

# Snimak stanja stare krovne konstrukcije i prijedlog sanacije

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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**

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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 Dlubal 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

1.	UVOD .....	1
2.	PROJEKTNI DIO .....	7
3.	ZAKLJUČAK.....	88
4.	LITERATURA .....	89

## POPIS ILUSTRACIJA

### Slike

Slika 1. Mehanizam otkazivanja nosivosti drvenih elemenata u požaru

Slika 2. Degradacija poprečnog presjeka drvenog elementa

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

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

Slika 5. Krovšte 1

Slika 6. Krovšte 2

Slika 7. Detalj krovšta 1

Slika 8. Detalj krovšta 2

Slika 9. Prvo mjerenje vlagomjerom

Slika 10. Prvo mjerenje vlagomjerom

Slika 11. Drugo mjerenje vlagomjerom

Slika 12. Treće mjerenje vlagomjerom

### Grafikoni

Grafikon 1. Faktori redukcije proračunske vrijednosti djelovanja  $E_d$

### Tablice

Tablica 1. Specifični toplinski kapacitet u ovisnosti od temperature  $\theta$

Tablica 2. Koeficijent toplinske vodljivosti drva u ovisnosti od temperature  $\theta$

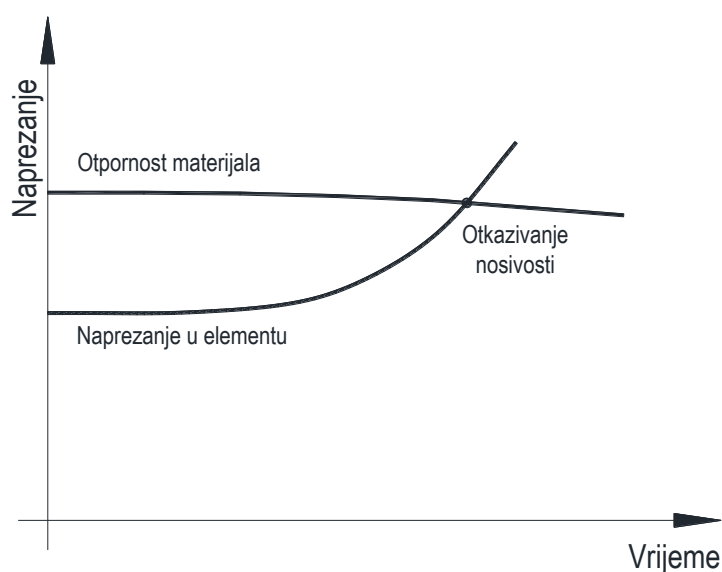
Tablica 3. Vrijednosti  $k_{fi}$

## 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.

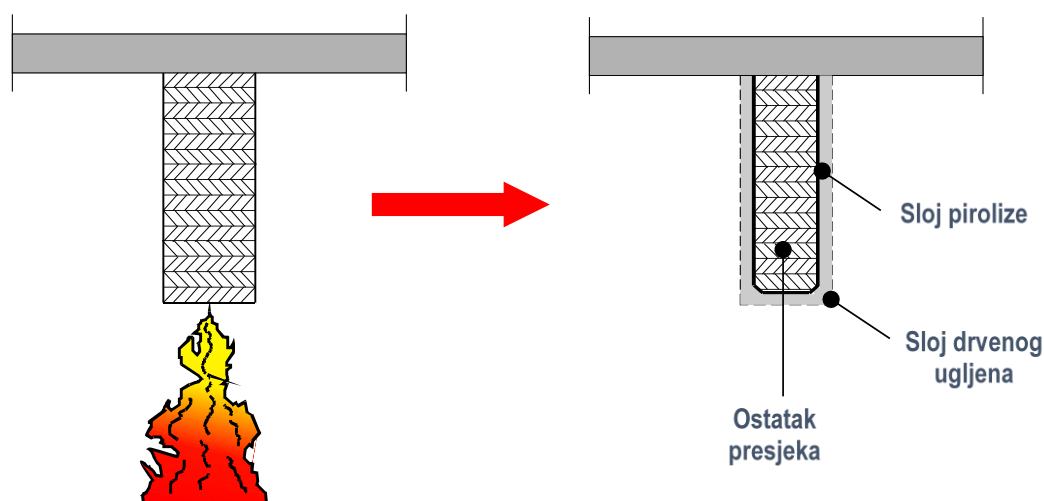
Drvene konstrukcije u građevinarstvu izvode se kao monolitne ili kao lijepljene lamelirane (složeni poprečni presjeci). Drvo je prirodan, ekološki visokovrijedan i tehnički svestran materijal koji posljednjih godina ponovo dobiva na značenju. Osnovne mehaničke, fizikalne i kemijske značajke drva od presudne 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]:

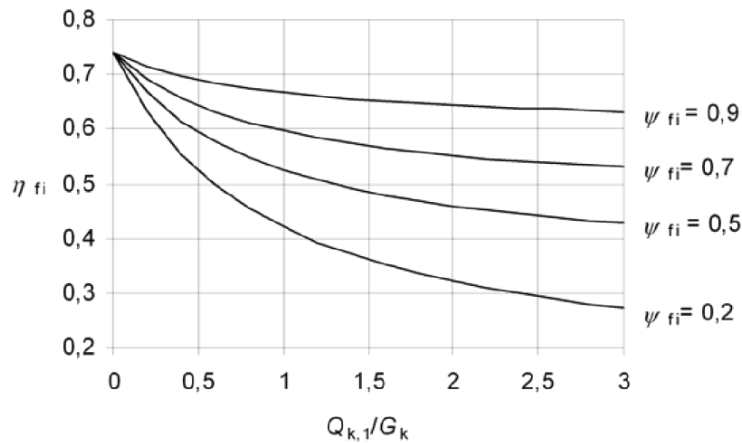
- metoda smanjenja poprečnog presjeka,
- metoda smanjenja mehaničkih svojstava.

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

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

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





Grafikon 1. Faktori redukcije proračunske vrijednosti djelovanja  $E_d$

gdje je:

- $\psi_{fi}$  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  $\theta$  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

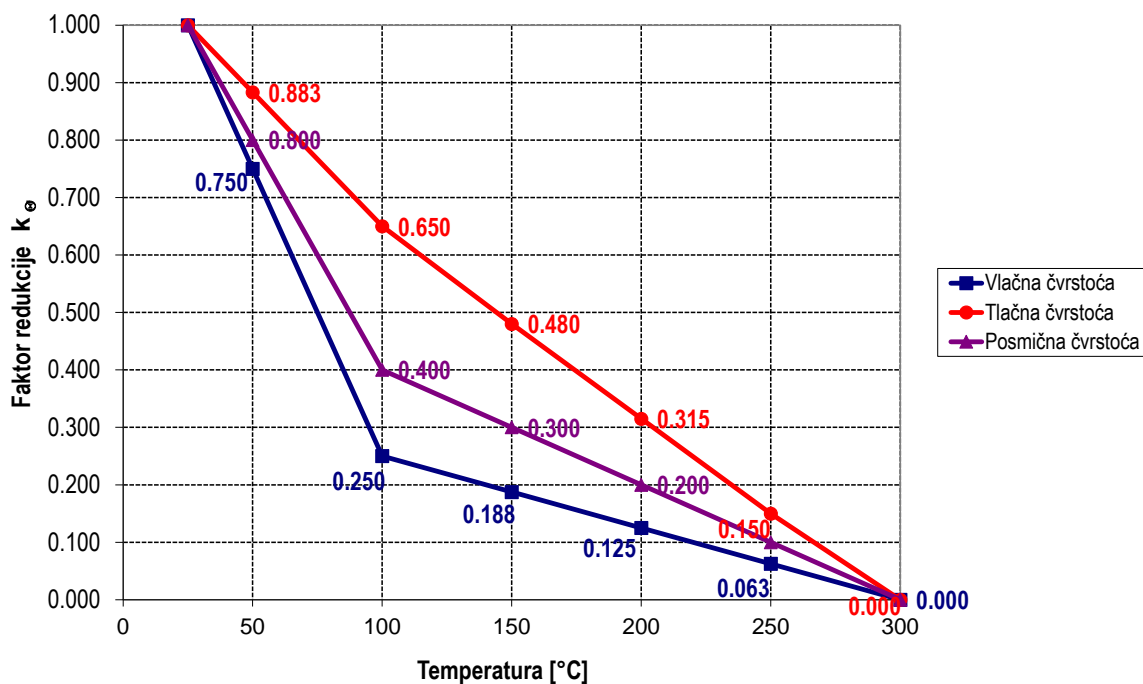
Tablica 1. Specifični toplinski kapacitet u ovisnosti od temperature  $\theta$

Koeficijent toplinske vodljivosti drva u ovisnosti od temperature  $\theta$  dan je u tablici [3]:

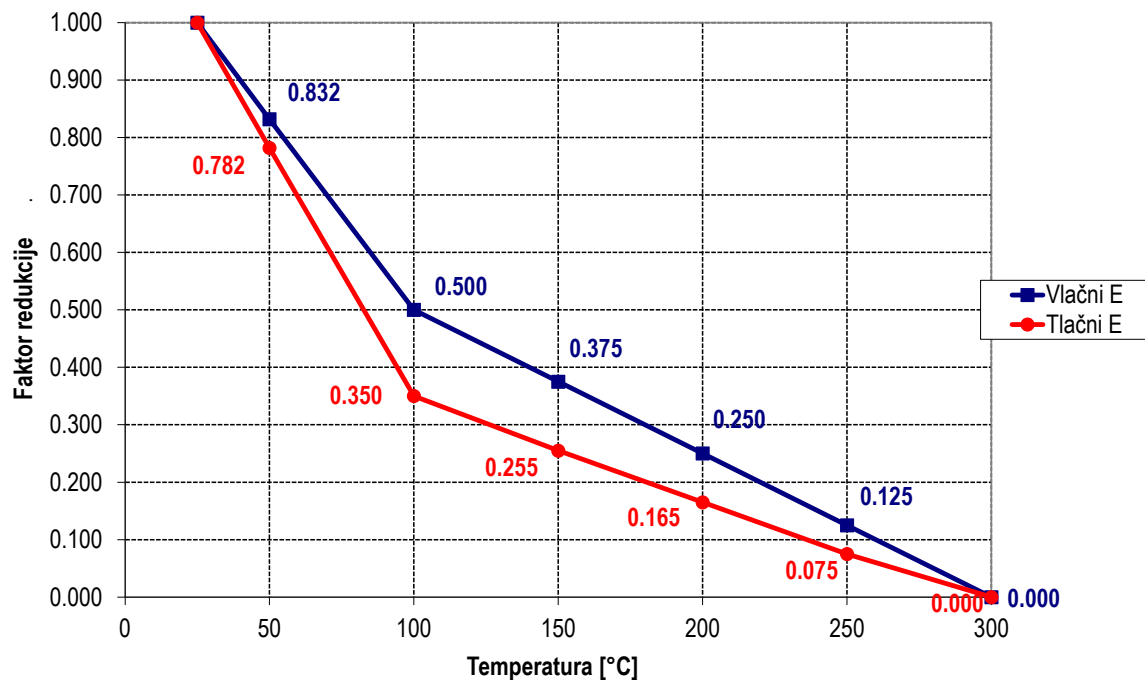
Temperatura [°C]	Koeficijent toplinske vodljivosti [W/mK]
20	0.12
200	0.15
350	0.07
500	0.09
500	0.35
800	1.50

Tablica 2. Koeficijent toplinske vodljivosti drva u ovisnosti od temperature  $\theta$

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 ( $k_{mod}=1$ ),
- $\eta$  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 krutosti (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  $k_{fi}$

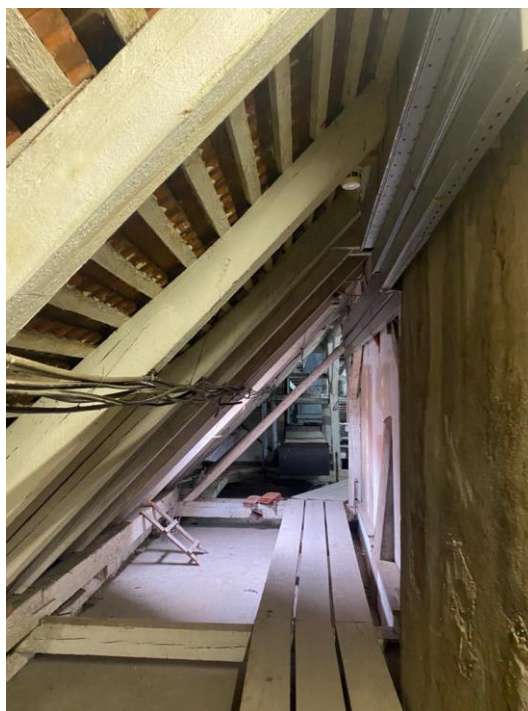
## 2. PROJEKTNI DIO

### Pregled i provjera drvenog krovišta Stare gradske vijećnice u Zagrebu

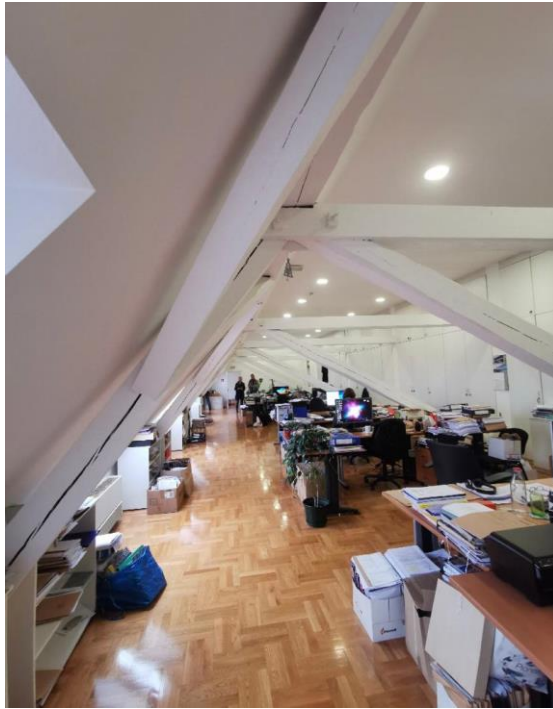
Projektni dio završnog rada sastoji se od pregleda krovišta zagrebačke Stare gradske vijećnice i provođenja nekoliko nerazornih ispitivanja s ciljem utvrđivanja stanja u kojem se krovište nalazi. Ispitivanja su provedena vlagomjerom kojim je utvrđeno da je drvo u 2. razredu uporabljivosti. Osim toga,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

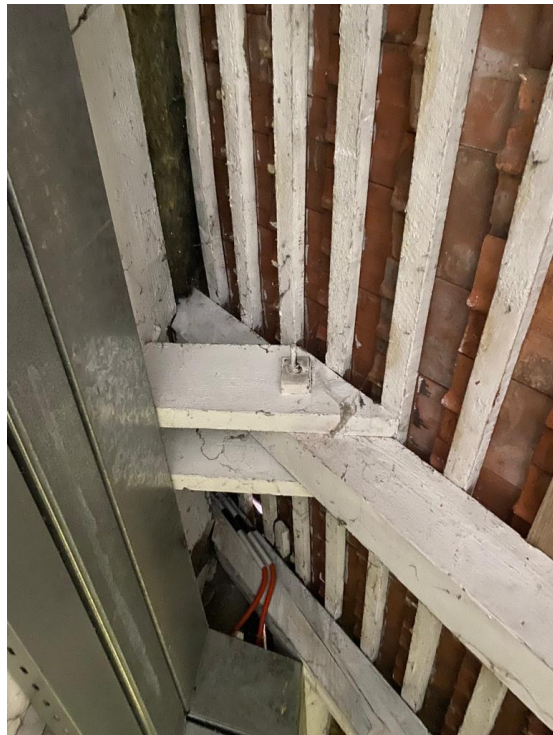
U nastavku su prikazane slike krovišta i rezultata mjerenja.



Slika 5. Krovište 1



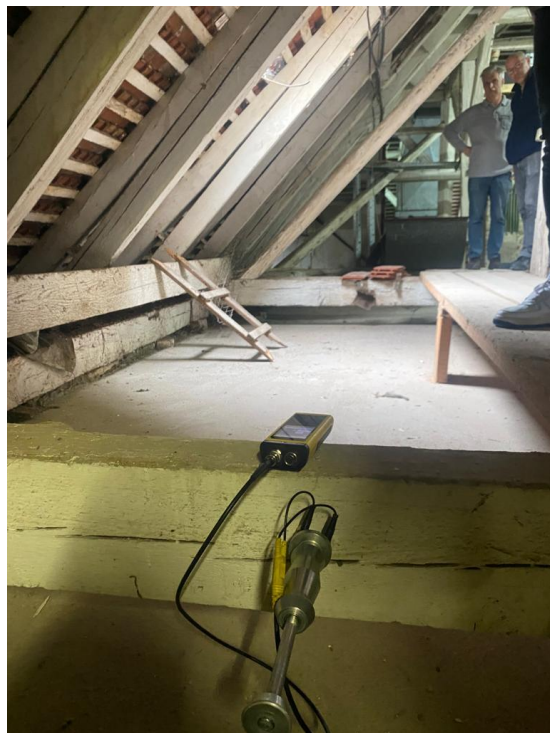
Slika 6. Krovšte 2



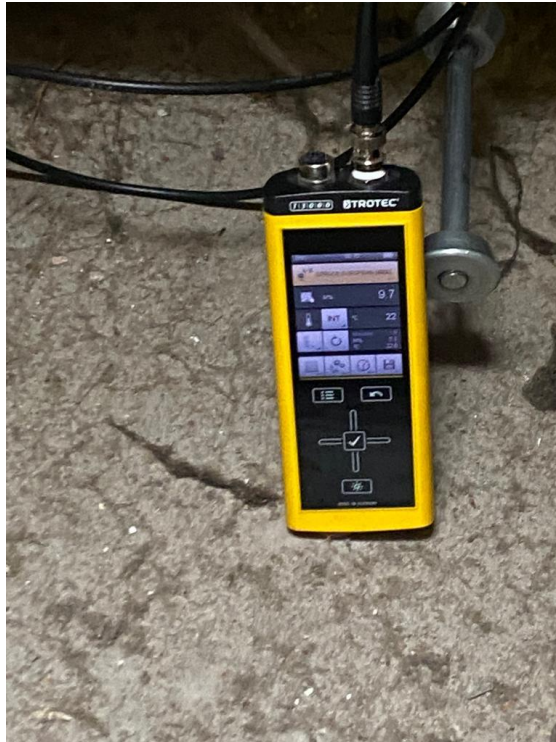
Slika 7. Detalj krovšta 1



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 Dlubal RFEM 6.



