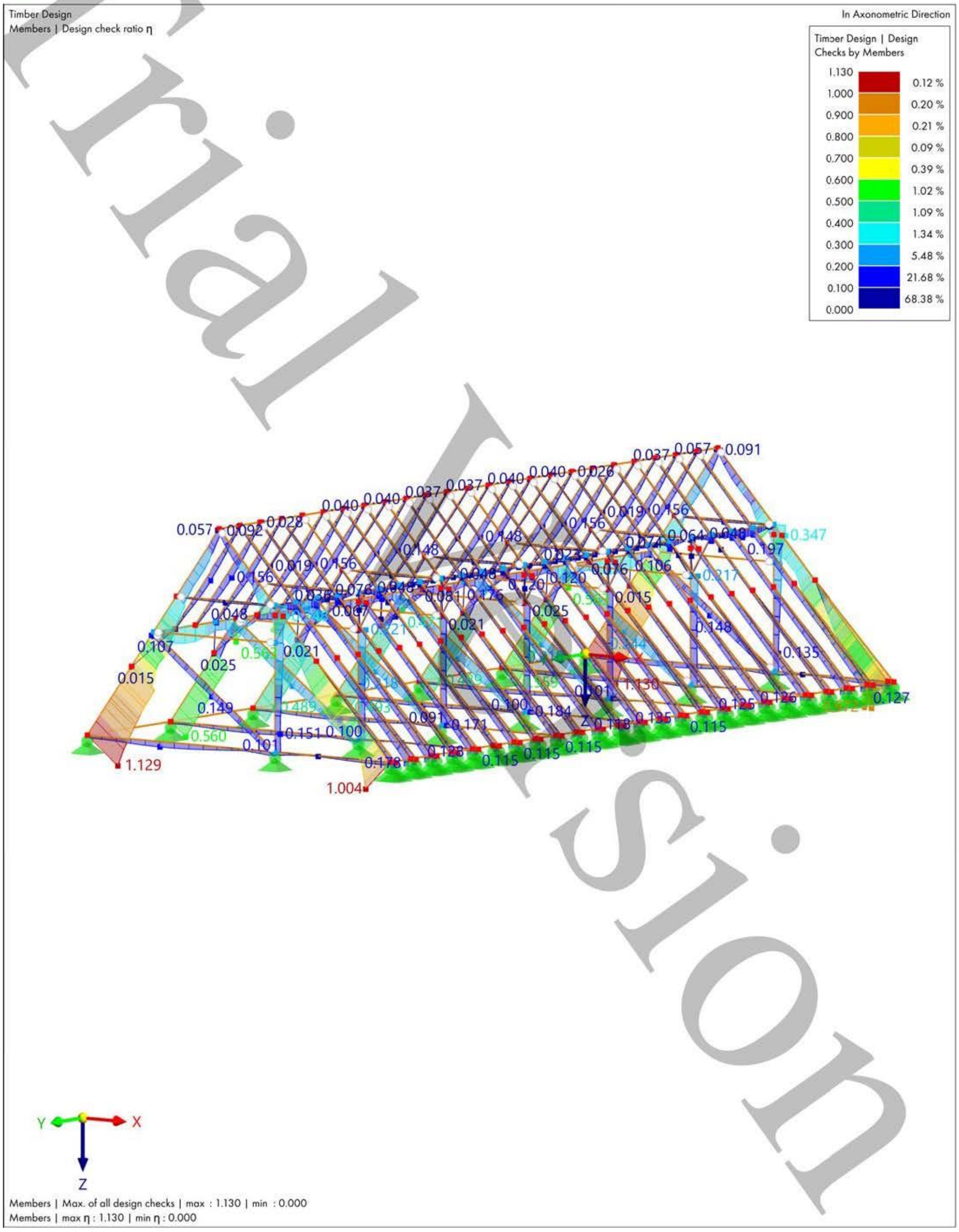
Members | Max. of all design checks | max : 1.130 | min : 0.000
Members | max η : 1.130 | min η : 0.000

9.8.2 **TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, DS3: LOADING, IN DIRECTION -Y** Timber Design