# Structural Analysis

## CLIENT

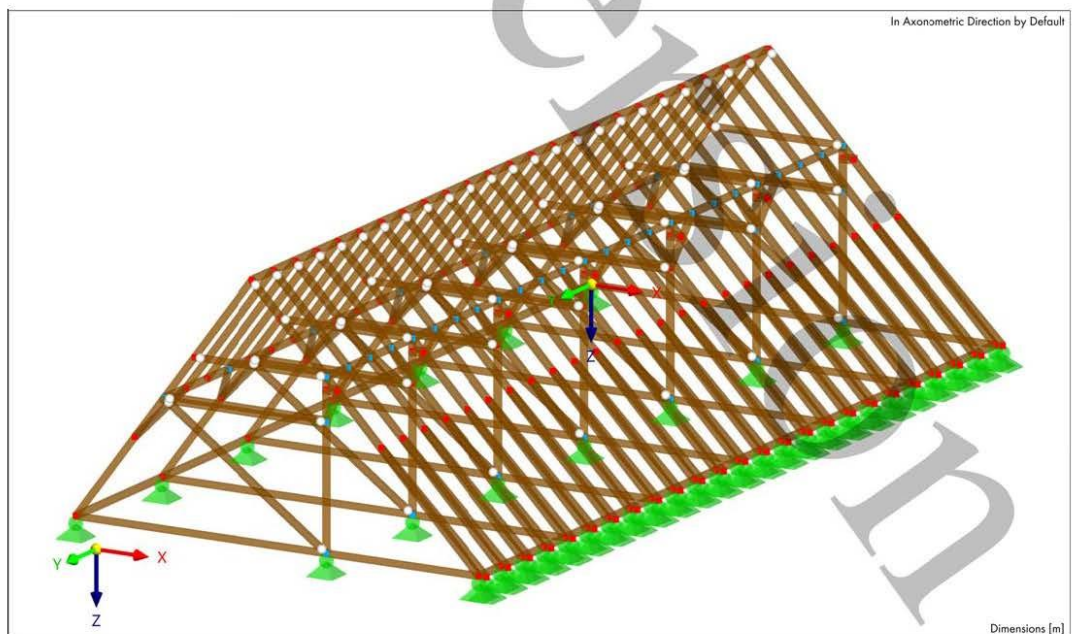
## CREATED BY

## PROJECT

### Chapters

1	Basic Objects	4
2	Types for Nodes	10
3	Types for Members	10
4	Types for Timber Design	10
5	Load Cases & Combinations	10
6	Loads	14
7	Guide Objects	23
8	Static Analysis Results	23
9	Timber Design	42
10	Design Overview	76
11	Parts List	77

## MODEL





CONTENTS

A	Model - Location	4							
<b>1</b>	<b>Basic Objects</b>	<b>4</b>							
1.1	Model, In Axonometric Direction	5							
1.2	Materials	6							
1.3	Sections	6							
1.4	Dimenzije	7							
1.5	Poprečni presjeci	8							
1.6	Member sets - numbering	9							
<b>2</b>	<b>Types for Nodes</b>	<b>10</b>							
2.1	Nodal Supports	10							
<b>3</b>	<b>Types for Members</b>	<b>10</b>							
3.1	Member Hinges	10							
<b>4</b>	<b>Types for Timber Design</b>	<b>10</b>							
4.1	Service Classes	10							
<b>5</b>	<b>Load Cases &amp; Combinations</b>	<b>10</b>							
5.1	Load Cases	10							
5.2	Actions	11							
5.3	Design Situations	11							
5.4	Action Combinations	11							
5.5	Load Combinations	12							
5.6	Static Analysis Settings	13							
5.7	Combination Wizards	14							
<b>6</b>	<b>Loads</b>	<b>14</b>							
6.1	Snijeg	15							
6.1.1	Snijeg.jpg	15							
6.2	Vjetar	15							
6.2.1	Vjetar.jpg	15							
6.3	Opterećenje	16							
6.3.1	Opterećenje.jpg	16							
6.4	LC1 - Self-weight	17							
6.4.1	LC1-Stalno	17							
6.4.2	LC1: Loading, In direction -Y	18							
6.5	LC2 - Snijeg	19							
6.5.1	LC2-Snijeg	19							
6.5.2	LC2: Loading, In direction -Y	20							
6.6	LC3 - Vjetar	21							
6.6.1	LC3-Vjetar	21							
6.6.2	LC3: Loading, In direction -Y	22							
<b>7</b>	<b>Guide Objects</b>	<b>23</b>							
7.1	Coordinate Systems	23							
<b>8</b>	<b>Static Analysis Results</b>	<b>23</b>							
8.1	DS1: Envelope Values - Max and Min Values, Internal Forces N, In Axonometric Direction	24							
8.2	DS1: Envelope Values - Max and Min Values, Internal Forces N, Loading, In direction -Y	25							
8.3	DS1: Envelope Values - Max and Min Values, Internal Forces V <sub>x</sub> , In Axonometric Direction	26							
8.4	DS1: Envelope Values - Max and Min Values, Internal Forces V <sub>y</sub> , Loading, In direction -Y	27							
8.5	DS1: Envelope Values - Max and Min Values, Internal Forces V <sub>z</sub> , In Axonometric Direction	28							
8.6	DS1: Envelope Values - Max and Min Values, Internal Forces V <sub>z</sub> , Loading, In direction -Y	29							
8.7	DS1: Envelope Values - Max and Min Values, Internal Forces M <sub>x</sub> , In Axonometric Direction	30							
8.8	DS1: Envelope Values - Max and Min Values, Internal Forces M <sub>x</sub> , Loading, In direction -Y	31							
8.9	DS1: Envelope Values - Max and Min Values, Internal Forces M <sub>y</sub> , In Axonometric Direction	32							
8.10	DS1: Envelope Values - Max and Min Values, Internal Forces M <sub>y</sub> , Loading, In direction -Y	33							
8.11	DS1: Envelope Values - Max and Min Values, Internal Forces M <sub>z</sub> , In Axonometric Direction	34							
8.12	DS1: Envelope Values - Max and Min Values, Internal Forces M <sub>z</sub> , Loading, In direction -Y	35							
8.13	DS1: Envelope Values - Max and Min Values, Nodal Supports P <sub>x</sub> , Nodal Supports P <sub>y</sub> , Nodal Supports P <sub>z</sub> , In Axonometric Direction	36							
8.14	DS1: Envelope Values - Max and Min Values, Nodal Supports P <sub>x</sub> , Nodal Supports P <sub>y</sub> , Nodal	37							
	Supports P <sub>z</sub> , Loading, In direction -Y		8.15						38
	DS2: Envelope Values - Max and Min Values, Global Deformations  u , In Axonometric Direction		8.16						39
	DS2: Envelope Values - Max and Min Values, Global Deformations  u , Loading, In direction -Y		8.17						40
	DS3: Envelope Values - Max and Min Values, Global Deformations  u , In Axonometric Direction		8.18						41
	DS3: Envelope Values - Max and Min Values, Global Deformations  u , Loading, In direction -Y								
<b>9</b>	<b>Timber Design</b>	<b>42</b>							
9.1	Objects to Design	42							
9.2	Design Situations	42							
9.3	Materials	42							
9.4	Sections	42							
9.5	Ultimate Configurations	42							
9.5.1	Ultimate Configurations - Settings - Members	42							
9.5.2	Ultimate Configurations - Settings - Surfaces	43							
9.6	Serviceability Configurations	43							
9.6.1	Serviceability Configurations - Settings - Members	43							
9.6.2	Serviceability Configurations - Settings - Surfaces	43							
9.7	Fire Resistance Configurations	44							
9.7.1	Fire Resistance Configurations - Settings - Members	44							
9.7.2	Fire Resistance Configurations - Settings - Surfaces	44							
9.8	Results	45							
9.8.1	Timber Design: Max. of all design checks, In Axonometric Direction	45							
9.8.2	Timber Design: Max. of all design checks, DS3: Loading, In direction -Y	46							
9.8.3	Timber Design: Max. of all design checks, In Axonometric Direction	47							
9.8.4	Timber Design: Max. of all design checks, DS3: Loading, In direction -Y	48							
9.8.5	Timber Design: Max. of all design checks, In Axonometric Direction	49							
9.8.6	Timber Design: Max. of all design checks, DS3: Loading, In direction -Y	50							
9.9	Member No. 1   DS1   CO2   0.000 m   Stress Point No. 7   ST1600.03	51							
9.10	Member No. 191   DS1   CO1   1.513 m   Stress Point No. 1   ST1600.02	53							
9.11	Member No. 8   DS1   CO1   0.000 m   Stress Point No. 7   ST1600.01	55							
9.12	Member No. 164   DS1   CO5   5.121 m   Stress Point No. 1   ST1300	57							
9.13	Member No. 189   DS1   CO2   8.345 m   Stress Point No. 9   SP6300	59							
9.14	Member No. 191   DS1   CO1   1.513 m   Stress Point No. 1   SP6200	60							
9.15	Member No. 8   DS1   CO1   0.000 m   Stress Point No. 7   SP6100	61							
9.16	Member No. 200   DS1   CO5   0.000 m   Stress Point No. 3   SP5300	62							
9.17	Member No. 113   DS1   CO1   0.950 m   Left Side   Stress Point No. 1   SP5200	63							
9.18	Member No. 2   DS1   CO2   3.129 m   Left Side   Stress Point No. 1   SP5100	64							
9.19	Member No. 237   DS1   CO2   0.950 m   Stress Point No. 1   SP4300	65							
9.20	Member No. 184   DS1   CO1   3.750 m   Stress Point No. 1   SP4200	66							
9.21	Member No. 3   DS1   CO2   10.300 m   Stress Point No. 1   SP4100	67							
9.22	Member No. 55   DS1   CO5   3.800 m   Stress Point No. 2   SP3200	68							
9.23	Member No. 4   DS1   CO2   3.750 m   Right Side   Stress Point No. 4   SP3100	69							
9.24	Member No. 84   DS1   CO4   0.000 m   Stress Point No. 2   SP2100	70							
9.25	Member No. 188   DS1   CO2   0.000 m   Stress Point No. 1   SP1200	71							
9.26	Member No. 239   DS1   CO2   0.000 m   Stress Point No. 1   SP1100	72							
9.27	Member No. 8   DS1   CO1   3.748 m   SP0100	73							





MODEL

CONTENTS

10	Design Overview	76	11	Parts List	77
10.1	Design Overview	76	11.1	Parts List - All by Material	77

Final Version





MODEL

A MODEL - LOCATION

Location



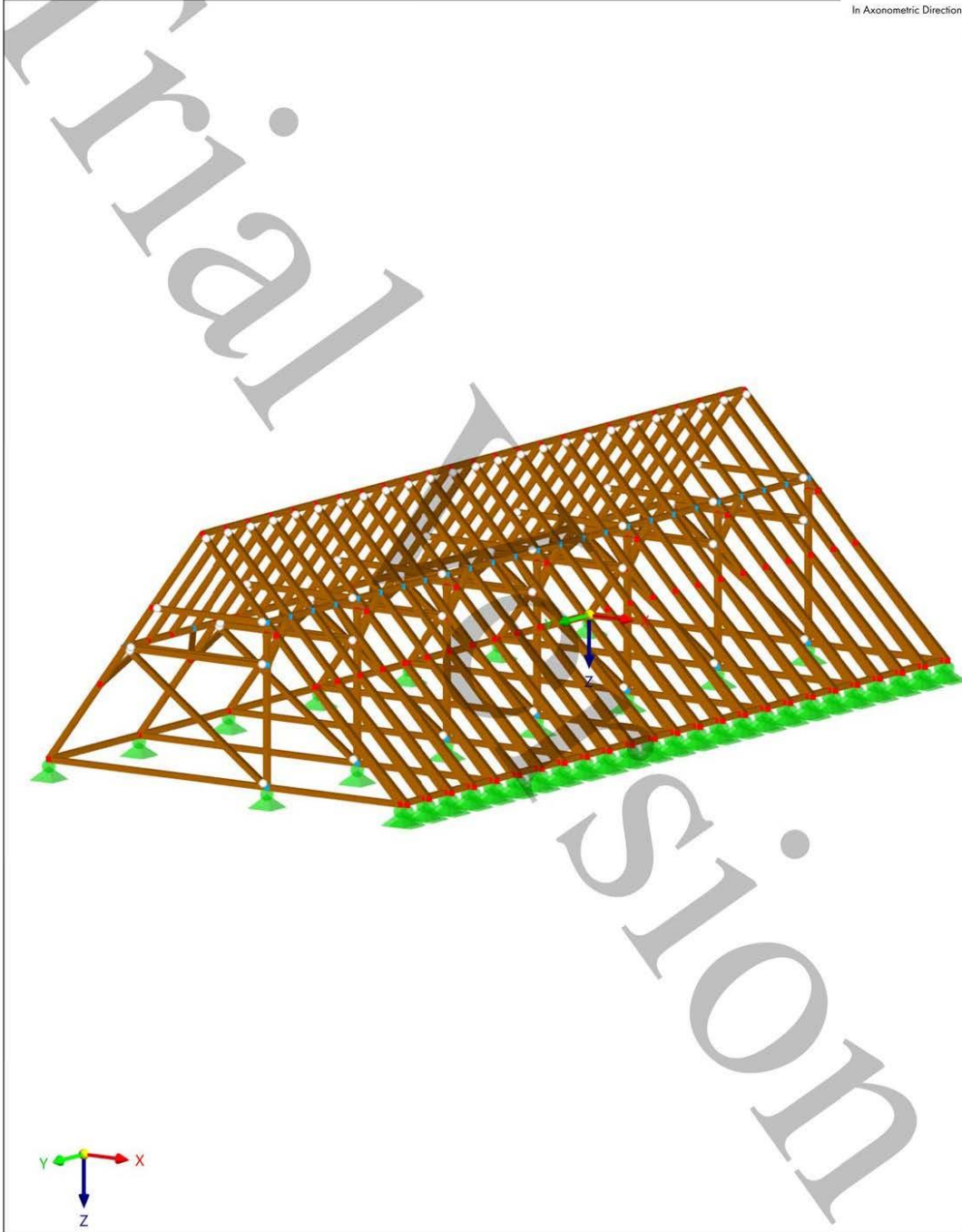
Country	:	--
Street	:	
Zip / Postal code	:	
City	:	
State	:	
Latitude	:	deg
Longitude	:	deg
Altitude	:	m

1 Basic Objects



1.1 MODEL, IN AXONOMETRIC DIRECTION

In Axonometric Direction





MODEL

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

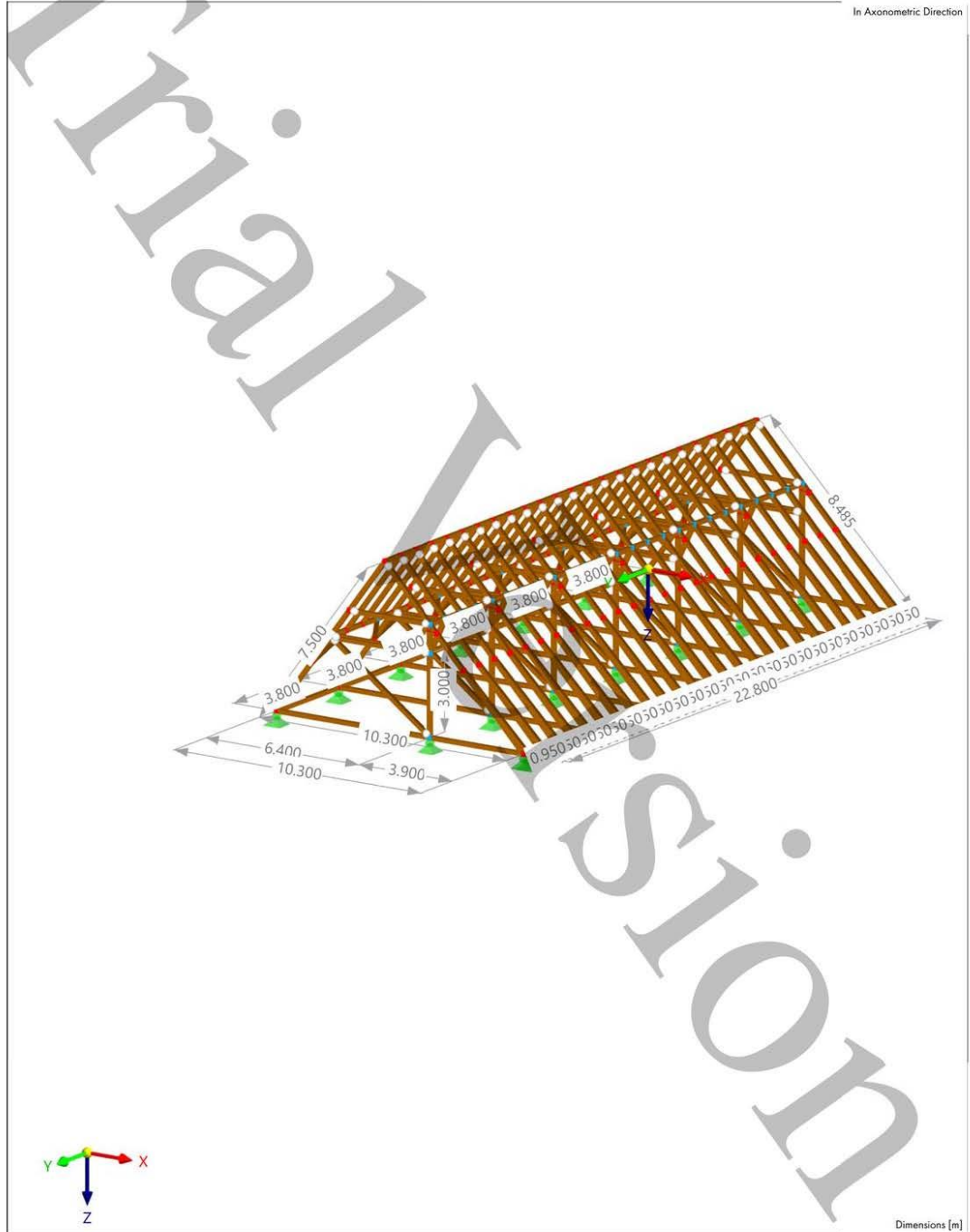


Section No.	Material No.	Section Type	Manufacturing Type	$I_x$ [cm <sup>4</sup> ] A [cm <sup>2</sup> ]	$I_y$ [cm <sup>4</sup> ] $A_y$ [cm <sup>2</sup> ]	$I_z$ [cm <sup>4</sup> ] $A_z$ [cm <sup>2</sup> ]	Overall Dimensions b [mm] h [mm]	
1	1	R_M1 120/120   1 - C24 Parametric - Massive I		2920.32	1728.00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

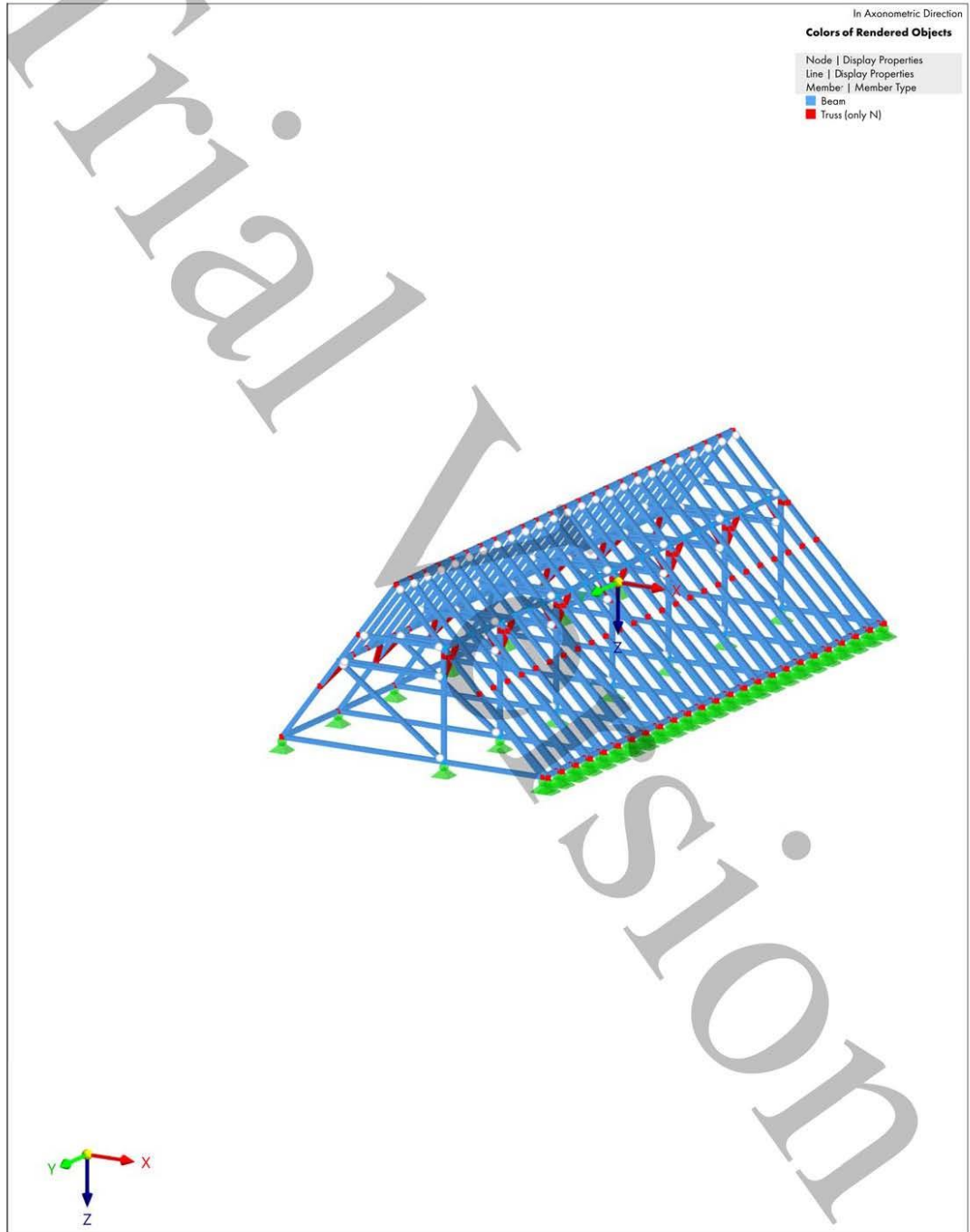


1.4 DIMENZIJE

In Axonometric Direction



1.5 POPREČNI PRESJECI

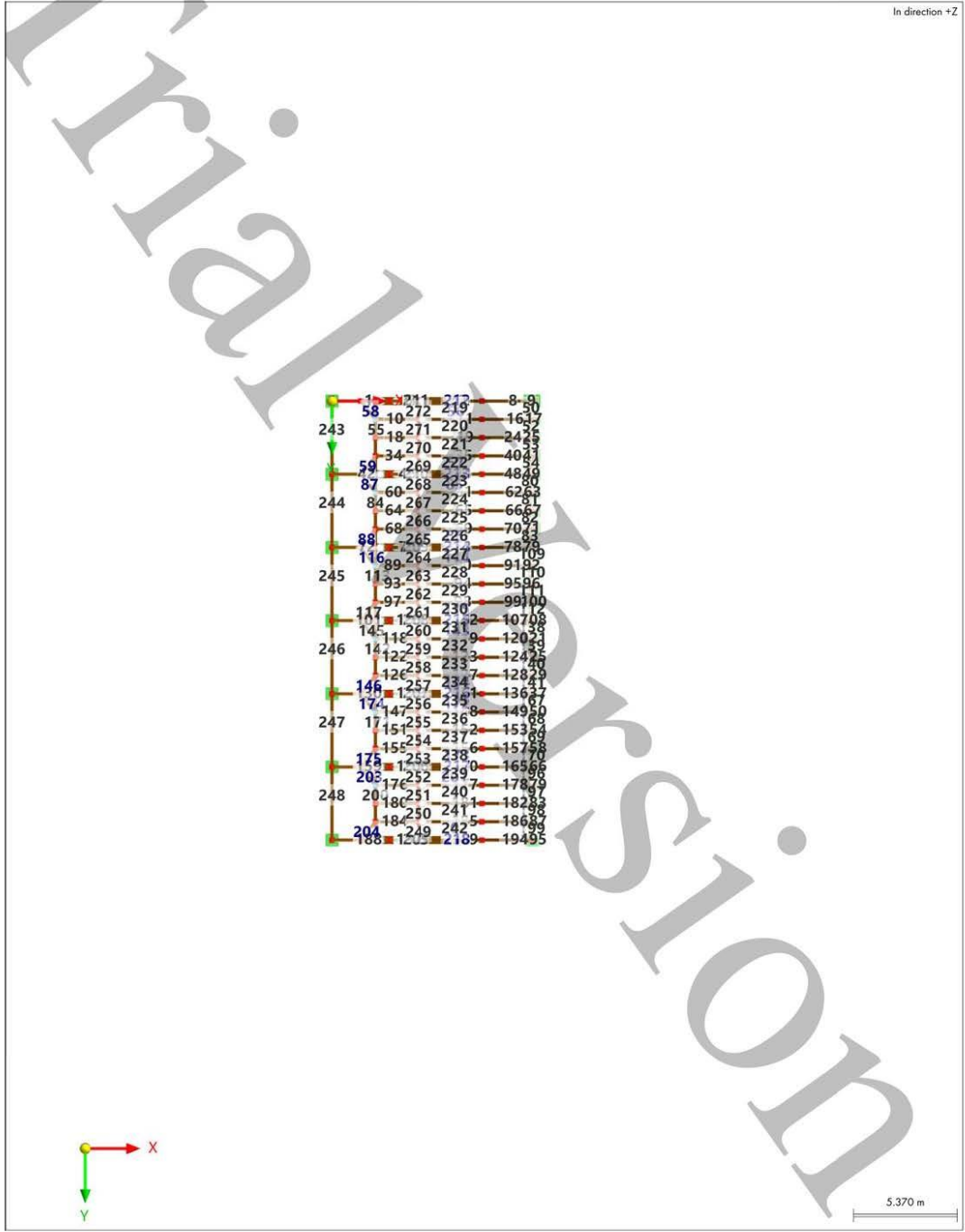






MODEL

1.6 MEMBER SETS - NUMBERING

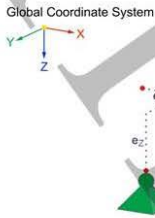




MODEL

2 Types for Nodes

2.1 NODAL SUPPORTS



Support No.	Nodes No.	Coordinate System	Translation Spring [kN/m]			Rotation Spring [kNm/rad]		
			C <sub>u,x</sub>	C <sub>u,y</sub>	C <sub>u,z</sub>	C <sub>φ,x</sub>	C <sub>φ,y</sub>	C <sub>φ,z</sub>
7	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> 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	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

3 Types for Members

3.1 MEMBER HINGES

Hinge No.	Coordinate System	Translation Spring [kN/m]			Rotation Spring [kNm/rad]		
		C <sub>u,x</sub>	C <sub>u,y</sub>	C <sub>u,z</sub>	C <sub>φ,x</sub>	C <sub>φ,y</sub>	C <sub>φ,z</sub>
1	<input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Local xyz	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

4 Types for Timber Design

4.1 SERVICE CLASSES

Class No.	Members	Assigned to		Service Class	Type	Comment
		Member Sets	Surfaces			
1	Service Class 1 (Members : 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	<input checked="" type="checkbox"/> Self-weight Analysis type Static analysis settings Action category Self-weight - Factor in direction X Self-weight - Factor in direction Y Self-weight - Factor in direction Z Load duration	Static Analysis SA1 - Geometrically linear <input checked="" type="checkbox"/> Permanent 0.000 0.000 1.000 Permanent	--	<input checked="" type="checkbox"/>
2	<input checked="" type="checkbox"/> Snijeg Analysis type Static analysis settings Action category Load duration	Static Analysis SA1 - Geometrically linear <input checked="" type="checkbox"/> Snow/Ice loads - Finland, Iceland, ... Medium-term		<input checked="" type="checkbox"/>
3	<input checked="" type="checkbox"/> Vjetar Analysis type Static analysis settings Action category Load duration	Static Analysis SA1 - Geometrically linear <input checked="" type="checkbox"/> Wind Short-term		<input checked="" type="checkbox"/>





MODEL

5.2 ACTIONS

Action No.	Settings	Value	Active
1	<b>Per</b> Permanent Action Category Action Type	<b>Per</b> Permanent Simultaneously	<input checked="" type="checkbox"/>
2	<b>Qs</b> Snow/Ice loads - Finland, Iceland, ... Action Category Action Type	<b>Qs</b> Snow/Ice loads - Finland, Iceland, ... Alternatively	<input checked="" type="checkbox"/>
3	<b>W</b> Wind Action Category Action Type	<b>W</b> Wind Alternatively	<input checked="" type="checkbox"/>

5.3 DESIGN SITUATIONS

DS No.	Settings	Value	Active
1	<b>ULS</b> ULS (STR/GEO) - Permanent and transient - Eq. 6.10 Design situation type Combination wizard Consider inclusive/exclusive load cases	<b>ULS</b> ULS (STR/GEO) - Permanent and transient - Eq. 6.10 2 <input type="checkbox"/>	<input checked="" type="checkbox"/>
2	<b>SCh</b> SLS - Characteristic Design situation type Combination wizard Consider inclusive/exclusive load cases	<b>SCh</b> SLS - Characteristic 1 <input type="checkbox"/>	<input checked="" type="checkbox"/>
3	<b>SLS</b> SLS - Quasi-permanent Design situation type Combination wizard Consider inclusive/exclusive load cases	<b>SLS</b> SLS - Quasi-permanent 1 <input type="checkbox"/>	<input checked="" type="checkbox"/>

5.4 ACTION COMBINATIONS

AC No.	Settings	Value	Active
1	<b>ULS</b> 1.35 * A1 Design Situation Generated load combinations Generated by	<b>ULS</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 1 Design Situation No. 1	<input checked="" type="checkbox"/>
2	<b>ULS</b> 1.35 * A1 + 1.50 * A2 Design Situation Generated load combinations Generated by	<b>ULS</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 2 Design Situation No. 1	<input checked="" type="checkbox"/>
3	<b>ULS</b> 1.35 * A1 + 1.50 * A2 + 0.90 * A3 Design Situation Generated load combinations Generated by	<b>ULS</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 3 Design Situation No. 1	<input checked="" type="checkbox"/>
4	<b>ULS</b> 1.35 * A1 + 1.50 * A3 Design Situation Generated load combinations Generated by	<b>ULS</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 4 Design Situation No. 1	<input checked="" type="checkbox"/>
5	<b>ULS</b> 1.35 * A1 + 1.05 * A2 + 1.50 * A3 Design Situation Generated load combinations Generated by	<b>ULS</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 5 Design Situation No. 1	<input checked="" type="checkbox"/>
6	<b>SCh</b> A1 Design Situation Generated load combinations Generated by	<b>SCh</b> DS2 - SLS - Characteristic 6 Design Situation No. 2	<input checked="" type="checkbox"/>
7	<b>SCh</b> A1 + A2 Design Situation Generated load combinations Generated by	<b>SCh</b> DS2 - SLS - Characteristic 7 Design Situation No. 2	<input checked="" type="checkbox"/>
8	<b>SCh</b> A1 + A2 + 0.60 * A3 Design Situation Generated load combinations Generated by	<b>SCh</b> DS2 - SLS - Characteristic 8 Design Situation No. 2	<input checked="" type="checkbox"/>





MODEL

5.4 ACTION COMBINATIONS

AC No.	Settings	Value	Active
9	<b>S.Ch</b> A1 + A3 Design Situation Generated load combinations Generated by	<b>S.Ch</b> DS2 - SLS - Characteristic 9 Design Situation No. 2	<input checked="" type="checkbox"/>
10	<b>S.Ch</b> A1 + 0.70 * A2 + A3 Design Situation Generated load combinations Generated by	<b>S.Ch</b> DS2 - SLS - Characteristic 10 Design Situation No. 2	<input checked="" type="checkbox"/>
11	<b>S.Sen</b> 1.60 * A1 Design Situation Generated load combinations Generated by	<b>S.Sen</b> DS3 - SLS - Quasi-permanent 11 Design Situation No. 3	<input checked="" type="checkbox"/>
12	<b>S.Sen</b> 1.60 * A1 + 1.12 * A2 Design Situation Generated load combinations Generated by	<b>S.Sen</b> DS3 - SLS - Quasi-permanent 12 Design Situation No. 3	<input checked="" type="checkbox"/>
13	<b>S.Sen</b> 1.60 * A1 + 1.12 * A2 + 0.60 * A3 Design Situation Generated load combinations Generated by	<b>S.Sen</b> DS3 - SLS - Quasi-permanent 13 Design Situation No. 3	<input checked="" type="checkbox"/>
14	<b>S.Sen</b> 1.60 * A1 + A3 Design Situation Generated load combinations Generated by	<b>S.Sen</b> DS3 - SLS - Quasi-permanent 14 Design Situation No. 3	<input checked="" type="checkbox"/>
15	<b>S.Sen</b> 1.60 * A1 + 0.82 * A2 + A3 Design Situation Generated load combinations Generated by	<b>S.Sen</b> DS3 - SLS - Quasi-permanent 15 Design Situation No. 3	<input checked="" type="checkbox"/>

5.5 LOAD COMBINATIONS

CO No.	Settings	Value	Unit	To Solve
1	<b>U.SI</b> 1.35 * LC1 Analysis type Static analysis settings Design Situation Load duration	Static Analysis SA1 - Geometrically linear <b>U.SI</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 Permanent		<input checked="" type="checkbox"/>
2	<b>U.SI</b> 1.35 * LC1 + 1.50 * LC2 Analysis type Static analysis settings Design Situation Load duration	Static Analysis SA1 - Geometrically linear <b>U.SI</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 Medium-term		<input checked="" type="checkbox"/>
3	<b>U.SI</b> 1.35 * LC1 + 1.50 * LC2 + 0.90 * LC3 Analysis type Static analysis settings Design Situation Load duration	Static Analysis SA1 - Geometrically linear <b>U.SI</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 Short-term		<input checked="" type="checkbox"/>
4	<b>U.SI</b> 1.35 * LC1 + 1.50 * LC3 Analysis type Static analysis settings Design Situation Load duration	Static Analysis SA1 - Geometrically linear <b>U.SI</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 Short-term		<input checked="" type="checkbox"/>
5	<b>U.SI</b> 1.35 * LC1 + 1.05 * LC2 + 1.50 * LC3 Analysis type Static analysis settings Design Situation Load duration	Static Analysis SA1 - Geometrically linear <b>U.SI</b> DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10 Short-term		<input checked="" type="checkbox"/>
6	<b>S.Ch</b> LC1 Analysis type Static analysis settings Design Situation Load duration	Static Analysis SA1 - Geometrically linear <b>S.Ch</b> DS2 - SLS - Characteristic Permanent		<input checked="" type="checkbox"/>
7	<b>S.Ch</b> LC1 + LC2			





MODEL

5.5 LOAD COMBINATIONS

CO No.	Settings	Value	Unit	To Solve
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SCh DS2 - SLS - Characteristic		
	Load duration	Medium-term		
8	SCh LC1 + LC2 + 0.60 * LC3			
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SCh DS2 - SLS - Characteristic		
	Load duration	Short-term		
9	SCh LC1 + LC3			
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SCh DS2 - SLS - Characteristic		
	Load duration	Short-term		
10	SCh LC1 + 0.70 * LC2 + LC3			
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SCh DS2 - SLS - Characteristic		
	Load duration	Short-term		
11	SLe 1.60 * LC1			
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SLe DS3 - SLS - Quasi-permanent		
	Load duration	Permanent		
12	SLe 1.60 * LC1 + 1.12 * LC2			
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SLe DS3 - SLS - Quasi-permanent		
	Load duration	Medium-term		
13	SLe 1.60 * LC1 + 1.12 * LC2 + 0.60 * LC3			
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SLe DS3 - SLS - Quasi-permanent		
	Load duration	Short-term		
14	SLe 1.60 * LC1 + LC3			
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SLe DS3 - SLS - Quasi-permanent		
	Load duration	Short-term		
15	SLe 1.60 * LC1 + 0.82 * LC2 + LC3			
	Analysis type	Static Analysis		<input checked="" type="checkbox"/>
	Static analysis settings	SA1 - Geometrically linear		
	Design Situation	SLe 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		<input type="checkbox"/>	
	Modify loading by multiplier factor		<input type="checkbox"/>	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		<input type="checkbox"/>	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		<input type="checkbox"/>	
	Asymmetric direct solver		<input checked="" type="checkbox"/>	
	Equilibrium for undeformed structure		<input type="checkbox"/>	
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		<input type="checkbox"/>	
	Ignore all nonlinearities		<input type="checkbox"/>	





5.6 **STATIC ANALYSIS SETTINGS**

Settings No.	Description	Symbol	Value	Unit
	Modify loading by multiplier factor		<input type="checkbox"/>	
	Consider favorable effect due to tension in members		<input checked="" type="checkbox"/>	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		<input type="checkbox"/>	
	Refer internal forces to deformed structure		<input checked="" type="checkbox"/>	
	Refer internal forces to deformed structure for normal forces		<input checked="" type="checkbox"/>	
	Refer internal forces to deformed structure for shear forces		<input checked="" type="checkbox"/>	
	Refer internal forces to deformed structure for moments		<input checked="" type="checkbox"/>	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		<input type="checkbox"/>	
	Asymmetric direct solver		<input checked="" type="checkbox"/>	
	Equilibrium for undeformed structure		<input type="checkbox"/>	
	Stability check based on deformation rate		<input type="checkbox"/>	
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		<input type="checkbox"/>	
	Ignore all nonlinearities		<input type="checkbox"/>	
	Modify loading by multiplier factor		<input type="checkbox"/>	
	Consider favorable effect due to tension in members		<input checked="" type="checkbox"/>	
	Try to calculate unstable structure		<input type="checkbox"/>	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		<input type="checkbox"/>	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		<input type="checkbox"/>	
	Asymmetric direct solver		<input checked="" type="checkbox"/>	
	Equilibrium for undeformed structure		<input type="checkbox"/>	
	Stability check based on deformation rate		<input type="checkbox"/>	

5.7 **COMBINATION WIZARDS**

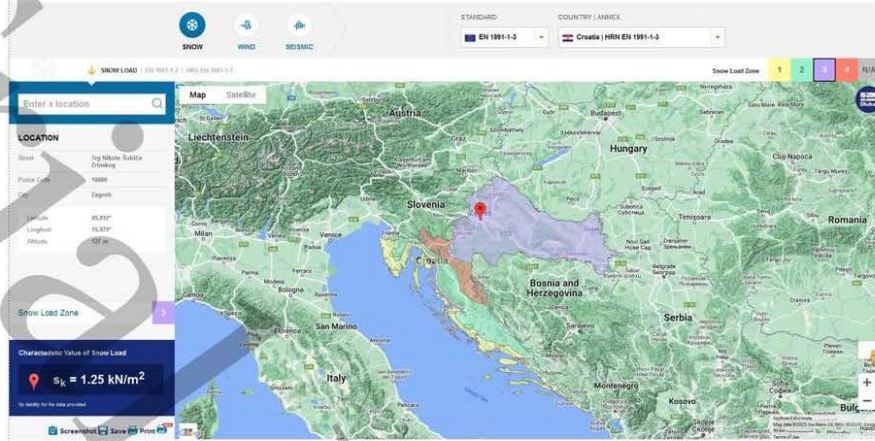
Wizard No.	Settings	Value
1	Load combinations   SA2 - Second-order (P-Δ)   Picard   100   1	
	Assigned to	DS 2,3
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA2 - Second-order (P-Δ)   Picard   100   1
	Consider imperfection case	<input checked="" type="checkbox"/>
	Consider initial state	<input type="checkbox"/>
	Structure modification enabled	<input type="checkbox"/>
	Generate same load combinations without imperfection case	<input type="checkbox"/>
	Consider construction stages	<input type="checkbox"/>
	User-defined action combinations	<input type="checkbox"/>
	Favorable permanent actions	<input type="checkbox"/>
	Reduce number of generated combinations	<input type="checkbox"/>
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	<input type="checkbox"/>
	Consider initial state	<input type="checkbox"/>
	Structure modification enabled	<input type="checkbox"/>
	Consider construction stages	<input type="checkbox"/>
	User-defined action combinations	<input type="checkbox"/>
	Favorable permanent actions	<input type="checkbox"/>
	Reduce number of generated combinations	<input type="checkbox"/>

6 **Loads**

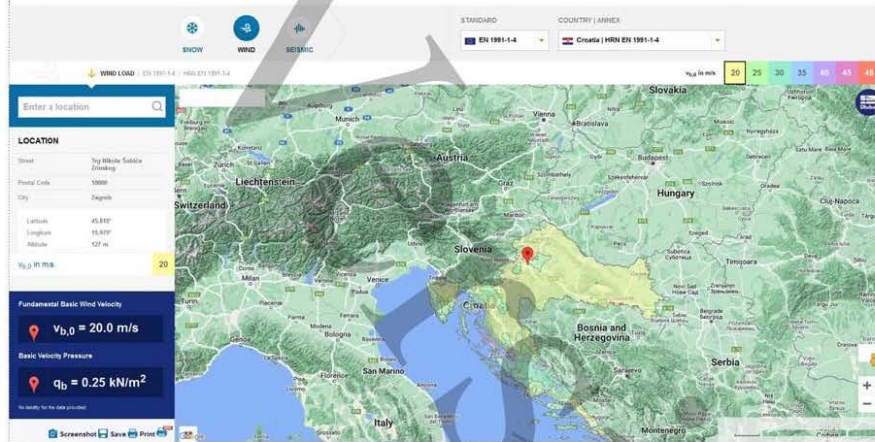




6.1.1 SNIJEG.JPG



6.2.1 VJETAR.JPG





MODEL

6.3.1 OPTEREĆENJE.JPG

ANALIZA OPTEREĆENJA - Ministarstvo vanjskih poslova

Pozicija		K1		
Opis pozicije		Krov		
Sloj		Zapreminska težina [kg/m <sup>3</sup> ]	Debljina sloja [cm]	Iznos površinskog opterećenja [kN/m <sup>2</sup> ]
Stalno opterećenje (g)	1 Biber crijepe			0,50
	2 Dodatno stalno			0,10
	<b>Ukupno:</b>			<b>0,60</b>
Položaj		Iznos opterećenja [kN/m <sup>2</sup> ]		
Promjenjivo opterećenje (g)	s Snijeg	1,00		
	w Vjetar	Software		

Snijeg (s)	Područje: 3	kontinentalna Hrvatska
	Nadmorska visina: 122 [m.n.m.]	
	$\alpha = 32$	
	$s_k = 1,25$ [kN/m <sup>2</sup> ]	karakteristična vrijednost opterećenja snijegom na tlu
	$\mu_1(\alpha) = 0,8$	koeficijent oblika opterećenja snijegom
	$C_e = 1$	koeficijent izloženosti
	$C_{te} = 1$	toplinski koeficijent
	$s_{te} = \mu_1(\alpha) \cdot C_{te} \cdot C_e \cdot s_k$	
	$s_{te} = 1,00$ [kN/m <sup>2</sup> ]	

Vjetar (w)	$c_{pe} = 1$	koeficijent srijera vjetra
	$c_{pe,stat} = 1$	koeficijent godišnjeg doba
	$v_{b,0} = 20$ [m/s]	fundamentalna vrijednost osnovne brzine vjetra
	$v_b = c_{dir} \cdot c_{temp} \cdot v_{b,0}$ [m/s]	osnovna brzina vjetra
	$v_b = 20$ [m/s]	
	$\rho = 1,25$ [kg/m <sup>3</sup> ]	gustoća zraka
	*kategorija terena: III	
	$c_s(z) = 1,9$	koeficijent izloženosti
	$q_0 = 1/2 \cdot \rho \cdot v_b^2$ [kN/m <sup>2</sup> ]	osnovni pritisak vjetra
	$q_0 = 0,25$ [kN/m <sup>2</sup> ]	
	$c_{pe}(H) = -0,96$	koeficijent vanjskog pritiska
	$c_{pe}(l) = -0,76$ [m <sup>2</sup> ]	koeficijent vanjskog pritiska
	$c_{pi} = 0,2$ [m <sup>2</sup> ]	koeficijent unutarnjeg pritiska
	$w_s(H) = q_0 \cdot c_s(z) \cdot c_{pe} \cdot c_{dir} \cdot c_{temp}$ = -0,55 [kN/m <sup>2</sup> ]	opterećenje vjetrom uključujući i unutarnji pritisak
$w_s(H) = q_0 \cdot c_s(z) \cdot c_{pe} \cdot c_{dir} \cdot c_{temp}$ = -0,46 [kN/m <sup>2</sup> ]	opterećenje vjetrom bez unutarnjeg pritiska	
$w_s(l) = q_0 \cdot c_s(z) \cdot c_{pe} \cdot c_{dir} \cdot c_{temp}$ = -0,46 [kN/m <sup>2</sup> ]	opterećenje vjetrom uključujući i unutarnji pritisak	
$w_s(l) = q_0 \cdot c_s(z) \cdot c_{pe} \cdot c_{dir} \cdot c_{temp}$ = -0,36 [kN/m <sup>2</sup> ]	opterećenje vjetrom bez unutarnjeg pritiska	

USVOJENE VRIJEDNOSTI ZA SVE PLOHE (POJEDINOSTAVLJENO)



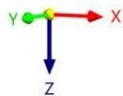
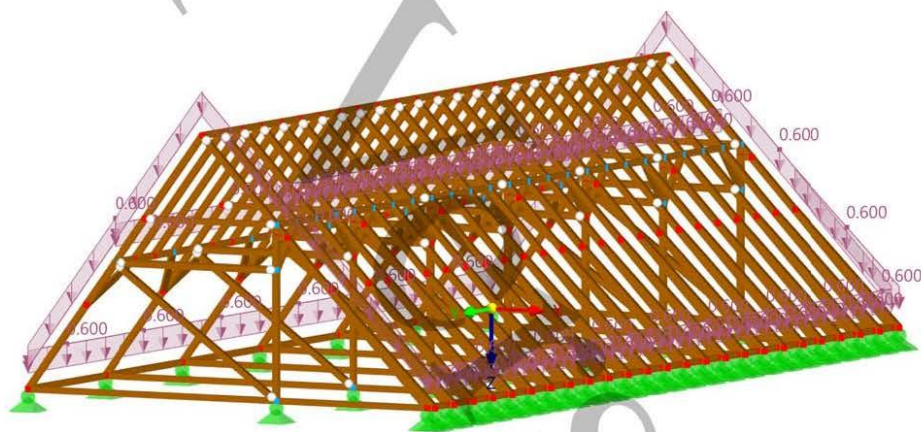