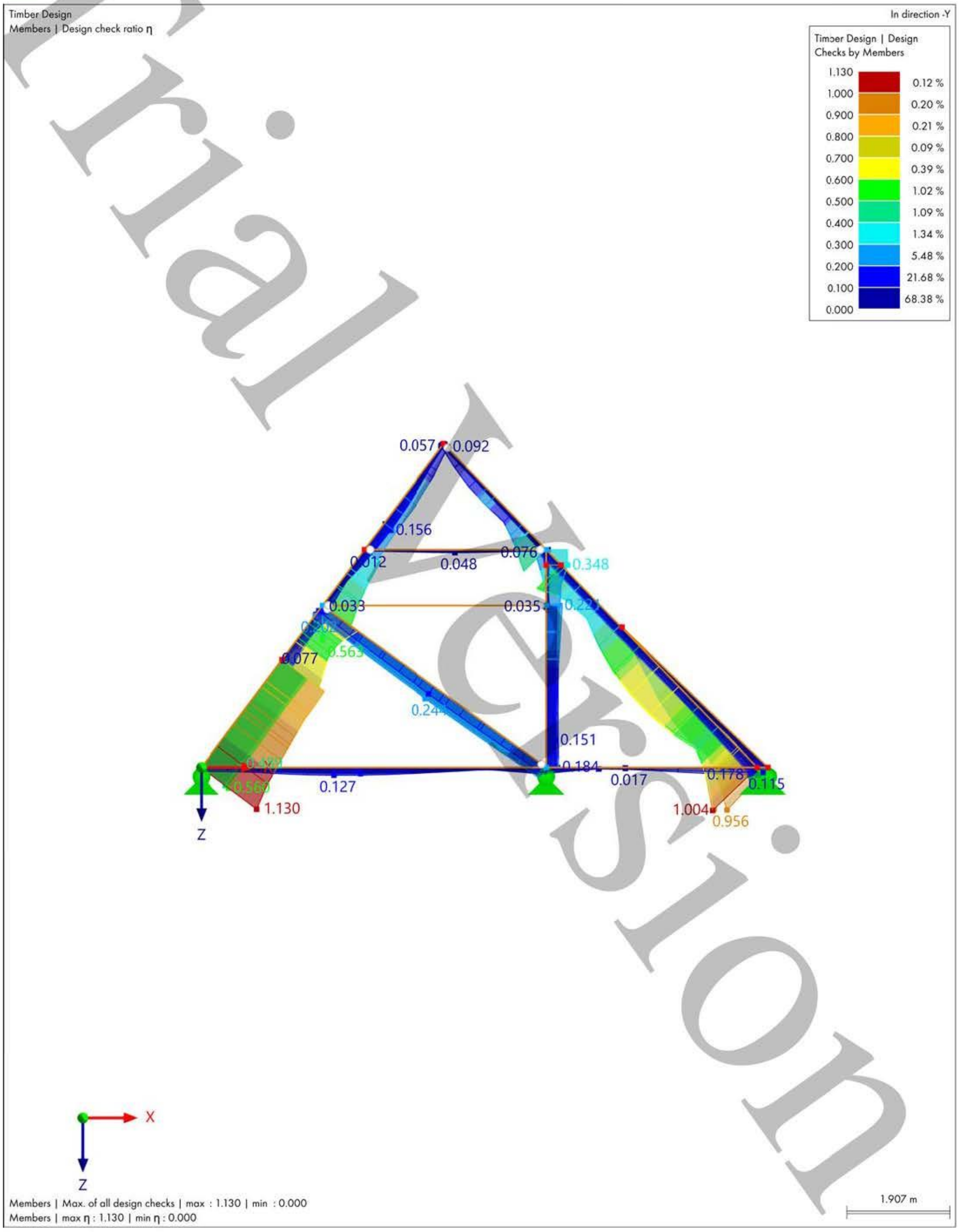


9.8.3 TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, IN AXONOMETRIC DIRECTION

Timber Design



9.8.4 **TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, DS3: LOADING, IN DIRECTION -Y** **Timber Design**



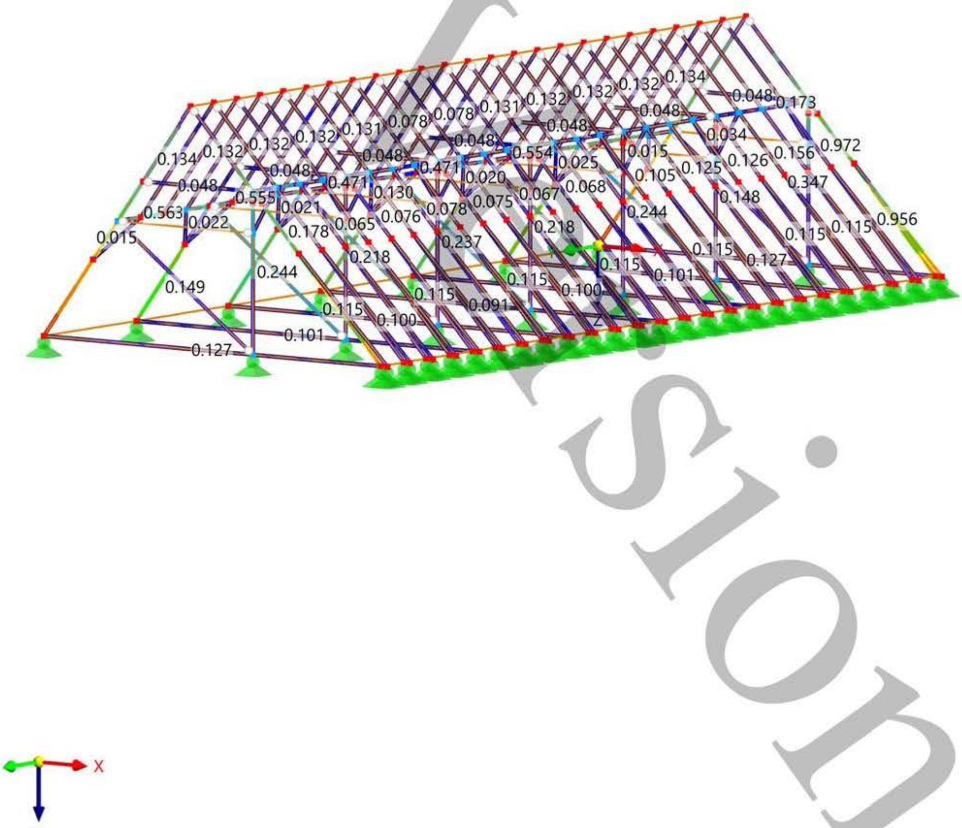
9.8.5 **TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, IN AXONOMETRIC DIRECTION** **Timber Design**