6.4.1 LC1-STALNO

Static Analysis

[C1 - Self-weight  
Loads [kN/m]  
Static Analysis

In Axonometric Direction





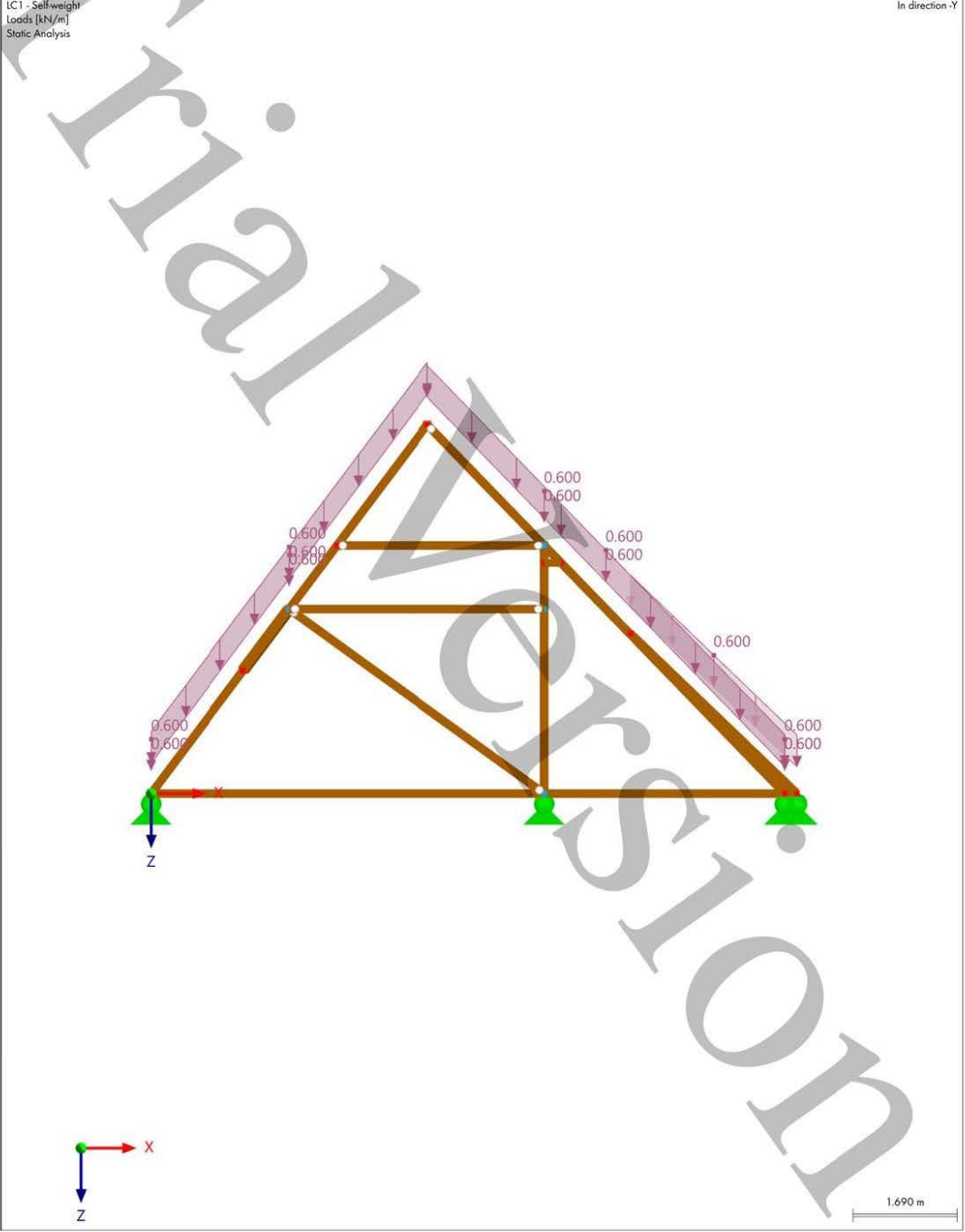
MODEL

6.4.2 LC1: , LOADING, IN DIRECTION -Y

Static Analysis

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

In direction -Y

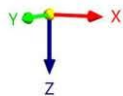
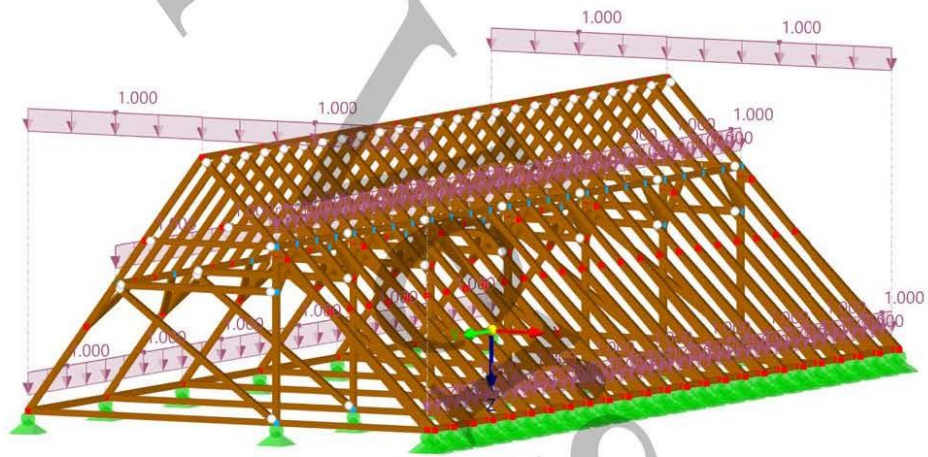


6.5.1 LC2-SNIJEG

Static Analysis

[LC2 - Snijeg  
Loads [kN/m]  
Static Analysis

In Axonometric Direction

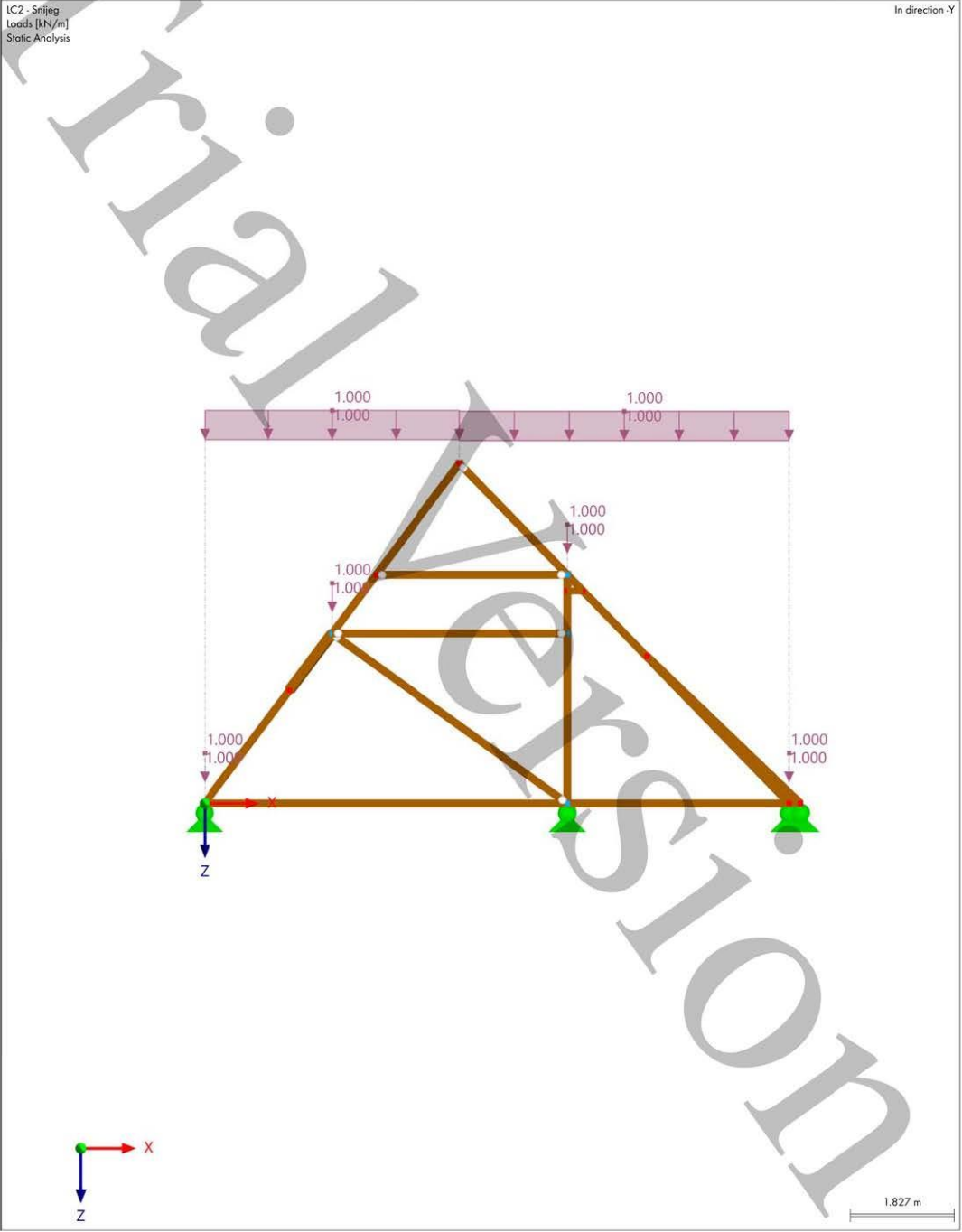


6.5.2 LC2: , LOADING, IN DIRECTION -Y

Static Analysis

LC2 - Snijeg  
Loads [kN/m]  
Static Analysis

In direction -Y

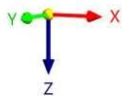
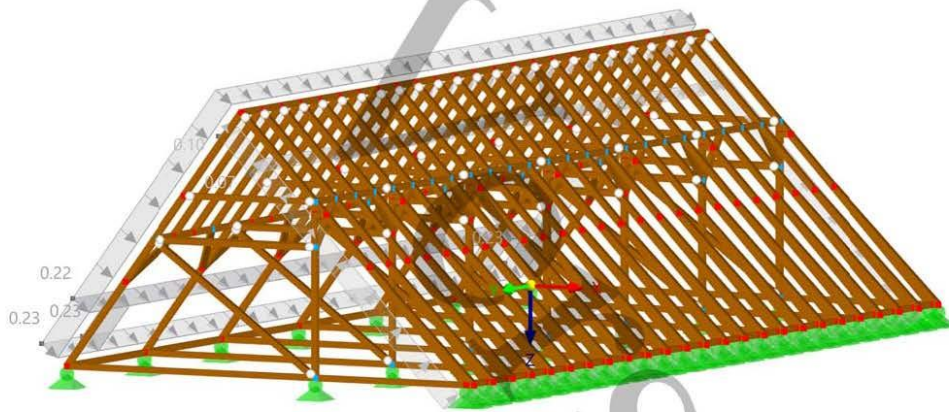


6.6.1 LC3-VJETAR

Static Analysis

[LC3 - Vjetar  
Loads [kN/m<sup>2</sup>]  
Static Analysis

In Axonometric Direction





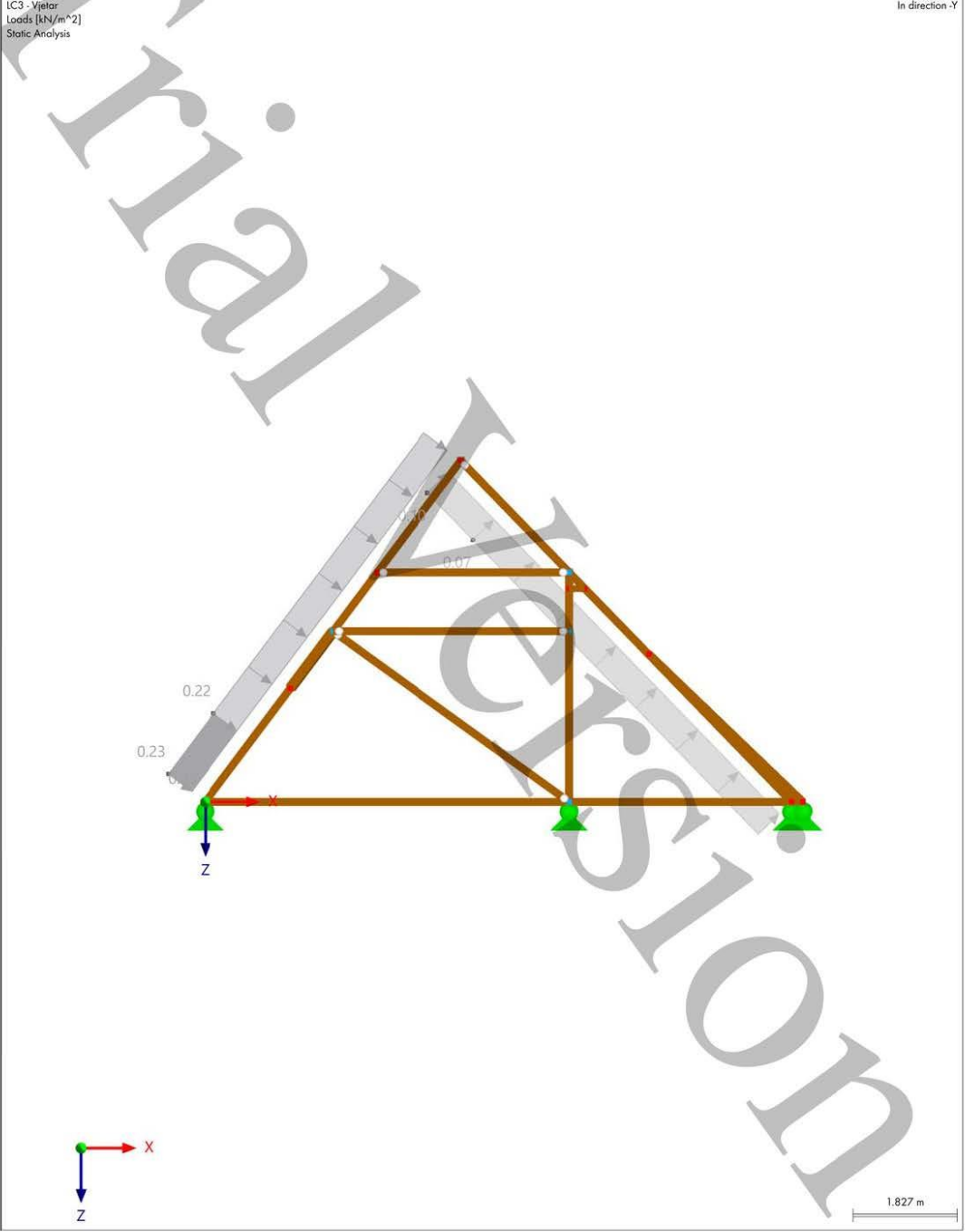
MODEL

6.6.2 LC3: , LOADING, IN DIRECTION -Y

Static Analysis

LC3 - Vjetar  
Loads [kN/m<sup>2</sup>]  
Static Analysis

In direction -Y

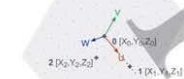




MODEL

## 7 Guide Objects

### 7.1 COORDINATE SYSTEMS



System No.	Type	Symbol	Coordinates			Rotation			Comment
			Value	Unit	Sequence	Symbol	Value	Unit	
1	Global XYZ								
2	3 Points   Load Wizard   Wind Load No. 1		4.500	22.800	-6.000	4.535	21.801	-5.964	3.781, 22.800, -5.305
	3 Points	X <sub>0</sub>	4.500	m					
		Y <sub>0</sub>	22.800	m					
		Z <sub>0</sub>	-6.000	m					
		X <sub>1</sub>	4.535	m					
		Y <sub>1</sub>	21.801	m					
		Z <sub>1</sub>	-5.964	m					
		X <sub>2</sub>	3.781	m					
		Y <sub>2</sub>	22.800	m					
		Z <sub>2</sub>	-5.305	m					
3	3 Points   Load Wizard   Wind Load No. 1		0.000	22.800	0.000	0.333	21.968	-0.444	0.800, 22.800, 0.600
	3 Points	X <sub>0</sub>	0.000	m					
		Y <sub>0</sub>	22.800	m					
		Z <sub>0</sub>	0.000	m					
		X <sub>1</sub>	0.333	m					
		Y <sub>1</sub>	21.968	m					
		Z <sub>1</sub>	-0.444	m					
		X <sub>2</sub>	0.800	m					
		Y <sub>2</sub>	22.800	m					
		Z <sub>2</sub>	0.600	m					

## 8 Static Analysis Results

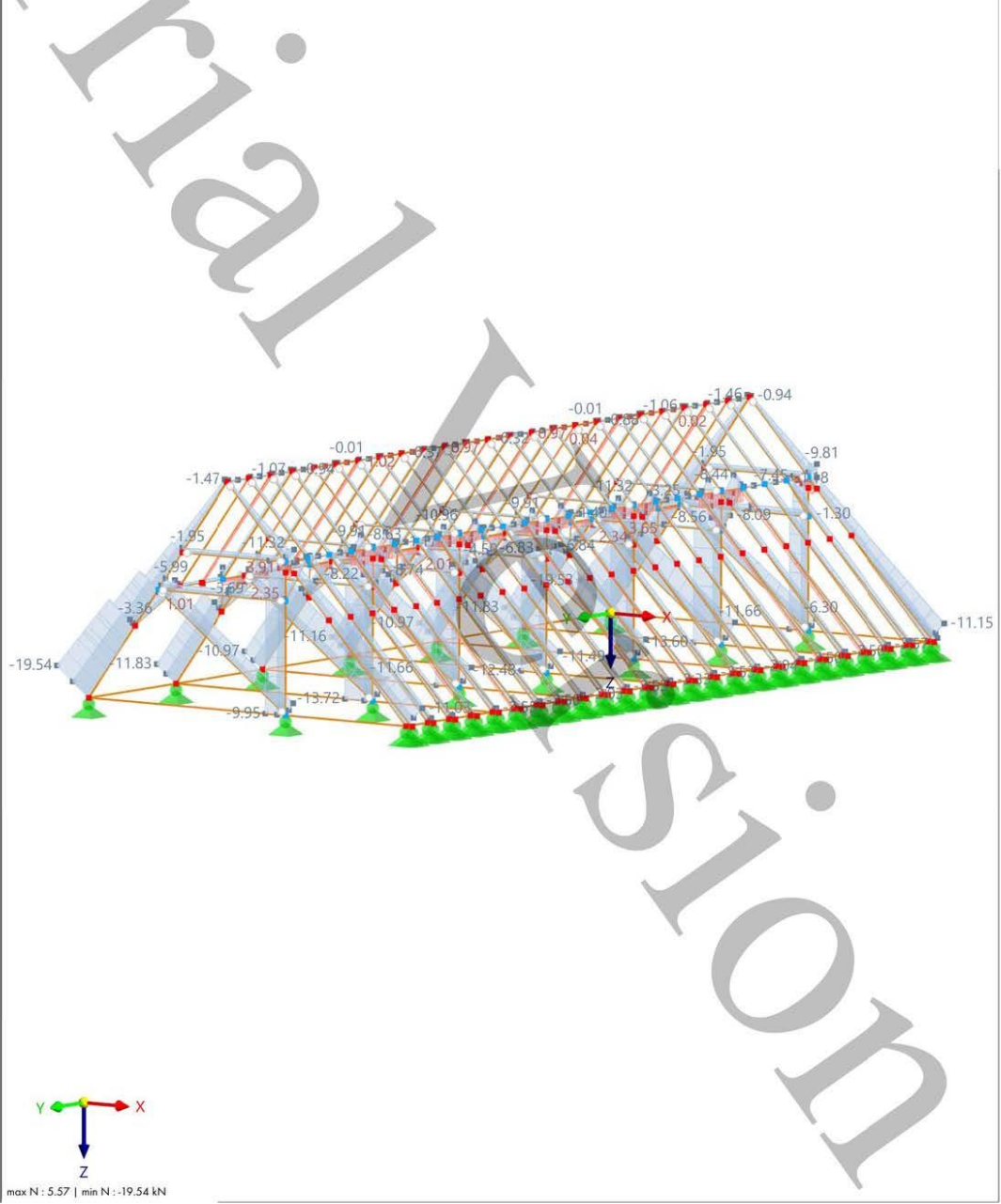


8.1 DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES N, IN AXONOMETRIC DIRECTION

Static Analysis

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

In Axonometric Direction



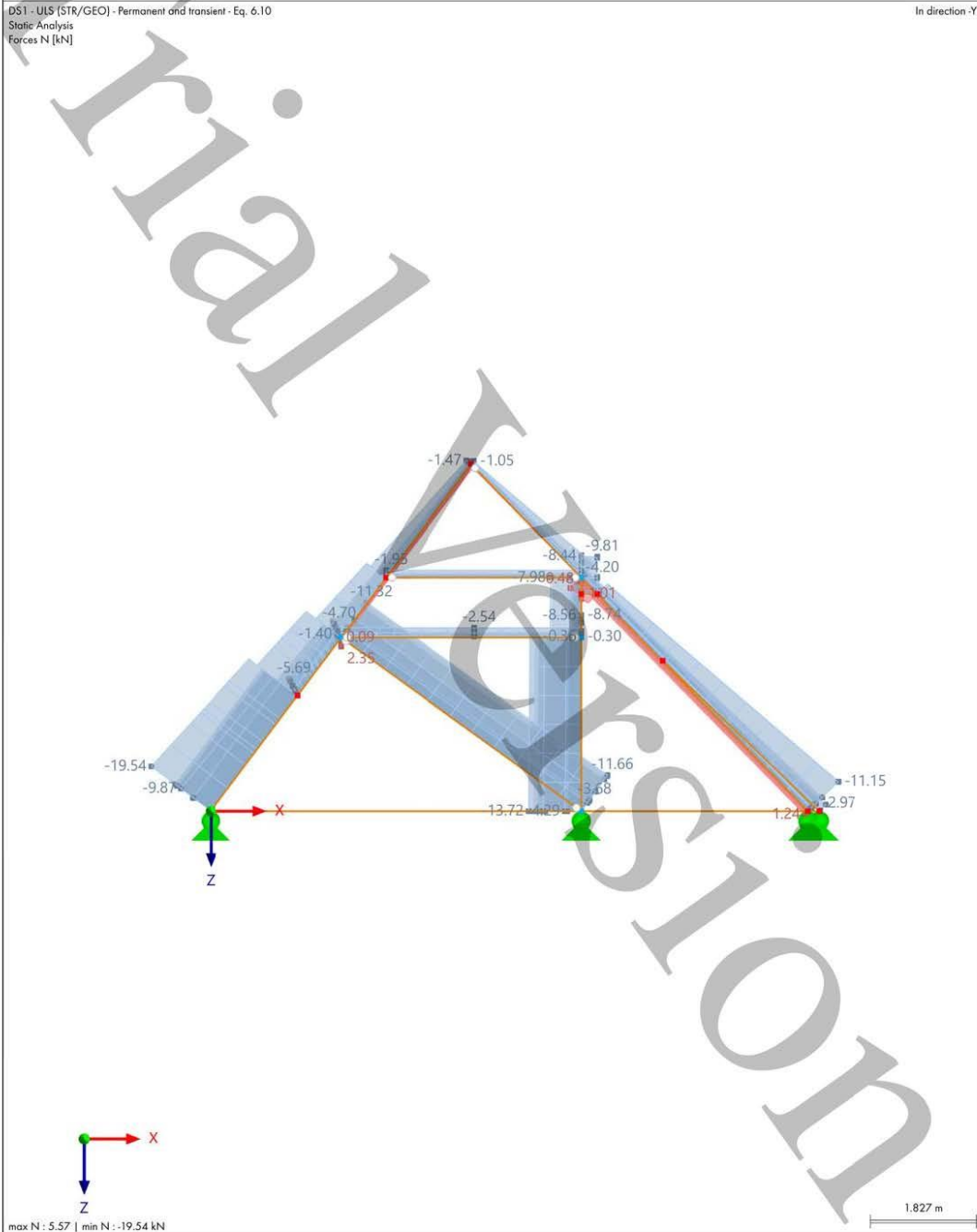




MODEL

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

Static Analysis

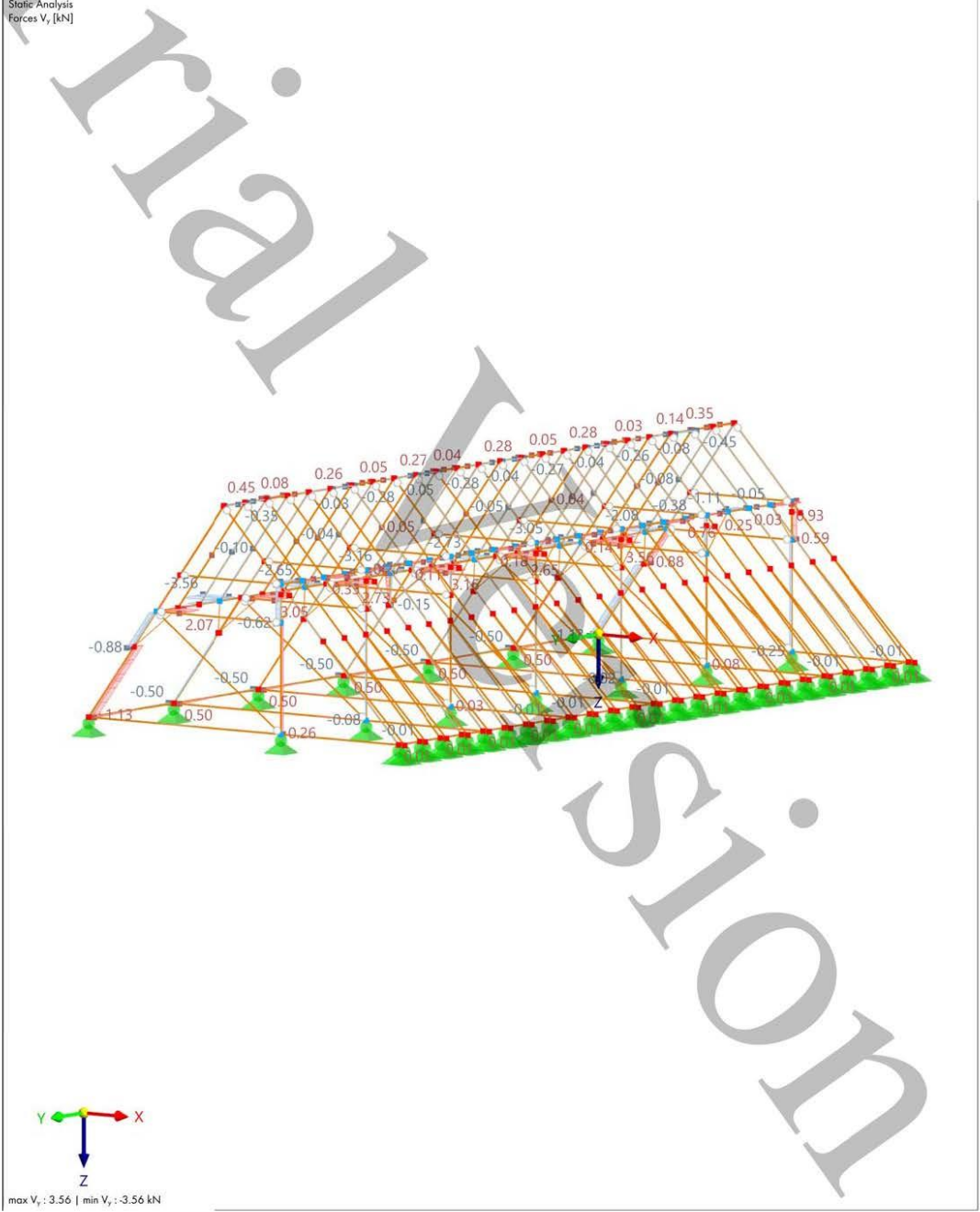


8.3 DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES  $V_y$ , IN AXONOMETRIC DIRECTION

Static Analysis

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

In Axonometric Direction

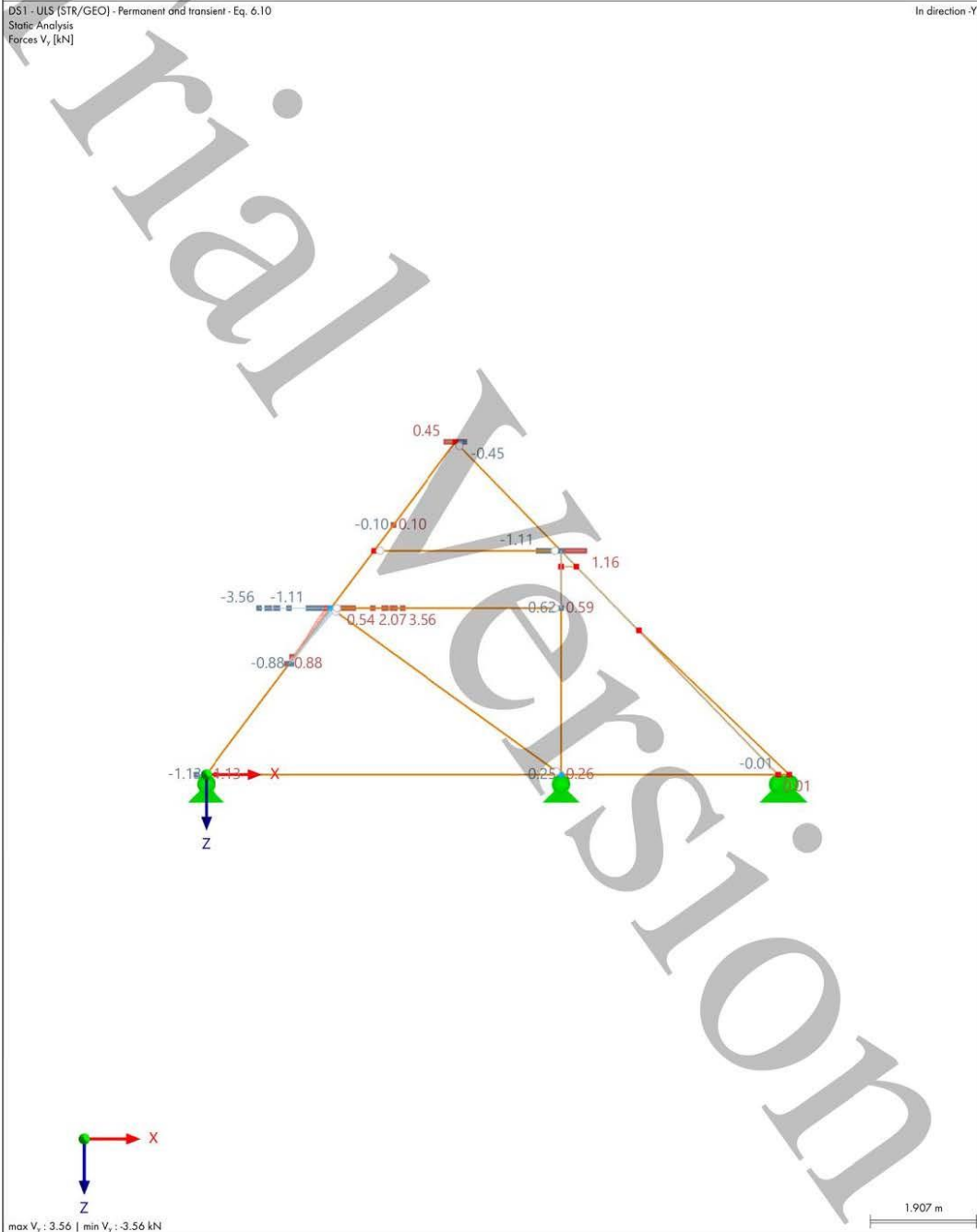




MODEL

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

Static Analysis

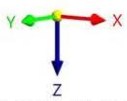
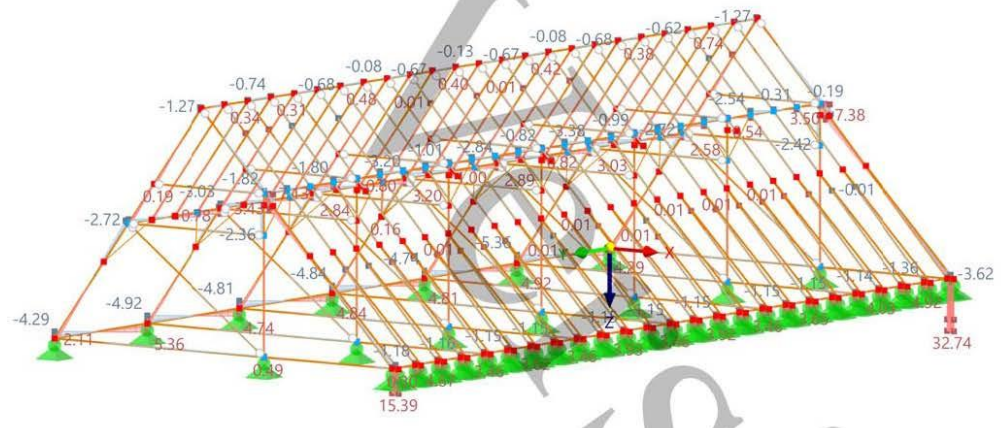


8.5 DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES  $V_z$ , IN AXONOMETRIC DIRECTION

Static Analysis

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

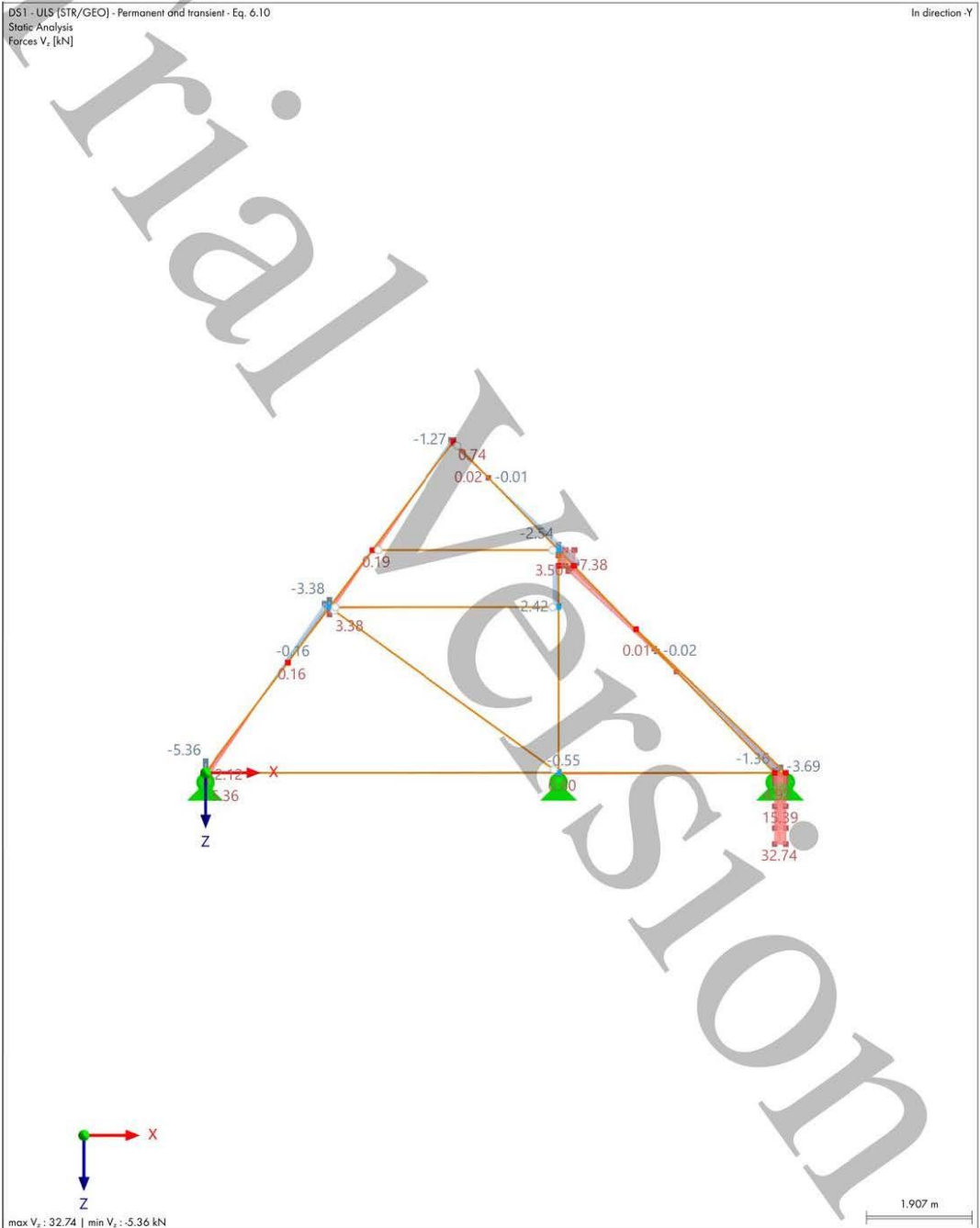
In Axonometric Direction



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

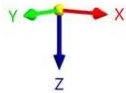
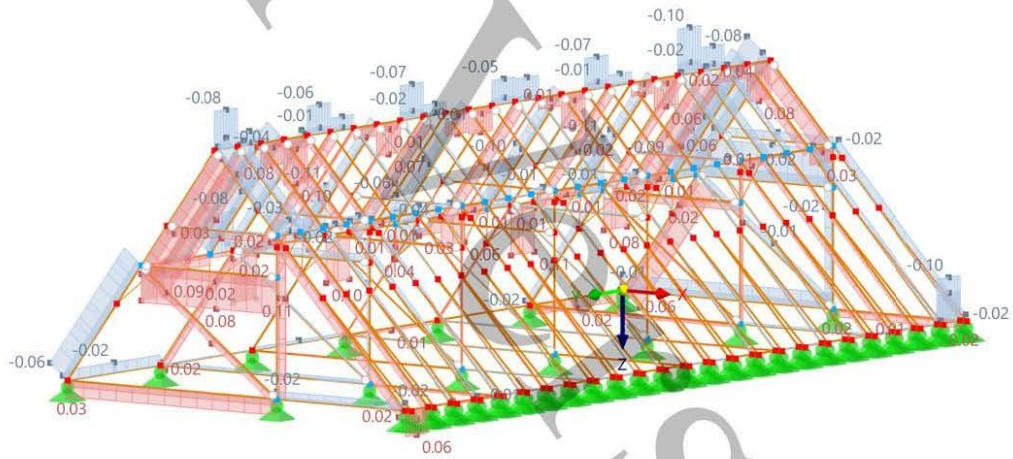


8.7 DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES  $M_{T1}$ , IN AXONOMETRIC DIRECTION

Static Analysis

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

In Axonometric Direction



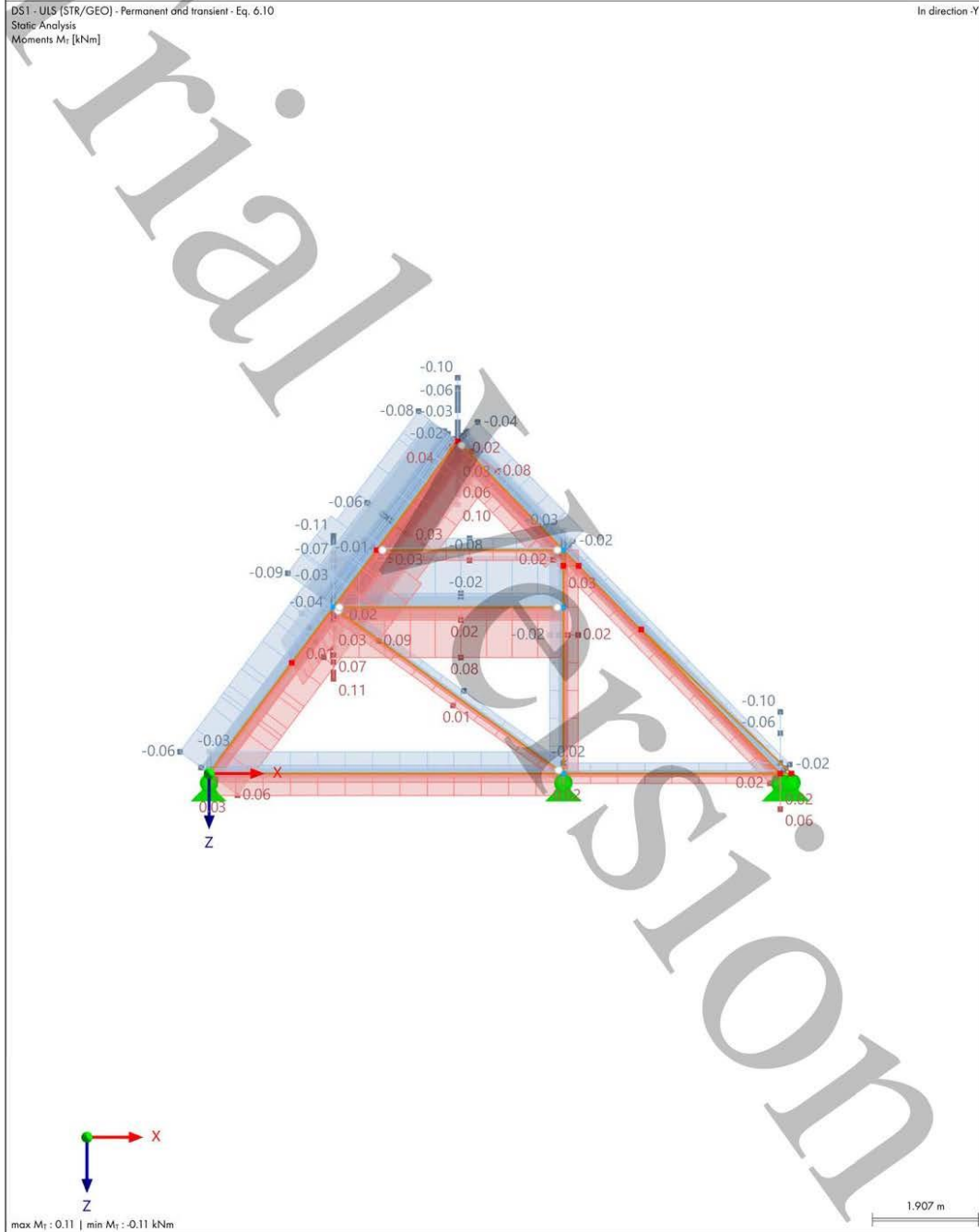
max  $M_T$ : 0.11 | min  $M_T$ : -0.11 kNm