Timber Design
Members | Design check ratio η

In Axonometric Direction

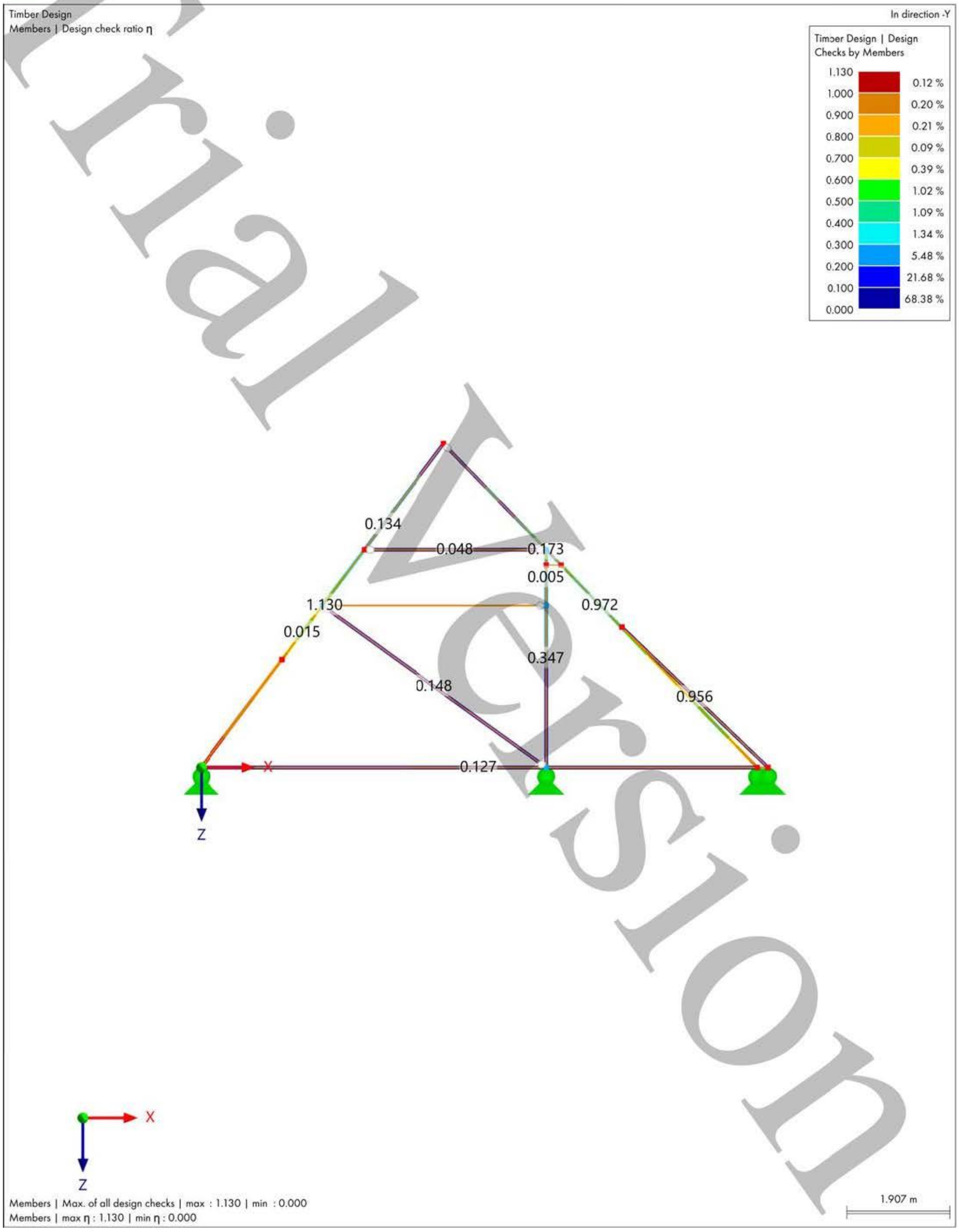
Timber Design | Design Checks by Members

1.130	
1.000	0.12 %
0.900	0.20 %
0.800	0.21 %
0.700	0.09 %
0.600	0.39 %
0.500	1.02 %
0.400	1.09 %
0.300	1.34 %
0.200	5.48 %
0.100	21.68 %
0.000	68.38 %



Members | Max. of all design checks | max : 1.130 | min : 0.000
Members | max η : 1.130 | min η : 0.000

9.8.6 **TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, DS3: LOADING, IN DIRECTION -Y** **Timber Design**



9.9 **MEMBER NO. 1 | DS1 | CO2 | 0.000 M | STRESS POINT NO. 7 | ST1600.03** **Timber Design**

Design Check ST1600.03 | EN 1995 | HRN | 2015-03

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.80 \cdot \frac{21.000\,N/mm^2}{1.30} = 12.923\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,N/mm^2}{1.30} = 14.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,N/mm^2}{1.30} = 14.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{7.500\,m}{40.4\,mm} = 185.58$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{7.500\,m}{40.4\,mm} = 185.58$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}} = \frac{185.58}{\pi} \cdot \sqrt{\frac{21.000\,N/mm^2}{7400.0\,N/mm^2}} = 3.15$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{185.58}{\pi} \cdot \sqrt{\frac{21.000\,N/mm^2}{7400.0\,N/mm^2}} = 3.15$$ 6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot (\lambda_{rel,y} - 0.3) + (\lambda_{rel,y})^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (3.15 - 0.3) + (3.15)^2\right) = 5.74$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot (\lambda_{rel,z} - 0.3) + (\lambda_{rel,z})^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (3.15 - 0.3) + (3.15)^2\right) = 5.74$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - (\lambda_{rel,y})^2}} = \frac{1}{5.74 + \sqrt{(5.74)^2 - (3.15)^2}} = 0.09$$ 6.3.2, Eq. 6.25

9.9 **MEMBER NO. 1 | DS1 | CO2 | 0.000 M | STRESS POINT NO. 7 | ST1600.03** **Timber Design**

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - (\lambda_{rel,z})^2}} = \frac{1}{5.74 + \sqrt{(5.74)^2 - (3.15)^2}} = 0.09$$ 6.3.2, Eq. 6.26

$$\eta_1 = \left|\frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|\frac{-0.997\,\text{N/mm}^2}{0.09 \cdot 12.923\,\text{N/mm}^2} + \frac{-0.791\,\text{N/mm}^2}{14.769\,\text{N/mm}^2} + 0.70 \cdot \frac{-4.136\,\text{N/mm}^2}{14.769\,\text{N/mm}^2}\right| = 1.062$$ Eq. 6.23

$$\eta_2 = \left|\frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|\frac{-0.997\,\text{N/mm}^2}{0.09 \cdot 12.923\,\text{N/mm}^2} + 0.70 \cdot \frac{-0.791\,\text{N/mm}^2}{14.769\,\text{N/mm}^2} + \frac{-4.136\,\text{N/mm}^2}{14.769\,\text{N/mm}^2}\right| = 1.130$$ Eq. 6.24

$$\eta = \max(\eta_1, \eta_2) = \max(1.062,\ 1.130) = 1.130$$ 6.3.2

$$\boxed{\eta = 1.130 > 1\ !}$$

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

9.10 MEMBER NO. 191 | DS1 | CO1 | 1.513 M | STRESS POINT NO. 1 | ST1600.02 — Timber Design

Design Check ST1600.02 | EN 1995 | HRN | 2015-03

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.60 \cdot \frac{21.000\,N/mm^2}{1.30} = 9.692\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\,N/mm^2}{1.30} = 11.077\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{4.034\,m}{40.4\,mm} = 99.83$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{4.034\,m}{40.4\,mm} = 99.83$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}} = \frac{99.83}{\pi} \cdot \sqrt{\frac{21.000\,N/mm^2}{7400.0\,N/mm^2}} = 1.69$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{99.83}{\pi} \cdot \sqrt{\frac{21.000\,N/mm^2}{7400.0\,N/mm^2}} = 1.69$$ 6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,y} - 0.3\right) + \left(\lambda_{rel,y}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (1.69 - 0.3) + (1.69)^2\right) = 2.07$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,z} - 0.3\right) + \left(\lambda_{rel,z}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (1.69 - 0.3) + (1.69)^2\right) = 2.07$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - \left(\lambda_{rel,y}\right)^2}} = \frac{1}{2.07 + \sqrt{(2.07)^2 - (1.69)^2}} = 0.31$$ 6.3.2, Eq. 6.25

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - \left(\lambda_{rel,z}\right)^2}} = \frac{1}{2.07 + \sqrt{(2.07)^2 - (1.69)^2}} = 0.31$$ 6.3.2, Eq. 6.26

9.10 MEMBER NO. 191 | DS1 | CO1 | 1.513 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

$$= \left| \frac{-0.258\,\text{N/mm}^2}{0.31 \cdot 9.692\,\text{N/mm}^2} + 0.70 \cdot \frac{-0.376\,\text{N/mm}^2}{11.077\,\text{N/mm}^2} \right|$$

$$= 0.111$$

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

$$= \left| \frac{-0.258\,\text{N/mm}^2}{0.31 \cdot 9.692\,\text{N/mm}^2} + \frac{-0.376\,\text{N/mm}^2}{11.077\,\text{N/mm}^2} \right|$$

$$= 0.121$$

$$\eta = \max(\eta_1, \eta_2) = \max(0.111, 0.121) = 0.121$$ 6.3.2

$$\eta = 0.121 \leq 1$$ ✓

$f_{c,0,d}$	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

9.11 MEMBER NO. 8 | DS1 | CO1 | 0.000 M | STRESS POINT NO. 7 | ST1600.01 — Timber Design

Design Check ST1600.01 | EN 1995 | HRN | 2015-03

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.60 \cdot \frac{21.000\,N/mm^2}{1.30} = 9.692\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\,N/mm^2}{1.30} = 11.077\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{3.748\,m}{40.4\,mm} = 92.75$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{3.748\,m}{40.4\,mm} = 92.75$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}} = \frac{92.75}{\pi} \cdot \sqrt{\frac{21.000\,N/mm^2}{7400.0\,N/mm^2}} = 1.57$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{92.75}{\pi} \cdot \sqrt{\frac{21.000\,N/mm^2}{7400.0\,N/mm^2}} = 1.57$$ 6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,y} - 0.3\right) + \left(\lambda_{rel,y}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (1.57 - 0.3) + (1.57)^2\right) = 1.86$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,z} - 0.3\right) + \left(\lambda_{rel,z}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (1.57 - 0.3) + (1.57)^2\right) = 1.86$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - \left(\lambda_{rel,y}\right)^2}} = \frac{1}{1.86 + \sqrt{(1.86)^2 - (1.57)^2}} = 0.35$$ 6.3.2, Eq. 6.25

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - \left(\lambda_{rel,z}\right)^2}} = \frac{1}{1.86 + \sqrt{(1.86)^2 - (1.57)^2}} = 0.35$$ 6.3.2, Eq. 6.26

9.11 MEMBER NO. 8 | DS1 | CO1 | 0.000 M | STRESS POINT NO. 7 | ST1600.01

Timber Design

$$\eta_1 = \left| \frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right| = \left| \frac{-0.122\,\text{N/mm}^2}{0.35 \cdot 9.692\,\text{N/mm}^2} + \frac{-10.192\,\text{N/mm}^2}{11.077\,\text{N/mm}^2} \right| = 0.956$$

Eq. 6.23

$$\eta_2 = \left| \frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right| = \left| \frac{-0.122\,\text{N/mm}^2}{0.35 \cdot 9.692\,\text{N/mm}^2} + 0.70 \cdot \frac{-10.192\,\text{N/mm}^2}{11.077\,\text{N/mm}^2} \right| = 0.680$$

Eq. 6.24

$$\eta = \max(\eta_1, \eta_2) = \max(0.956,\ 0.680) = 0.956$$

6.3.2

$$\eta = 0.956 \leq 1$$

$f_{c,0,d}$	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

9.12 **MEMBER NO. 164 | DS1 | CO5 | 5.121 M | STRESS POINT NO. 1 | ST1300** **Timber Design**

Design Check ST1300 | EN 1995 | HRN | 2015-03

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.90 \cdot \frac{21.000\,N/mm^2}{1.30} = 14.538\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{5.121\,m}{40.4\,mm} = 126.71$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{5.121\,m}{40.4\,mm} = 126.71$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}} = \frac{126.71}{\pi} \cdot \sqrt{\frac{21.000\,N/mm^2}{7400.0\,N/mm^2}} = 2.15$$ 6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}} = \frac{126.71}{\pi} \cdot \sqrt{\frac{21.000\,N/mm^2}{7400.0\,N/mm^2}} = 2.15$$ 6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,y} - 0.3\right) + \left(\lambda_{rel,y}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (2.15 - 0.3) + (2.15)^2\right) = 2.99$$ 6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,z} - 0.3\right) + \left(\lambda_{rel,z}\right)^2\right) = 0.5 \cdot \left(1 + 0.20 \cdot (2.15 - 0.3) + (2.15)^2\right) = 2.99$$ 6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - \left(\lambda_{rel,y}\right)^2}} = \frac{1}{2.99 + \sqrt{(2.99)^2 - (2.15)^2}} = 0.20$$ 6.3.2, Eq. 6.25

$$k_{c,z} = \frac{1}{k_z + \sqrt{(k_z)^2 - \left(\lambda_{rel,z}\right)^2}} = \frac{1}{2.99 + \sqrt{(2.99)^2 - (2.15)^2}} = 0.20$$ 6.3.2, Eq. 6.26

$$\eta_1 = \frac{\left|\sigma_{c,0,d}\right|}{k_{c,y} \cdot f_{c,0,d}} = \frac{\left|-0.595\,N/mm^2\right|}{0.20 \cdot 14.538\,N/mm^2} = 0.208$$ Eq. 6.23

9.12 MEMBER NO. 164 | DS1 | CO5 | 5.121 M | STRESS POINT NO. 1 | ST1300

Timber Design

$$\eta_2 = \frac{|\sigma_{c,0,d}|}{k_{c,z} \cdot f_{c,0,d}} = \frac{|-0.595\,\text{N/mm}^2|}{0.20 \cdot 14.538\,\text{N/mm}^2} = 0.208$$