MODEL

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

Static Analysis

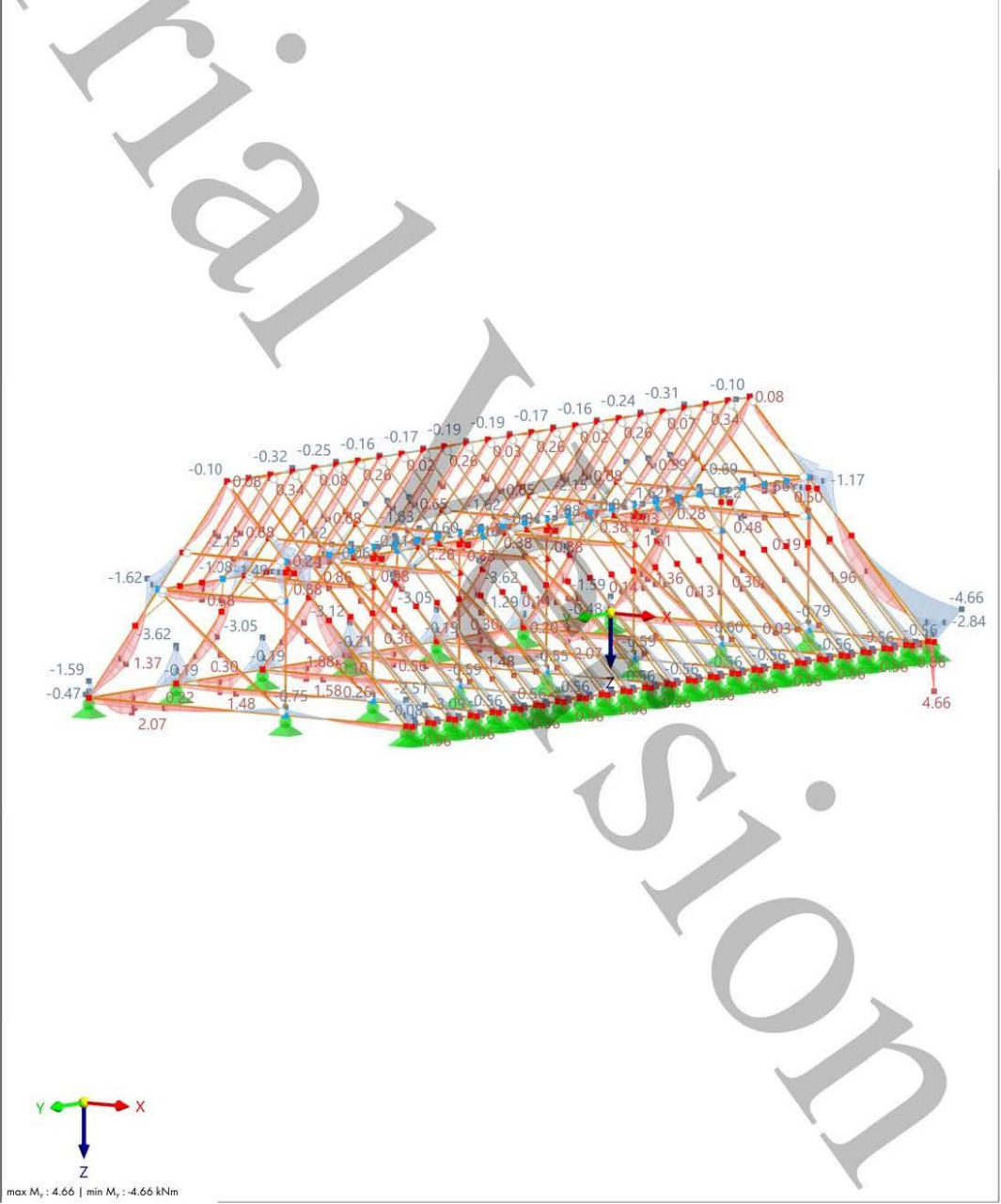


8.9 DS1: ENVELOPE VALUES - MAX AND MIN VALUES, INTERNAL FORCES  $M_y$ , IN AXONOMETRIC DIRECTION

Static Analysis

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

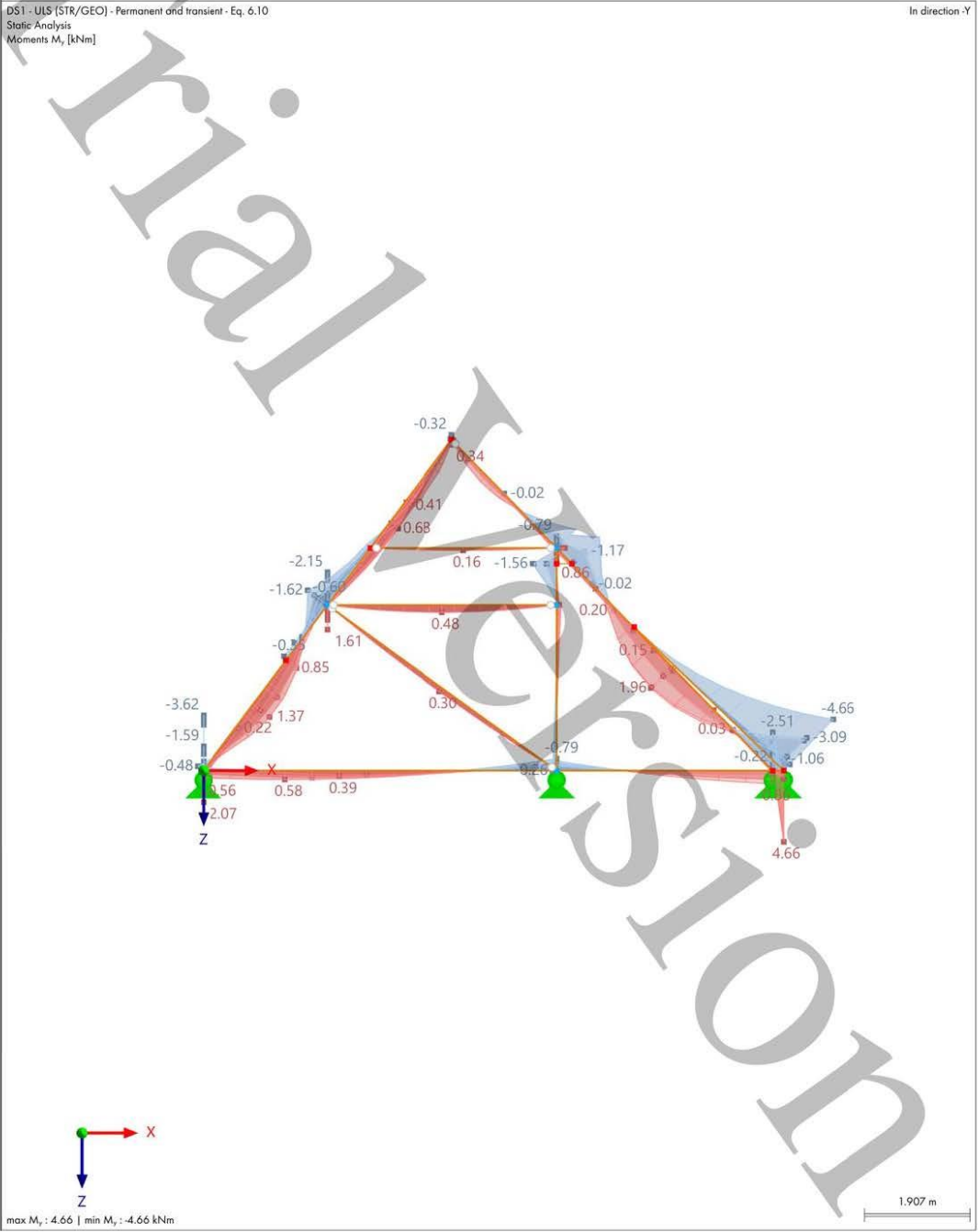
In Axonometric Direction





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

Static Analysis





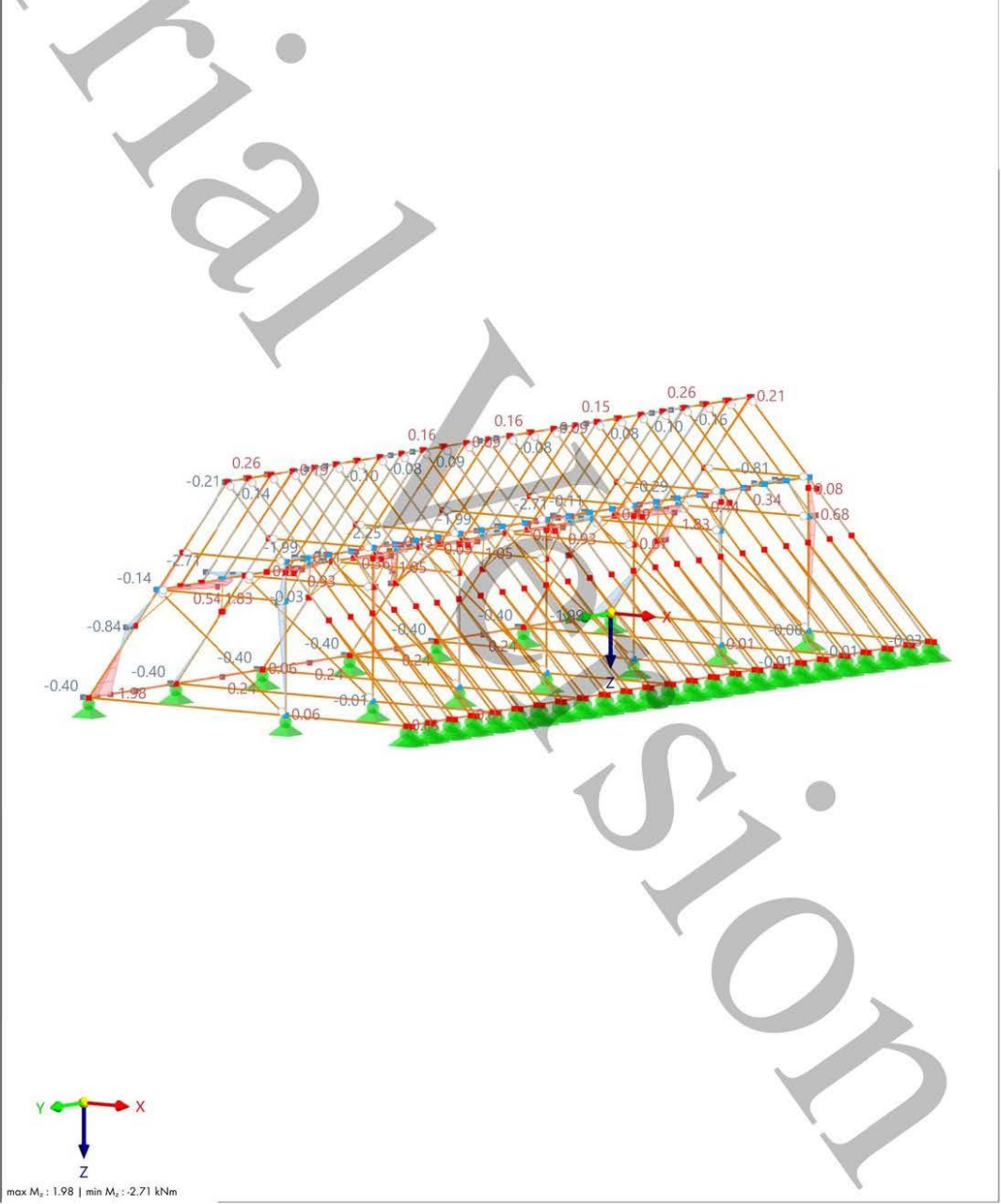
MODEL

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

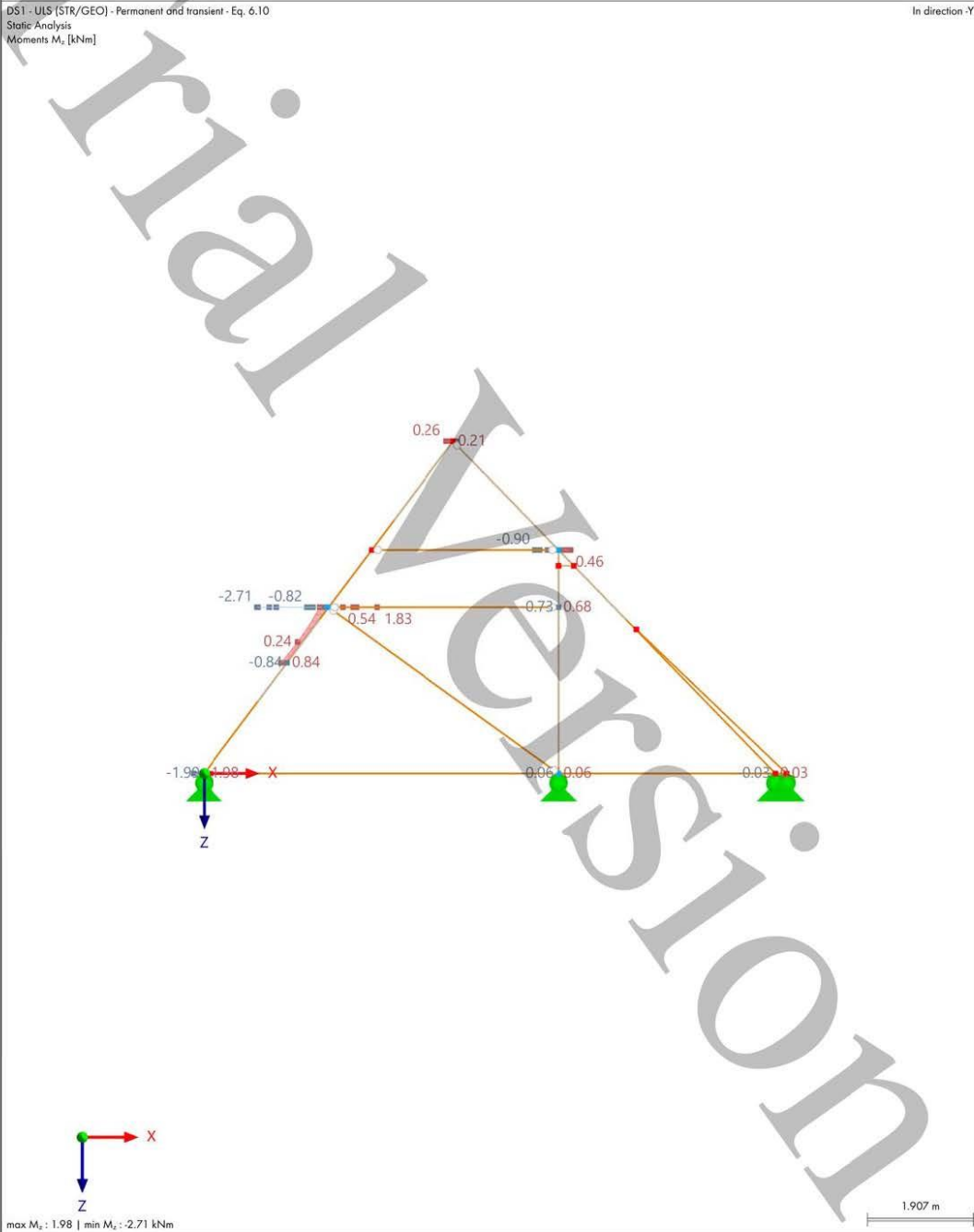




MODEL

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

Static Analysis

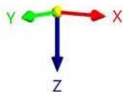
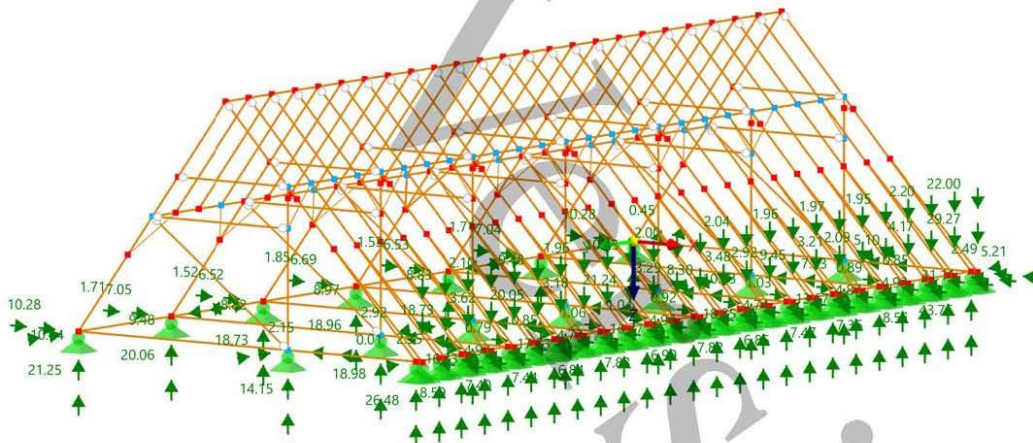


8.13 DS1: ENVELOPE VALUES - MAX AND MIN VALUES, NODAL SUPPORTS  $P_x$ , NODAL SUPPORTS  $P_y$ , NODAL SUPPORTS  $P_z$ , IN AXONOMETRIC DIRECTION

Static Analysis

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

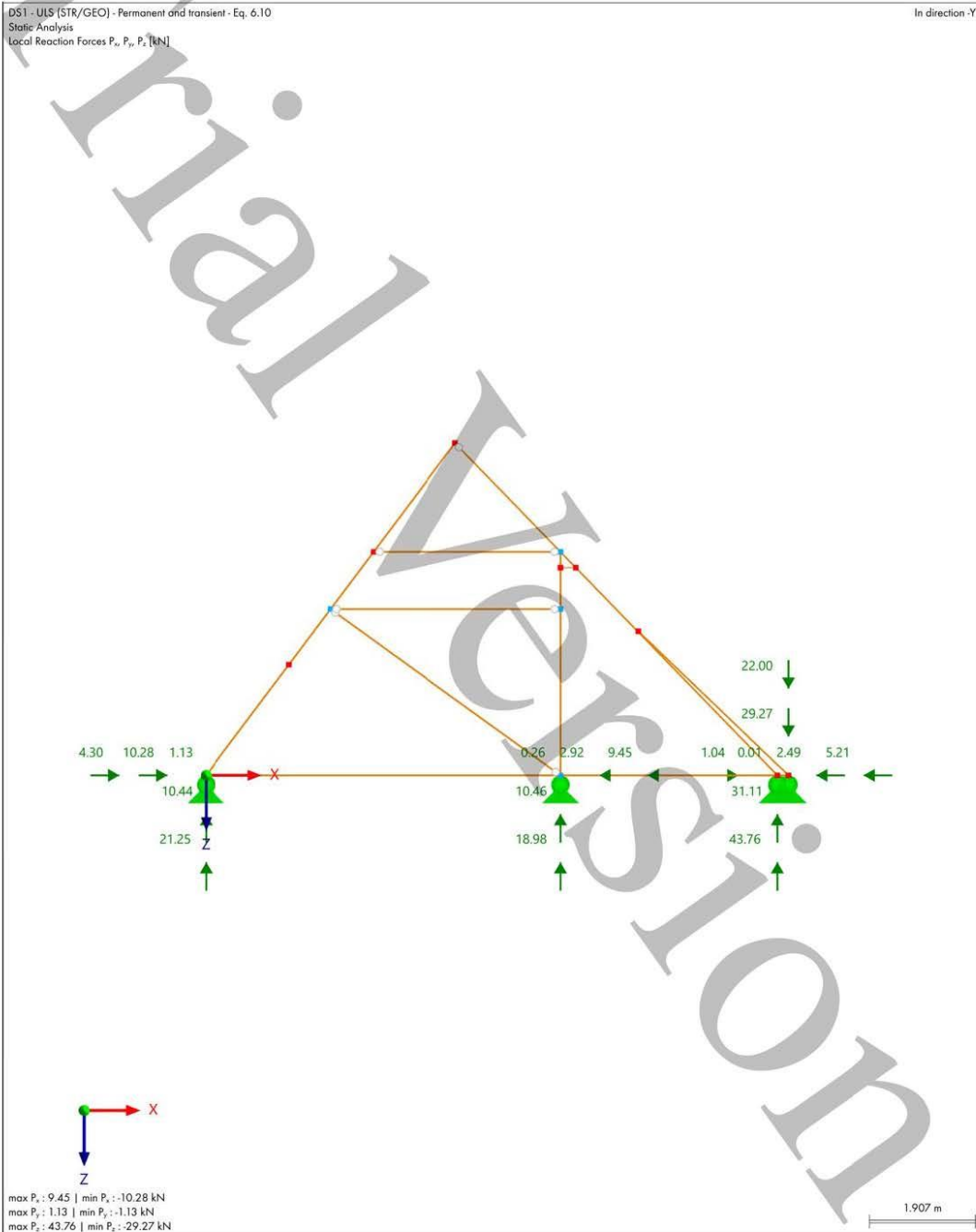
In Axonometric Direction



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

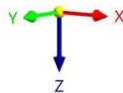
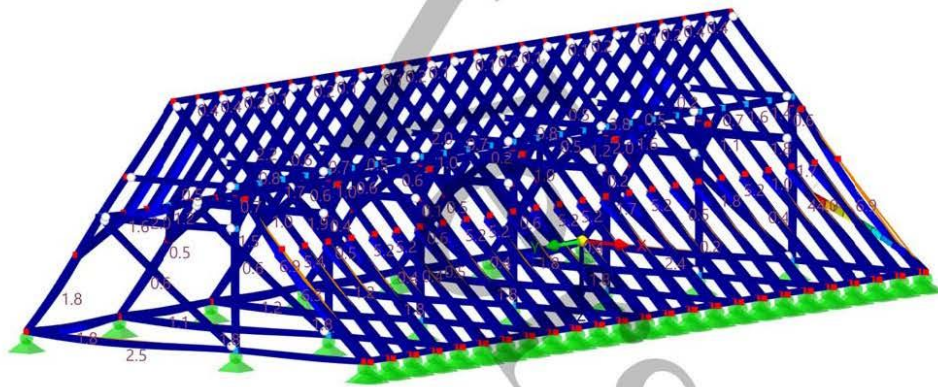
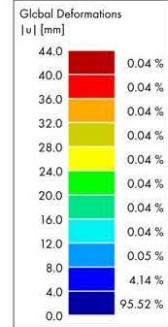


8.15 DS2: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS [U], IN AXONOMETRIC DIRECTION

Static Analysis

DS2 - SLS - Characteristic  
Static Analysis  
Displacements |u| [mm]

In Axonometric Direction

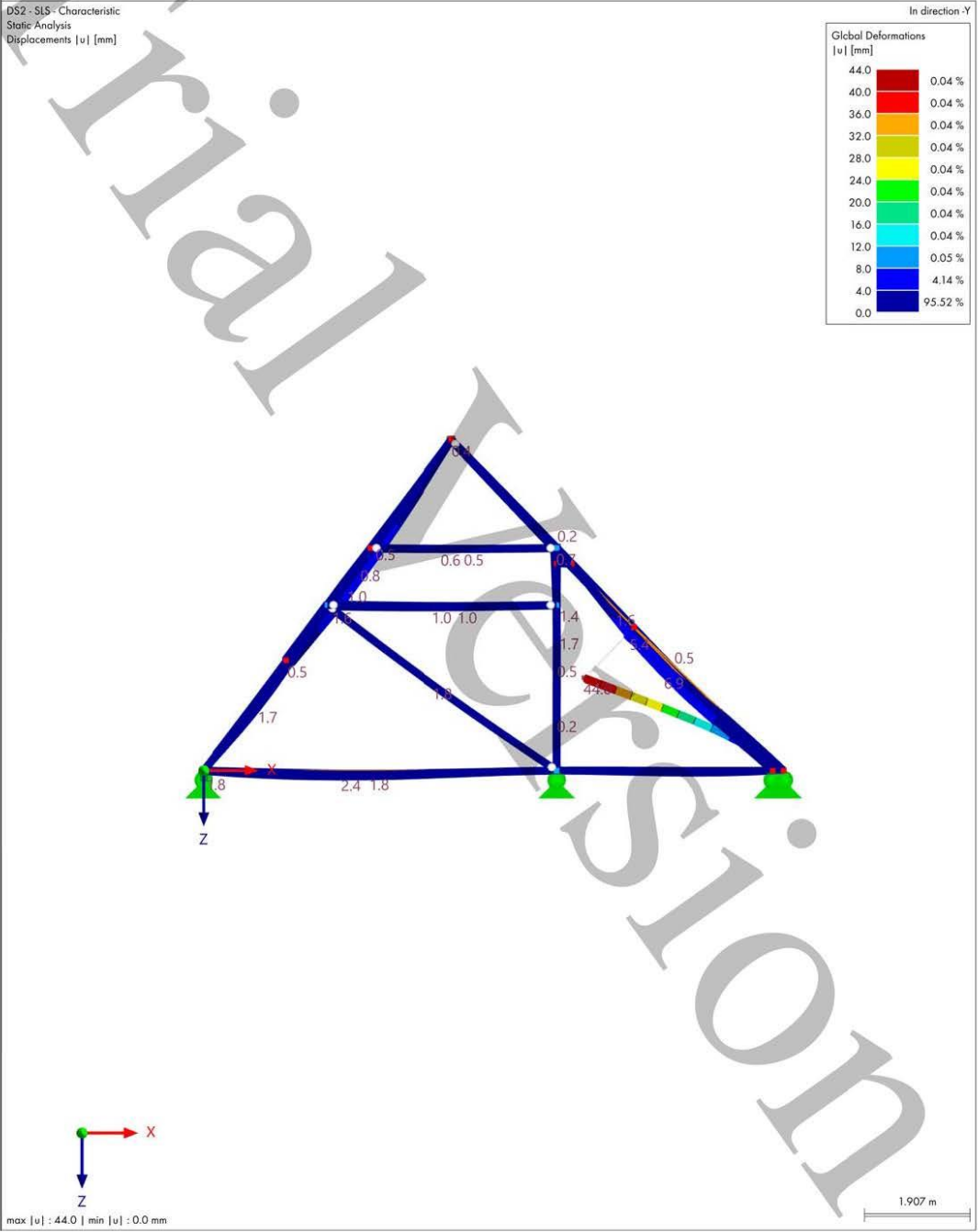


max |u| : 44.0 | min |u| : 0.0 mm



MODEL

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

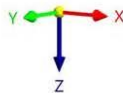
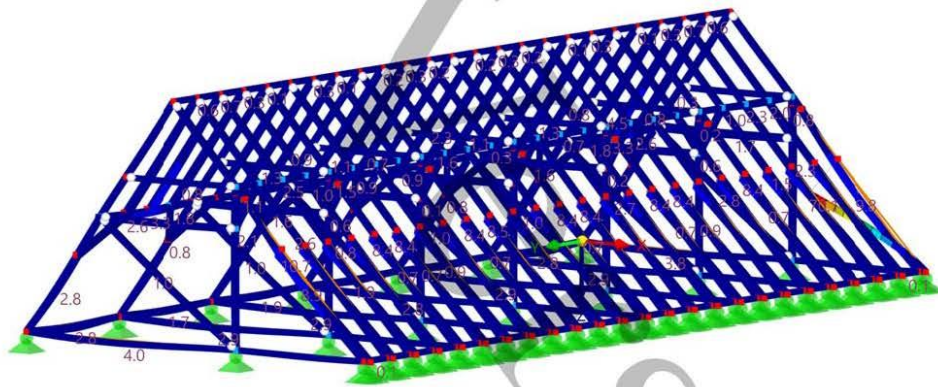
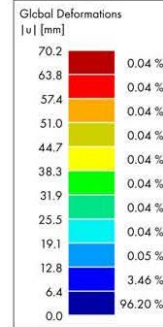


8.17 DS3: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS [U], IN AXONOMETRIC DIRECTION

Static Analysis

DS3 - SLS - Quasi-permanent  
Static Analysis  
Displacements |u| [mm]

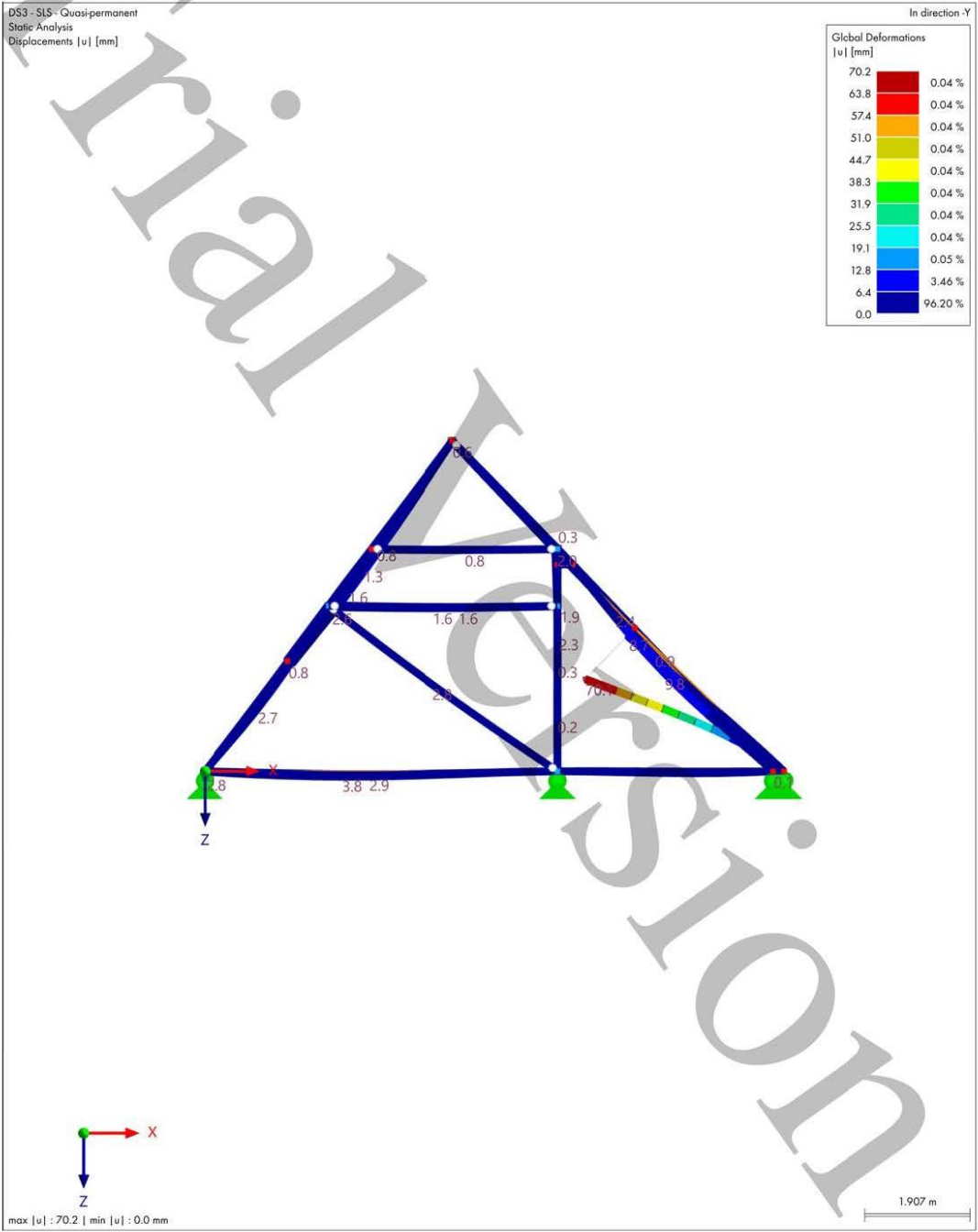
In Axonometric Direction



max |u| : 70.2 | min |u| : 0.0 mm



8.18 DS3: ENVELOPE VALUES - MAX AND MIN VALUES, GLOBAL DEFORMATIONS |U|, LOADING, IN Static Analysis  
DIRECTION -Y





TIMBER

## 9 Timber Design

### 9.1 OBJECTS TO DESIGN

Object Type	Design All	Objects to Design				Not Valid / Deact.	Comment
		Selected	To Calculate	Removed			
Members	<input type="checkbox"/>	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- 95,97-99,101-107,1- 13-120,122-124,12 6-128,130-136,142 -149,151-153,155- 157,159-165,171-1 78,180-182,184-18 6,188-194,200-242	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- 99,101-104,106,10 7,113-120,122-124, 126-128,130-133,1 35,136,142-149,15 1-153,155-157,159 -162,164,165,171-1 78,180-182,184-18 6,188-191,193,194, 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
2	S.Ch SLS - Characteristic	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	S.Ch SLS - Characteristic	All
3	S.Geo SLS - Quasi-permanent	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	S.Geo1 SLS - Quasi-permanent 1	All

### 9.3 MATERIALS

Legend  
 Stiffness modification

Material No.	Name	To Design	Material Type	Options	Comment
1	C24	<input checked="" type="checkbox"/>	Timber	<input checked="" type="checkbox"/>	

### 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	<input checked="" type="checkbox"/>	Parametric - Massive I	--	A
2	R_M1 140/140	1	<input checked="" type="checkbox"/>	Parametric - Massive I	--	A
3	2R_M2 140/140/140/1	1	<input checked="" type="checkbox"/>	Parametric - Massive II	--	A
4	2R_M2 120/120/140/1	1	<input checked="" type="checkbox"/>	Parametric - Massive II	--	A

### 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			
	<input checked="" type="checkbox"/> Perform stability design			
	Limit Values for Special Cases			
	Tension ( $\sigma_{t,0,d} / f_{t,0,d}$ )	$\eta_{ot,lim}$	0.001	--
	Compression ( $\sigma_{c,0,d} / f_{c,0,d}$ )	$\eta_{oc,lim}$	0.001	--
	Shear ( $\tau_{xy,d} / f_{v,d}$ )	$\eta_{xy,lim}$	0.001	--
	Shear ( $\tau_{xz,d} / f_{v,d}$ )	$\eta_{xz,lim}$	0.001	--
	Torsion ( $\tau_{tw,d} / f_{t,d}$ )	$\eta_{tw,lim}$	0.010	--
	Bending ( $\sigma_{m,y,d} / f_{m,d}$ )	$\eta_{om,y,lim}$	0.001	--
	Bending ( $\sigma_{m,z,d} / f_{m,d}$ )	$\eta_{om,z,lim}$	0.001	--
	Curved and Saddle Members:			
	<input checked="" type="checkbox"/> Perpendicular tension design of curved members			
	<input checked="" type="checkbox"/> 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





TIMBER

9.5.1 **ULTIMATE CONFIGURATIONS - SETTINGS - MEMBERS**

Config. No.	Description	Symbol	Value	Unit
	System Strength Acc. to 6.6			
	<input type="checkbox"/> Consider system strength factor			
	Settings for Stability Design			
	Stiffness Reduction			
	<input type="checkbox"/> Reduction of stiffness with coefficient $1/(1+k_{st})$ acc. to DIN EN 1995-1-1			
	Position of Positive Transverse Load Application			
	Vertical position			
	<input checked="" type="radio"/> On section edge (destabilizing effect)			
	<input type="radio"/> At shear point			
	<input type="radio"/> At center point			
	<input type="radio"/> On section edge (stabilizing effect)			
	<input type="checkbox"/> 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 ( $\sigma_{t,0,d} / f_{t,0,d}$ )	$\eta_{t,0,lim}$	0.001	--
	Tension perpendicular ( $\sigma_{t,90,d} / f_{t,90,d}$ )	$\eta_{t,90,lim}$	0.001	--
	Compression ( $\sigma_{c,0,d} / f_{c,0,d}$ )	$\eta_{c,0,lim}$	0.001	--
	Compression perpendicular ( $\sigma_{c,90,d} / f_{c,90,d}$ )	$\eta_{c,90,lim}$	0.001	--
	Shear in yz-plane ( $\tau_{yz} / f_{v,yz,d}$ )	$\eta_{yz,lim}$	0.001	--
	Shear in xz-plane ( $\tau_{xz} / f_{v,xz,d}$ )	$\eta_{xz,lim}$	0.001	--
	Shear in xy-plane ( $\tau_{xy} / f_{v,xy,d}$ )	$\eta_{xy,lim}$	0.001	--
	Shear on net section ( $\tau_{net} / f_{v,net,d}$ )	$\eta_{net,lim}$	0.001	--
	Equivalent torsion ( $\tau_{tor} / f_{v,tor,d}$ )	$\eta_{tor,lim}$	0.001	--
	Bending ( $\sigma_{b,0,d} / f_{m,0,d}$ )	$\eta_{b,0,lim}$	0.001	--
	Bending perpendicular ( $\sigma_{b,90,d} / f_{m,90,d}$ )	$\eta_{b,90,lim}$	0.001	--
	System Strength			
	<input type="checkbox"/> 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	$L_c /$	300	--
	Quasi-permanent 1	$L_c /$	250	--
	Quasi-permanent 2	$L_c /$	150	--
	Cantilever limits			
	Characteristic	$L_c /$	150	--
	Quasi-permanent 1	$L_c /$	125	--
	Quasi-permanent 2	$L_c /$	75	--
	Vibration Design			
	Vibration design	$w_{st,lim}$	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	$L_c /$	300	--
	Quasi-permanent 1	$L_c /$	250	--
	Quasi-permanent 2	$L_c /$	150	--





TIMBER

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	Members	Assigned to			
			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)			
	<input checked="" type="checkbox"/> Top (-z)			
	<input checked="" type="checkbox"/> Left (-y)			
	<input checked="" type="checkbox"/> Right (+y)			
	<input checked="" type="checkbox"/> 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
	<input type="radio"/> Heat-proof adhesion of cross-laminated timber layers			
	<input checked="" type="radio"/> Non-heat-proof adhesion of cross-laminated timber layers			
	Coefficient increasing charring rate of inner layers	$k_{90}$	2.00	--
	<input type="checkbox"/> User-defined coefficient of layer thickness with zero strength			
	Thickness to omit fire reduced layer		3.0	mm
	Fire exposure			
	<input checked="" type="checkbox"/> Top (-z)			
	<input type="checkbox"/> Initial fire protection from top (-z)			
	<input checked="" type="checkbox"/> Bottom (+z)			
	<input type="checkbox"/> Initial fire protection from bottom (+z)			

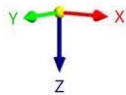
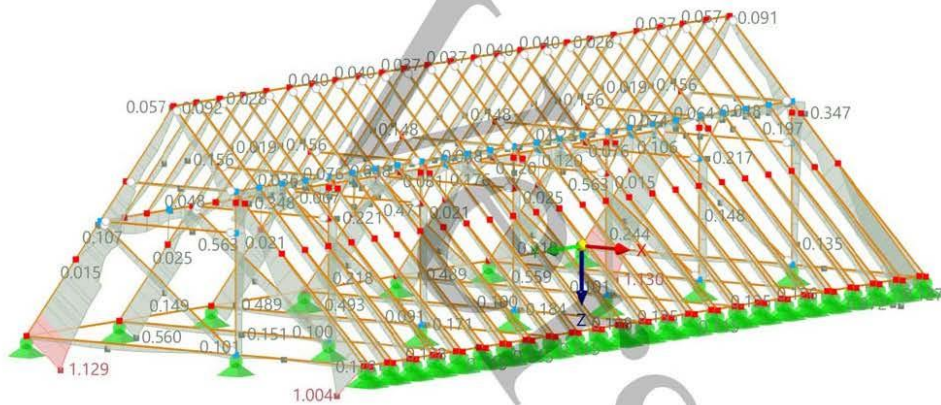


9.8.1 TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, IN AXONOMETRIC DIRECTION

Timber Design

Timber Design  
Members | Design check ratio  $\eta$

In Axonometric Direction



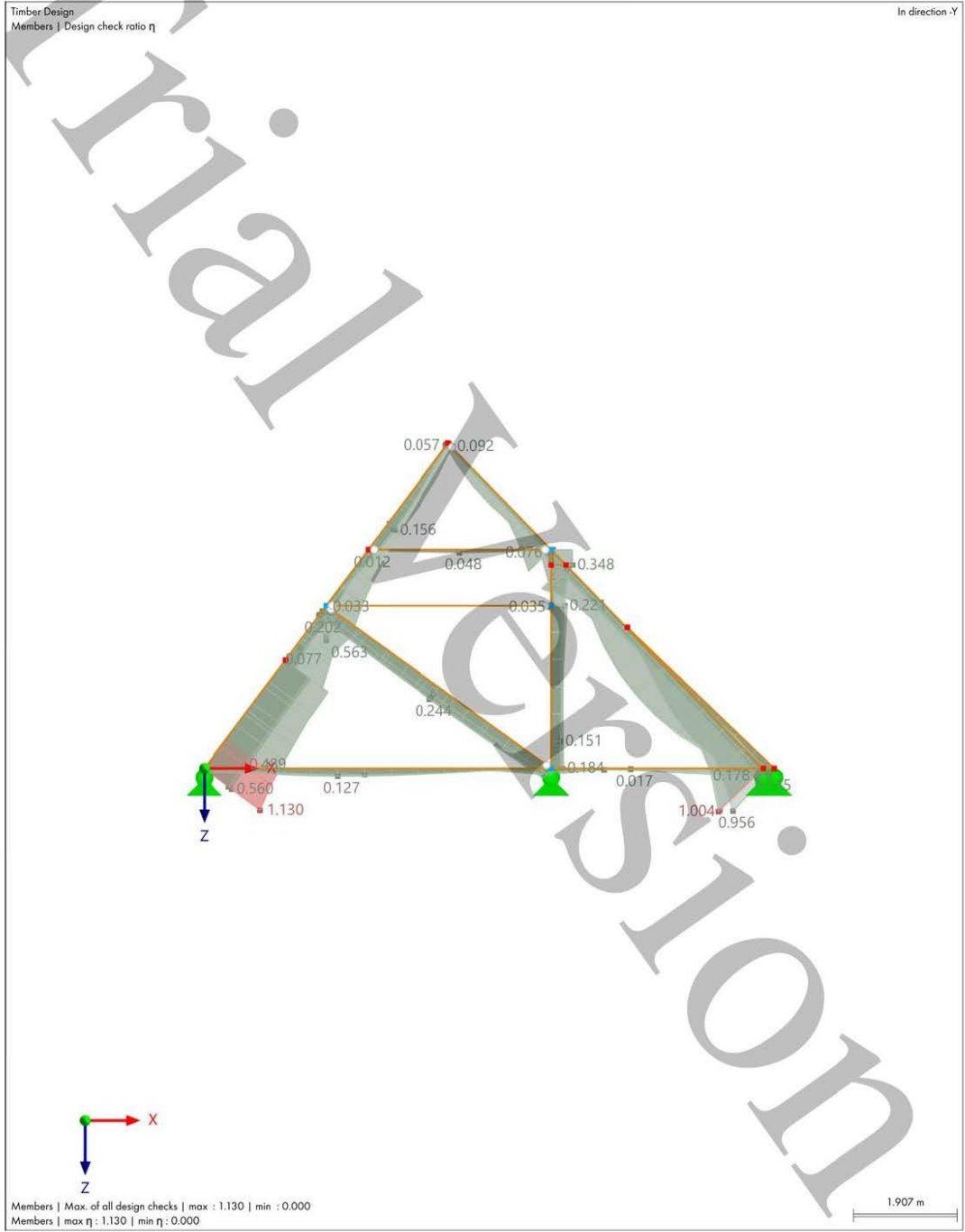
Members | Max. of all design checks | max : 1.130 | min : 0.000  
Members | max  $\eta$  : 1.130 | min  $\eta$  : 0.000