Eq. 6.24

$$\eta = \max(\eta_1, \eta_2) = \max(0.208, 0.208) = 0.208$$

6.3.2

$$\boxed{\eta = 0.208 \leq 1}$$

$f_{c,0,d}$	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

9.13 **MEMBER NO. 189 | DS1 | CO2 | 8.345 M | STRESS POINT NO. 9 | SP6300** **Timber Design**

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

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.80 \cdot \frac{21.000\,N/mm^2}{1.30} = 12.923\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,N/mm^2}{1.30} = 14.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,N/mm^2}{1.30} = 14.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta_1 = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-0.542\,N/mm^2}{12.923\,N/mm^2}\right)^2 + \frac{-6.757\,N/mm^2}{14.769\,N/mm^2} + 0.70 \cdot \frac{-0.063\,N/mm^2}{14.769\,N/mm^2} \right| = 0.462$$ 6.2.4, Eq. 6.19

$$\eta_2 = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-0.542\,N/mm^2}{12.923\,N/mm^2}\right)^2 + 0.70 \cdot \frac{-6.757\,N/mm^2}{14.769\,N/mm^2} + \frac{-0.063\,N/mm^2}{14.769\,N/mm^2} \right| = 0.326$$ 6.2.4, Eq. 6.20

$$\eta = \max(\eta_1, \eta_2) = \max(0.462,\ 0.326) = 0.462$$ 6.2.4

$$\boxed{\eta = 0.462 \leq 1}$$ ✓

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

9.14 MEMBER NO. 191 | DS1 | CO1 | 1.513 M | STRESS POINT NO. 1 | SP6200 — Timber Design

Design Check SP6200 | EN 1995 | HRN | 2015-03

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.60 \cdot \frac{21.000\ N/mm^2}{1.30} = 9.692\ N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\ N/mm^2}{1.30} = 11.077\ N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right| = \left| -\left(\frac{-0.258\ N/mm^2}{9.692\ N/mm^2}\right)^2 + \frac{-0.376\ N/mm^2}{11.077\ N/mm^2} \right| = 0.035$$ 6.2.4, Eq. 6.20

$$\eta = 0.035 \leq 1$$ ✓

$f_{c,0,d}$	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

9.15 **MEMBER NO. 8 | DS1 | CO1 | 0.000 M | STRESS POINT NO. 7 | SP6100** **Timber Design**

Design Check SP6100 | EN 1995 | HRN | 2015-03

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.60 \cdot \frac{21.000\,N/mm^2}{1.30} = 9.692\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\,N/mm^2}{1.30} = 11.077\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \left| -\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right| = \left| -\left(\frac{-0.122\,N/mm^2}{9.692\,N/mm^2}\right)^2 + \frac{-10.192\,N/mm^2}{11.077\,N/mm^2} \right| = 0.920$$ 6.2.4, Eq. 6.19

$$\eta = 0.920 \le 1$$ ✓

$f_{c,0,d}$	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

9.16 **MEMBER NO. 200 | DS1 | CO5 | 0.000 M | STRESS POINT NO. 3 | SP5300** **Timber Design**

Design Check SP5300 | EN 1995 | HRN | 2015-03

Section Proof
Biaxial bending and tensile axial force acc. to 6.2.3

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M} = 0.90 \cdot \frac{14.500\,N/mm^2}{1.30} = 10.038\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.90 \cdot \frac{24.000\,N/mm^2}{1.30} = 16.615\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.90 \cdot \frac{24.000\,N/mm^2}{1.30} = 16.615\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta_1 = \left|\frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|\frac{0.083\,N/mm^2}{10.038\,N/mm^2} + \frac{4.692\,N/mm^2}{16.615\,N/mm^2} + 0.70 \cdot \frac{5.928\,N/mm^2}{16.615\,N/mm^2}\right| = 0.540$$ 6.2.3, Eq. 6.17

$$\eta_2 = \left|\frac{\sigma_{t,0,d}}{f_{t,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|\frac{0.083\,N/mm^2}{10.038\,N/mm^2} + 0.70 \cdot \frac{4.692\,N/mm^2}{16.615\,N/mm^2} + \frac{5.928\,N/mm^2}{16.615\,N/mm^2}\right| = 0.563$$ 6.2.3, Eq. 6.18

$$\eta = \max(\eta_1, \eta_2) = \max(0.540, 0.563) = 0.563$$ 6.2.3

$$\boxed{\eta = 0.563 \leq 1 ✓}$$

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

9.17 MEMBER NO. 113 | DS1 | CO1 | 0.950 M | LEFT SIDE | STRESS POINT NO. 1 | SP5200 — Timber Design

Design Check SP5200 | EN 1995 | HRN | 2015-03

Section Proof
Bending about z-axis and tensile axial force acc. to 6.2.3

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M} = 0.60 \cdot \frac{14.500\,N/mm^2}{1.30} = 6.692\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\,N/mm^2}{1.30} = 11.077\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \left|\frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|\frac{0.053\,N/mm^2}{6.692\,N/mm^2} + \frac{0.427\,N/mm^2}{11.077\,N/mm^2}\right| = 0.046$$ 6.2.3, Eq. 6.18

$$\boxed{\eta = 0.046 \leq 1}$$ ✓

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

9.18 **MEMBER NO. 2 | DS1 | CO2 | 3.129 M | LEFT SIDE | STRESS POINT NO. 1 | SP5100** **Timber Design**

Design Check SP5100 | EN 1995 | HRN | 2015-03

Section Proof
Bending about y-axis and tensile axial force acc. to 6.2.3

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M} = 0.80 \cdot \frac{14.500\,N/mm^2}{1.30} = 8.923\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,N/mm^2}{1.30} = 14.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \left| \frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right| = \left| \frac{0.176\,N/mm^2}{8.923\,N/mm^2} + \frac{5.529\,N/mm^2}{14.769\,N/mm^2} \right| = 0.394$$ 6.2.3, Eq. 6.17

$$\boxed{\eta = 0.394 \leq 1}$$ ✓

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

9.19 MEMBER NO. 237 | DS1 | CO2 | 0.950 M | STRESS POINT NO. 1 | SP4300 — Timber Design

Design Check SP4300 | EN 1995 | HRN | 2015-03

Section Proof
Biaxial bending acc. to 6.1.6

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,N/mm^2}{1.30} = 14.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,N/mm^2}{1.30} = 14.769\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta_1 = \left|\frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|\frac{1.727\,N/mm^2}{14.769\,N/mm^2} + 0.70 \cdot \frac{1.009\,N/mm^2}{14.769\,N/mm^2}\right| = 0.165$$ 6.1.6, Eq. 6.11

$$\eta_2 = \left|k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}}\right| = \left|0.70 \cdot \frac{1.727\,N/mm^2}{14.769\,N/mm^2} + \frac{1.009\,N/mm^2}{14.769\,N/mm^2}\right| = 0.150$$ 6.1.6, Eq. 6.12

$$\eta = \max(\eta_1, \eta_2) = \max(0.165, 0.150) = 0.165$$ 6.1.6

$$\boxed{\eta = 0.165 \leq 1}$$ ✓

$f_{m,y,d}$	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

9.20 MEMBER NO. 184 | DS1 | CO1 | 3.750 M | STRESS POINT NO. 1 | SP4200 — Timber Design

Design Check SP4200 | EN 1995 | HRN | 2015-03

Section Proof
Bending about z-axis acc. to 6.1.6

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\ \mathrm{N/mm^2}}{1.30} = 11.077\ \mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$\eta = \frac{|\sigma_{m,z,d}|}{f_{m,z,d}} = \frac{|-0.183\ \mathrm{N/mm^2}|}{11.077\ \mathrm{N/mm^2}} = 0.017$$ 6.1.6, Eq. 6.12

$$\boxed{\eta = 0.017 \leq 1}$$ ✓

$f_{m,z,d}$	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

9.21 MEMBER NO. 3 | DS1 | CO2 | 10.300 M | STRESS POINT NO. 1 | SP4100

Timber Design

Design Check SP4100 | EN 1995 | HRN | 2015-03

Section Proof
Bending about y-axis acc. to 6.1.6

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.80 \cdot \frac{24.000\,\text{N/mm}^2}{1.30} = 14.769\,\text{N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta = \frac{|\sigma_{m,y,d}|}{f_{m,y,d}} = \frac{|-1.875\,\text{N/mm}^2|}{14.769\,\text{N/mm}^2} = 0.127$$

6.1.6, Eq. 6.11

$$\boxed{\eta = 0.127 \leq 1}$$ ✓

$f_{m,y,d}$	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

9.22 MEMBER NO. 55 | DS1 | CO5 | 3.800 M | STRESS POINT NO. 2 | SP3200 — Timber Design

Design Check SP3200 | EN 1995 | HRN | 2015-03

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

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M} = 0.90 \cdot \frac{4.000\ \text{N/mm}^2}{1.30} = 2.769\ \text{N/mm}^2$$ 2.4.1, Eq. 2.14

$$\tau_{xy,d} = \frac{\tau_{xy}}{k_{cr}} = \frac{0.272\ \text{N/mm}^2}{0.67} = 0.405\ \text{N/mm}^2$$

$$\eta = \frac{|\tau_{xy,d}|}{f_{v,y,d}} = \frac{|0.405\ \text{N/mm}^2|}{2.769\ \text{N/mm}^2} = 0.146$$ 6.1.7, Eq. 6.13

$$\boxed{\eta = 0.146 \leq 1}$$ ✓

$f_{v,y,d}$	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

9.23 MEMBER NO. 4 | DS1 | CO2 | 3.750 M | RIGHT SIDE | STRESS POINT NO. 4 | SP3100 — Timber Design

Design Check SP3100 | EN 1995 | HRN | 2015-03

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

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M} = 0.80 \cdot \frac{4.000\ \text{N/mm}^2}{1.30} = 2.462\ \text{N/mm}^2$$ 2.4.1, Eq. 2.14

$$\tau_{xz,d} = \frac{\tau_{xz}}{k_{cr}} = \frac{0.563\ \text{N/mm}^2}{0.67} = 0.841\ \text{N/mm}^2$$

$$\eta = \frac{|\tau_{xz,d}|}{f_{v,z,d}} = \frac{|0.841\ \text{N/mm}^2|}{2.462\ \text{N/mm}^2} = 0.342$$ 6.1.7, Eq. 6.13

$$\boxed{\eta = 0.342 \leq 1}$$ ✓

$f_{v,z,d}$	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

9.24 MEMBER NO. 84 | DS1 | CO4 | 0.000 M | STRESS POINT NO. 2 | SP2100 — Timber Design

Design Check SP2100 | EN 1995 | HRN | 2015-03

Section Proof
Shear due to torsion acc. to 6.1.8

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M} = 0.90 \cdot \frac{4.000\ \mathrm{N/mm^2}}{1.30} = 2.769\ \mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M} = 0.90 \cdot \frac{4.000\ \mathrm{N/mm^2}}{1.30} = 2.769\ \mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$\eta = \frac{\tau_{tor,d}}{k_{shape} \cdot f_{v,d}} = \frac{0.193\ \mathrm{N/mm^2}}{1.05 \cdot 2.769\ \mathrm{N/mm^2}} = 0.066$$ 6.1.8, Eq. 6.14

$$\boxed{\eta = 0.066 \leq 1}$$ ✓

$f_{v,z,d}$	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

9.25 **MEMBER NO. 188 | DS1 | CO2 | 0.000 M | STRESS POINT NO. 1 | SP1200** **Timber Design**

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

Section Proof
Compression along grain acc. to 6.1.4

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0.80 \cdot \frac{21.000\ \text{N/mm}^2}{1.30} = 12.923\ \text{N/mm}^2$$ 2.4.1, Eq. 2.14

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}} = \frac{|-0.997\ \text{N/mm}^2|}{12.923\ \text{N/mm}^2} = 0.077$$ 6.1.4, Eq. 6.2

$$\boxed{\eta = 0.077 \leq 1}$$ ✓

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

9.26 MEMBER NO. 239 | DS1 | CO2 | 0.000 M | STRESS POINT NO. 1 | SP1100

Timber Design

Design Check SP1100 | EN 1995 | HRN | 2015-03

Section Proof
Tension along grain acc. to 6.1.2

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M} = 0.80 \cdot \frac{14.500\,N/mm^2}{1.30} = 8.923\,N/mm^2$$ 2.4.1, Eq. 2.14

$$\eta = \frac{\sigma_{t,0,d}}{f_{t,0,d}} = \frac{0.284\,N/mm^2}{8.923\,N/mm^2} = 0.032$$ 6.1.2(1), Eq. 6.1

$$\boxed{\eta = 0.032 \leq 1}$$ ✓

$f_{t,0,d}$	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

9.27 **MEMBER NO. 8 | DS1 | CO1 | 3.748 M | SP0100** **Timber Design**

Design Check SP0100 | EN 1995 | HRN | 2015-03

Section Proof
Negligible internal forces

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M} = 0.60 \cdot \frac{14.500\,\mathrm{N/mm^2}}{1.30} = 6.692\,\mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M} = 0.60 \cdot \frac{4.000\,\mathrm{N/mm^2}}{1.30} = 1.846\,\mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M} = 0.60 \cdot \frac{4.000\,\mathrm{N/mm^2}}{1.30} = 1.846\,\mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\,\mathrm{N/mm^2}}{1.30} = 11.077\,\mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M} = 0.60 \cdot \frac{24.000\,\mathrm{N/mm^2}}{1.30} = 11.077\,\mathrm{N/mm^2}$$ 2.4.1, Eq. 2.14

Tension:

$$\eta_{\sigma_t} = \frac{\sigma_{t,0,d}}{f_{t,0,d}} = \frac{0.000\,\mathrm{N/mm^2}}{6.692\,\mathrm{N/mm^2}} = 0.000$$

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

N_t is negligible.

Shear in y-axis:

$$\eta_{\tau_{xy}} = \frac{|\tau_{xy}|}{f_{v,y,d}} = \frac{|0.000\,\mathrm{N/mm^2}|}{1.846\,\mathrm{N/mm^2}} = 0.000$$

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

τ_{xy} is negligible.

Shear in z-axis:

$$\eta_{\tau_{xz}} = \frac{|\tau_{xz}|}{f_{v,z,d}} = \frac{|0.000\,\mathrm{N/mm^2}|}{1.846\,\mathrm{N/mm^2}} = 0.000$$

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

9.27 **MEMBER NO. 8 | DS1 | CO1 | 3.748 M | SP0100** **Timber Design**

τ_{xz} is negligible.

Torsion:

$$\eta_{\tau_{tor}} = \frac{|\tau_{tor,d}|}{f_{v,d}} = \frac{|0.000\ \mathrm{N/mm^2}|}{1.846\ \mathrm{N/mm^2}} = 0.000$$

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

M_t is negligible.

Bending about y-axis:

$$\eta_{\sigma_y} = \frac{|\sigma_{m,y,d}|}{f_{m,y,d}} = \frac{|0.000\ \mathrm{N/mm^2}|}{11.077\ \mathrm{N/mm^2}} = 0.000$$

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

$M_{Ed,y}$ is negligible.

Bending about z-axis:

$$\eta_{\sigma_z} = \frac{|\sigma_{m,z,d}|}{f_{m,z,d}} = \frac{|0.000\ \mathrm{N/mm^2}|}{11.077\ \mathrm{N/mm^2}} = 0.000$$

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

$M_{Ed,z}$ 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
$\eta_{\tau_{xy}}$	Design component for shear
τ_{xy}	Shear stress
$\eta_{\tau_{xy,lim}}$	Limit value of design ratio for shear
$\eta_{\tau_{xz}}$	Design component for shear
τ_{xz}	Shear stress
$\eta_{\tau_{xz,lim}}$	Limit value of design ratio for shear
$\eta_{\tau_{tor}}$	Design component for torsional moment

9.27 **MEMBER NO. 8 | DS1 | CO1 | 3.748 M | SP0100** **Timber Design**

$\tau_{tor,d}$	Design torsional stress
$f_{v,d}$	Design shear strength
$\eta_{\tau_{tor,lim}}$	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

Objects Addon	Objects Type	Objects No.	Location [m]	Design Situation	Loading No.	Design Check Ratio η [--]	Design Check Type	Description
Timber Design	Member	1	x: 0.000	DS1	CO2	1.130 !	ST1600.03	Stability | Biaxial bending and compression with buckling about both axes acc. to 6.3.2
Timber Design	Member	8	x: 0.000	DS1	CO1	0.956 ✓	ST1600.01	Stability | Bending about y-axis and compression with buckling about both axes acc. to 6.3.2
Timber Design	Member	8	x: 0.000	DS1	CO1	0.920 ✓	SP6100.00	Section Proof | Bending about y-axis and compressive axial force acc. to 6.2.4
Timber Design	Member	8	x: 1.406	DS3	CO14	0.571 ✓	SE1200.02	Serviceability | Combination of actions 'Quasi-permanent 1' | z-direction acc. to 7.2
Timber Design	Member	200	x: 0.000	DS1	CO5	0.563 ✓	SP5300.00	Section Proof | Biaxial bending and tensile axial force acc. to 6.2.3
Timber Design	Member	189	x: 8.345	DS1	CO2	0.462 ✓	SP6300.00	Section Proof | Biaxial bending and compressive axial force acc. to 6.2.4
Timber Design	Member	8	x: 1.406	DS2	CO6	0.428 ✓	SE1200.01	Serviceability | Combination of actions 'Characteristic' | z-direction acc. to 7.2
Timber Design	Member	2	x: 3.129	DS1	CO2	0.394 ✓	SP5100.00	Section Proof | Bending about y-axis and tensile axial force acc. to 6.2.3
Timber Design	Member	55	x: 1.880	DS3	CO15	0.374 ✓	SE1100.02	Serviceability | Combination of actions 'Quasi-permanent 1' | y-direction acc. to 7.2
Timber Design	Member	55	x: 1.880	DS2	CO10	0.365 ✓	SE1100.01	Serviceability | Combination of actions 'Characteristic' | y-direction acc. to 7.2
Timber Design	Member	4	x: 3.750	DS1	CO2	0.342 ✓	SP3100.00	Section Proof | Shear in z-axis acc. to 6.1.7 | Rectangular section
Timber Design	Member	164	x: 5.121	DS1	CO5	0.208 ✓	ST1300.00	Stability | Axial compression with buckling about both axes acc. to 6.3.2
Timber Design	Member	237	x: 0.950	DS1	CO2	0.165 ✓	SP4300.00	Section Proof | Biaxial bending acc. to 6.1.6
Timber Design	Member	55	x: 3.800	DS1	CO5	0.146 ✓	SP3200.00	Section Proof | Shear in y-axis acc. to 6.1.7 | Rectangular section
Timber Design	Member	3	x: 10.300	DS1	CO2	0.127 ✓	SP4100.00	Section Proof | Bending about y-axis acc. to 6.1.6
Timber Design	Member	191	x: 1.513	DS1	CO1	0.121 ✓	ST1600.02	Stability | Bending about z-axis and compression with buckling about both axes acc. to 6.3.2
Timber Design	Member	188	x: 0.000	DS1	CO2	0.077 ✓	SP1200.00	Section Proof | Compression along grain acc. to 6.1.4
Timber Design	Member	84,171	x: 0.000	DS1	CO4	0.066 ✓	SP2100.00	Section Proof | Shear due to torsion acc. to 6.1.8
Timber Design	Member	113	x: 0.950	DS1	CO1	0.046 ✓	SP5200.00	Section Proof | Bending about z-axis and tensile axial force acc. to 6.2.3
Timber Design	Member	191	x: 1.513	DS1	CO1	0.035 ✓	SP6200.00	Section Proof | Bending about z-axis and compressive axial force acc. to 6.2.4
Timber Design	Member	239	x: 0.000	DS1	CO2	0.032 ✓	SP1100.00	Section Proof | Tension along grain acc. to 6.1.2
Timber Design	Member	184	x: 3.750	DS1	CO1	0.017 ✓	SP4200.00	Section Proof | Bending about z-axis acc. to 6.1.6
Timber Design	Member	8, 16,24,35,40,43,48, 56,61,62,66,70,78, 91,95,99,102,107, 120,124,128,136,1 49,153,157,160,16 5,177,178,182,186 ,194,202	x: 3.748	DS1	CO1	0.000 ✓	SP0100.00	Section Proof | Negligible internal forces
Timber Design	Member	1-4,7,8,10,11,16,1 8,19,24,34,35,40,4 2-45,47,48,55-62, 64-66,68-70,72-75 ,77,78,84-91,93-9 5,97-99,101-104,1 06,107,113-120,12 2-124,126-128,13 0-133,135,136,14 2-149,151-153,15 5-157,159-162,16 4,165,171-178,18 0-182,184-186,18 8-191,193,194,20	x: 0.000	DS2	CO6	0.000 ✓	SE0100.01	Serviceability | Negligible deflection | Combination of actions 'Characteristic'

10.1 **DESIGN OVERVIEW** — Design Overview

	Addon	Objects Type	No.	Location [m]	Design Situation	Loading No.	Design Check Ratio η [--]	Type	Description
			0-211,219-242						
	Timber Design	Member	1-4,7,8,10,11,16,18,19,24,34,35,40,42-45,47,48,55-62,64-66,68-70,72-75,77,78,84-91,93-95,97-99,101-104,106,107,113-120,122-124,126-128,130-133,135,136,142-149,151-153,155-157,159-162,164,165,171-178,180-182,184-186,188-191,193,194,200-211,219-242	x: 0.000	DS3	CO11	0.000 ✓	SE0100.02	Serviceability | Negligible deflection | Combination of actions 'Quasi-permanent 1'

11 Parts List

11.1 **PARTS LIST - ALL BY MATERIAL** — Parts Lists

Material No.	Material Name	Object Type	Tot. Coating C_Σ [m²]	Tot. Volume V_Σ [m³]	Total Mass M_Σ [t]
1	C24	Members	457.216	15.636	6.567
Total			457.216	15.636	6.567
Σ Total			457.216	15.636	6.567

Rezultati ovih proračuna pokazali su da svi dijelovi nosivog sustava krovišta, osim pojedinih rogova, zadovoljavaju provjeru graničnih stanja nosivosti i graničnih stanja uporabljivosti prema Eurokodu 5. Konstrukcijski elementi koji ne zadovoljavaju uvjet stabilnosti, ne mogu podnijeti zadano opterećenje. Da bi se ipak zadovoljio uvjet stabilnosti tih elemenata, potrebno je izvršiti ojačanje istih dodavanjem drvenih elemenata.

3. ZAKLJUČAK

Kroz ovaj je rad prvo prikazano ponašanje drvenih konstrukcija u požaru na temelju opisa metoda požarnog proračuna konstrukcija. Drugi dio rada sastoji se od vizualnog pregleda dijela krovišta zagrebačke Stare gradske vijećnice, ocjene mehaničkih karakteristika elemenata krovišta nerazornim ispitivanjima koristeći vlagomjer i rezistograf. Na koncu, izrađen je statički model i proveden proračun krovišta.

Teorijski okvir predstavljen u uvodnom dijelu rada pokazuje da je prilikom dokaza mehaničke otpornosti i stabilnosti potrebno dokazati otpornost nosive drvene konstrukcije u slučaju djelovanja požara u ovisnosti o zahtjevu otpornosti konstrukcije na požar (R30, R60, R90, …) kao jednom od bitnih zahtjeva u građevini. Prilikom analize požarne otpornosti potrebno je u obzir uzeti smanjenje poprečnog presjeka ili smanjenje mehaničkih svojstava konstrukcijskih elemenata.

Ovim ispitivanjima i analizom bilo je važno provjeriti zadovoljava li trenutno stanje krovišta uvjete sigurnosti nosivih konstrukcija. Analizom je utvrđeno da određeni konstrukcijski elementi ne zadovoljavaju uvjete graničnog stanja nosivosti i graničnog stanja uporabljivosti sukladno Eurokodu 5 te je iste potrebno ojačati kako bi se postigla njihova stabilnost i stabilnost cijelog krovišta.

4. LITERATURA

[1] Bjelanović, A.; Rajčić, V.: Drvene konstrukcije prema europskim normama, Sveučilište u Zagrebu Građevinski fakultet, 2007.

[2] Peroš, B.; Boko, I.: Sigurnost konstrukcija u požaru, Sveučilište u Splitu Fakultet građevinarstva, arhitekture i geodezije, 2015.

[3] HRN EN 1995-1-2:2013, Eurokod 5: Projektiranje drvenih konstrukcija -- Dio 1-2: Općenito -- Proračun konstrukcija na djelovanje požara (EN 1995-1-2:2004+AC:2009), HZN, 2013.

[4] HRN EN 1995-1-2:2013/NA:2013, Eurokod 5: Projektiranje drvenih konstrukcija -- Dio 1-2: Općenito -- Proračun konstrukcija na djelovanje požara -- Nacionalni dodatak, HZN, 2013.

[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.