MODEL

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

Timber Design

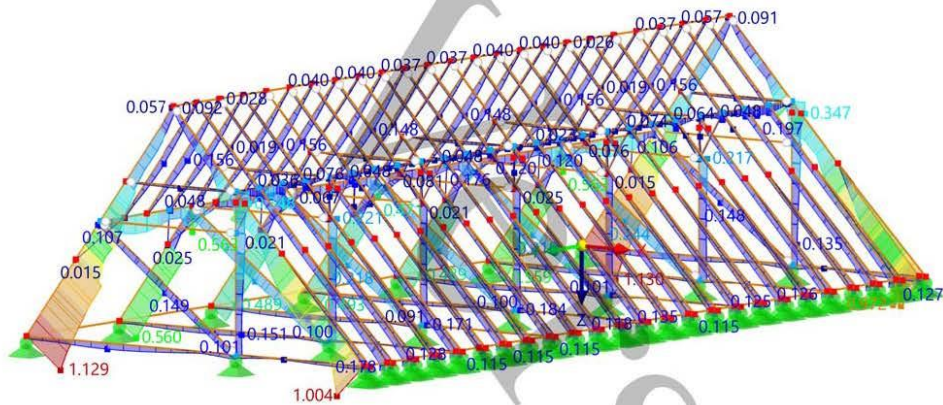


9.8.3 TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, IN AXONOMETRIC DIRECTION

Timber Design

Timber Design  
Members | Design check ratio  $\eta$

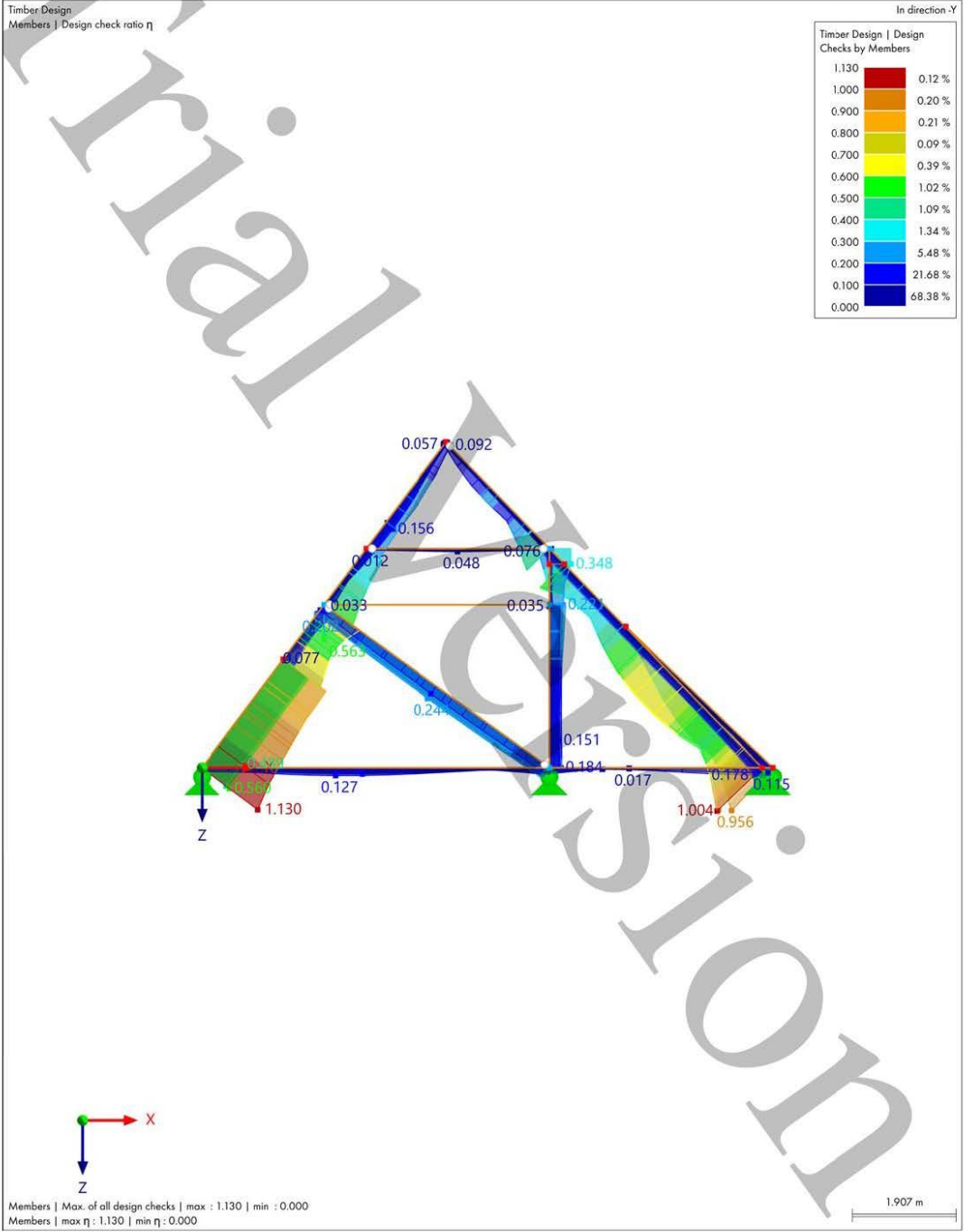
In Axonometric Direction



Members | Max. of all design checks | max : 1.130 | min : 0.000  
Members | max  $\eta$  : 1.130 | min  $\eta$  : 0.000

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

Timber Design



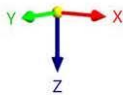
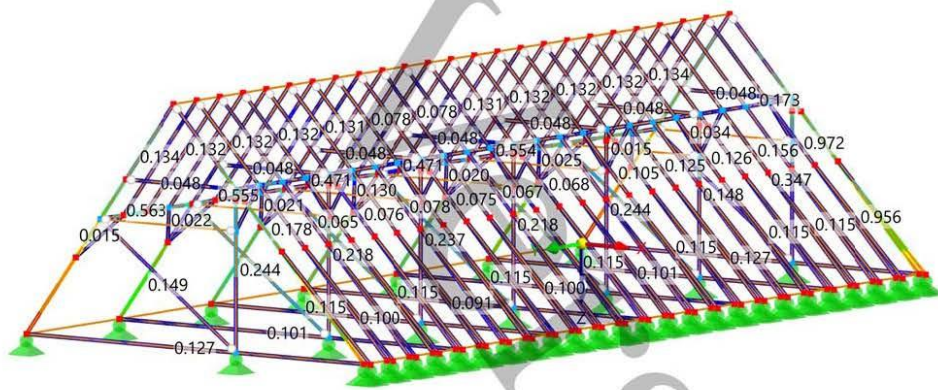


9.8.5 TIMBER DESIGN: MAX. OF ALL DESIGN CHECKS, IN AXONOMETRIC DIRECTION

Timber Design

Timber Design  
Members | Design check ratio  $\eta$

In Axonometric Direction



Members | Max. of all design checks | max : 1.130 | min : 0.000  
Members | max  $\eta$  : 1.130 | min  $\eta$  : 0.000

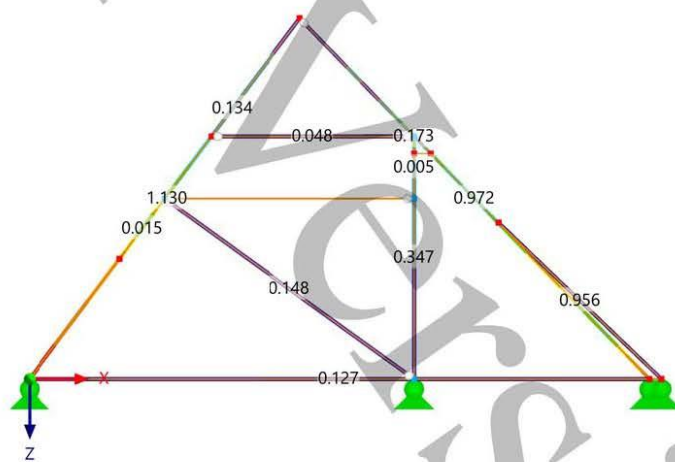
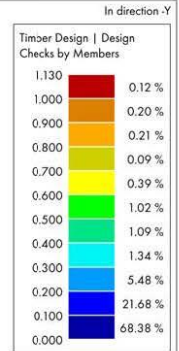


MODEL

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

Timber Design

Timber Design  
Members | Design check ratio  $\eta$



Members | Max. of all design checks | max : 1.130 | min : 0.000  
Members | max  $\eta$  : 1.130 | min  $\eta$  : 0.000

1,907 m



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

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

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

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

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

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

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

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

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

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

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

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

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

Timber Design

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

$$= \frac{1}{5.74 + \sqrt{(5.74)^2 - (3.15)^2}}$$

$$= 0.09$$

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

$$= 1.062$$

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

$$= 1.130$$

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

$$= \max(1.062, 1.130)$$

$$= 1.130$$

$\eta = 1.130 > 1$  ❌

6.3.2, Eq. 6.26

Eq. 6.23

Eq. 6.24

6.3.2

- $f_{c,0,d}$  Design compressive strength
- $k_{mod}$  Modification factor
- $f_{c,0,k}$  Characteristic compressive strength
- $\gamma_M$  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
- $\lambda_y$  Slenderness ratio
- $L_{cr,y}$  Equivalent member length
- $i_y$  Radius of gyration
- $\lambda_z$  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
- $\beta_c$  Straightness factor
- $k_z$  Instability factor
- $k_{c,y}$  Instability factor
- $k_{c,z}$  Instability factor
- $\eta_1$  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
- $\eta_2$  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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{21.000 \text{ N/mm}^2}{1,30}$$

$$= 9.692 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 11.077 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y}$$

$$= \frac{4.034 \text{ m}}{40.4 \text{ mm}}$$

$$= 99.83$$

$$\lambda_z = \frac{L_{cr,z}}{i_z}$$

$$= \frac{4.034 \text{ m}}{40.4 \text{ mm}}$$

$$= 99.83$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}}$$

$$= \frac{99.83}{\pi} \cdot \sqrt{\frac{21.000 \text{ N/mm}^2}{7400.0 \text{ N/mm}^2}}$$

$$= 1.69$$

6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}}$$

$$= \frac{99.83}{\pi} \cdot \sqrt{\frac{21.000 \text{ N/mm}^2}{7400.0 \text{ N/mm}^2}}$$

$$= 1.69$$

6.3.2, Eq. 6.22

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

$$k_y = 0.5 \cdot \left( 1 + \beta_c \cdot (\lambda_{rel,y} - 0.3) + (\lambda_{rel,y})^2 \right)$$

$$= 0.5 \cdot \left( 1 + 0.20 \cdot (1.69 - 0.3) + (1.69)^2 \right)$$

$$= 2.07$$

6.3.2, Eq. 6.27

$$k_z = 0.5 \cdot \left( 1 + \beta_c \cdot (\lambda_{rel,z} - 0.3) + (\lambda_{rel,z})^2 \right)$$

$$= 0.5 \cdot \left( 1 + 0.20 \cdot (1.69 - 0.3) + (1.69)^2 \right)$$

$$= 2.07$$

6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - (\lambda_{rel,y})^2}}$$

$$= \frac{1}{2.07 + \sqrt{(2.07)^2 - (1.69)^2}}$$

$$= 0.31$$

6.3.2, Eq. 6.25

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

$$= \frac{1}{2.07 + \sqrt{(2.07)^2 - (1.69)^2}}$$

$$= 0.31$$

6.3.2, Eq. 6.26



MODEL

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

Timber Design

$$\eta_1 = \frac{\frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}}}{\frac{-0.258 \text{ N/mm}^2}{0.31 \cdot 9.692 \text{ N/mm}^2} + 0.70 \cdot \frac{-0.376 \text{ N/mm}^2}{11.077 \text{ N/mm}^2}}$$

$$= 0.111$$

$$\eta_2 = \frac{\frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}}}{\frac{-0.258 \text{ N/mm}^2}{0.31 \cdot 9.692 \text{ N/mm}^2} + \frac{-0.376 \text{ N/mm}^2}{11.077 \text{ N/mm}^2}}$$

$$= 0.121$$

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

$$= \max(0.111, 0.121)$$

$$= 0.121$$

$$\eta = 0.121 \leq 1$$

Eq. 6.23

Eq. 6.24

6.3.2

- $f_{c,0,d}$  Design compressive strength
- $k_{mod}$  Modification factor
- $f_{c,0,k}$  Characteristic compressive strength
- $\gamma_M$  Partial factor
- $f_{m,z,d}$  Design bending strength
- $f_{m,z,k}$  Characteristic bending strength
- $\lambda_y$  Slenderness ratio
- $l_{cr,y}$  Equivalent member length
- $i_y$  Radius of gyration
- $\lambda_z$  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
- $\beta_c$  Straightness factor
- $k_z$  Instability factor
- $k_{c,y}$  Instability factor
- $k_{c,z}$  Instability factor
- $\eta_1$  Design ratio 1
- $\sigma_{c,0,d}$  Design compressive stress
- $k_m$  Redistribution factor
- $\sigma_{m,z,d}$  Design bending stress
- $\eta_2$  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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{21.000 \text{ N/mm}^2}{1,30}$$

$$= 9.692 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 11.077 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y}$$

$$= \frac{3.748 \text{ m}}{40,4 \text{ mm}}$$

$$= 92,75$$

$$\lambda_z = \frac{L_{cr,z}}{i_z}$$

$$= \frac{3.748 \text{ m}}{40,4 \text{ mm}}$$

$$= 92,75$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}}$$

$$= \frac{92,75}{\pi} \cdot \sqrt{\frac{21.000 \text{ N/mm}^2}{7400,0 \text{ N/mm}^2}}$$

$$= 1,57$$

6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}}$$

$$= \frac{92,75}{\pi} \cdot \sqrt{\frac{21.000 \text{ N/mm}^2}{7400,0 \text{ N/mm}^2}}$$

$$= 1,57$$

6.3.2, Eq. 6.22

$$\lambda_{rel,y} > 0,3 \text{ or } \lambda_{rel,z} > 0,3$$

$$k_y = 0,5 \cdot \left( 1 + \beta_c \cdot (\lambda_{rel,y} - 0,3) + (\lambda_{rel,y})^2 \right)$$

$$= 0,5 \cdot \left( 1 + 0,20 \cdot (1,57 - 0,3) + (1,57)^2 \right)$$

$$= 1,86$$

6.3.2, Eq. 6.27

$$k_z = 0,5 \cdot \left( 1 + \beta_c \cdot (\lambda_{rel,z} - 0,3) + (\lambda_{rel,z})^2 \right)$$

$$= 0,5 \cdot \left( 1 + 0,20 \cdot (1,57 - 0,3) + (1,57)^2 \right)$$

$$= 1,86$$

6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - (\lambda_{rel,y})^2}}$$

$$= \frac{1}{1,86 + \sqrt{(1,86)^2 - (1,57)^2}}$$

$$= 0,35$$

6.3.2, Eq. 6.25

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

$$= \frac{1}{1,86 + \sqrt{(1,86)^2 - (1,57)^2}}$$

$$= 0,35$$

6.3.2, Eq. 6.26

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

Timber Design

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

$$= 0.956$$

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

$$= 0.680$$

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

$$= \max(0.956, 0.680)$$

$$= 0.956$$

$$\eta = 0.956 \leq 1 \quad \checkmark$$

Eq. 6.23

Eq. 6.24

6.3.2

- $f_{c,0,d}$  Design compressive strength
- $k_{mod}$  Modification factor
- $f_{c,0,k}$  Characteristic compressive strength
- $\gamma_M$  Partial factor
- $f_{m,y,d}$  Design bending strength
- $f_{m,y,k}$  Characteristic bending strength
- $\lambda_y$  Slenderness ratio
- $l_{cr,y}$  Equivalent member length
- $i_y$  Radius of gyration
- $\lambda_z$  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
- $\beta_c$  Straightness factor
- $k_z$  Instability factor
- $k_{c,y}$  Instability factor
- $k_{c,z}$  Instability factor
- $\eta_1$  Design ratio 1
- $\sigma_{c,0,d}$  Design compressive stress
- $\sigma_{m,y,d}$  Design bending stress
- $\eta_2$  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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$

$$= 0,90 \cdot \frac{21.000 \text{ N/mm}^2}{1,30}$$

$$= 14.538 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\lambda_y = \frac{L_{cr,y}}{i_y}$$

$$= \frac{5.121 \text{ m}}{40,4 \text{ mm}}$$

$$= 126,71$$

$$\lambda_z = \frac{L_{cr,z}}{i_z}$$

$$= \frac{5.121 \text{ m}}{40,4 \text{ mm}}$$

$$= 126,71$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,y}}}$$

$$= \frac{126,71}{\pi} \cdot \sqrt{\frac{21.000 \text{ N/mm}^2}{7400,0 \text{ N/mm}^2}}$$

$$= 2,15$$

6.3.2, Eq. 6.21

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05,z}}}$$

$$= \frac{126,71}{\pi} \cdot \sqrt{\frac{21.000 \text{ N/mm}^2}{7400,0 \text{ N/mm}^2}}$$

$$= 2,15$$

6.3.2, Eq. 6.22

$$\lambda_{rel,y} > 0,3 \text{ or } \lambda_{rel,z} > 0,3$$

$$k_y = 0,5 \cdot \left( 1 + \beta_c \cdot (\lambda_{rel,y} - 0,3) + (\lambda_{rel,y})^2 \right)$$

$$= 0,5 \cdot \left( 1 + 0,20 \cdot (2,15 - 0,3) + (2,15)^2 \right)$$

$$= 2,99$$

6.3.2, Eq. 6.27

$$k_z = 0,5 \cdot \left( 1 + \beta_c \cdot (\lambda_{rel,z} - 0,3) + (\lambda_{rel,z})^2 \right)$$

$$= 0,5 \cdot \left( 1 + 0,20 \cdot (2,15 - 0,3) + (2,15)^2 \right)$$

$$= 2,99$$

6.3.2, Eq. 6.28

$$k_{c,y} = \frac{1}{k_y + \sqrt{(k_y)^2 - (\lambda_{rel,y})^2}}$$

$$= \frac{1}{2,99 + \sqrt{(2,99)^2 - (2,15)^2}}$$

$$= 0,20$$

6.3.2, Eq. 6.25

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

$$= \frac{1}{2,99 + \sqrt{(2,99)^2 - (2,15)^2}}$$

$$= 0,20$$

6.3.2, Eq. 6.26

$$\eta_1 = \frac{|\sigma_{c,0,d}|}{k_{c,y} \cdot f_{c,0,d}}$$

$$= \frac{|-0,595 \text{ N/mm}^2|}{0,20 \cdot 14.538 \text{ N/mm}^2}$$

$$= 0,208$$

Eq. 6.23



MODEL

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

Timber Design

$$\eta_2 = \frac{|\sigma_{c,0,d}|}{k_{c,z} \cdot f_{c,0,d}}$$

$$= \frac{|-0.595 \text{ N/mm}^2|}{0.20 \cdot 14.538 \text{ N/mm}^2}$$

$$= 0.208$$

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

$$= \max(0.208, 0.208)$$

$$= 0.208$$

$$\eta = 0.208 \leq 1 \quad \checkmark$$

Eq. 6.24

6.3.2

- $f_{c,0,d}$  Design compressive strength
- $k_{mod}$  Modification factor
- $f_{c,0,k}$  Characteristic compressive strength
- $\gamma_M$  Partial factor
- $\lambda_y$  Slenderness ratio
- $L_{cr,y}$  Equivalent member length
- $i_y$  Radius of gyration
- $\lambda_z$  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
- $\beta_c$  Straightness factor
- $k_z$  Instability factor
- $k_{c,y}$  Instability factor
- $k_{c,z}$  Instability factor
- $\eta_1$  Design ratio 1
- $\sigma_{c,0,d}$  Design compressive stress
- $\eta_2$  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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$

$$= 0.80 \cdot \frac{21.000 \text{ N/mm}^2}{1.30}$$

$$= 12.923 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M}$$

$$= 0.80 \cdot \frac{24.000 \text{ N/mm}^2}{1.30}$$

$$= 14.769 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M}$$

$$= 0.80 \cdot \frac{24.000 \text{ N/mm}^2}{1.30}$$

$$= 14.769 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta_1 = \sqrt{\left( \frac{\sigma_{c,0,d}}{f_{c,0,d}} \right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}}}$$

$$= \sqrt{\left( \frac{-0.542 \text{ N/mm}^2}{12.923 \text{ N/mm}^2} \right)^2 + \frac{-6.757 \text{ N/mm}^2}{14.769 \text{ N/mm}^2} + 0.70 \cdot \frac{-0.063 \text{ N/mm}^2}{14.769 \text{ N/mm}^2}}$$

$$= 0.462$$

6.2.4, Eq. 6.19

$$\eta_2 = \sqrt{\left( \frac{\sigma_{c,0,d}}{f_{c,0,d}} \right)^2 + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}}}$$

$$= \sqrt{\left( \frac{-0.542 \text{ N/mm}^2}{12.923 \text{ N/mm}^2} \right)^2 + 0.70 \cdot \frac{-6.757 \text{ N/mm}^2}{14.769 \text{ N/mm}^2} + \frac{-0.063 \text{ N/mm}^2}{14.769 \text{ N/mm}^2}}$$

$$= 0.326$$

6.2.4, Eq. 6.20

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

$$= \max(0.462, 0.326)$$

$$= 0.462$$

6.2.4

$$\eta = 0.462 \leq 1 \quad \checkmark$$

- $f_{c,0,d}$  Design compressive strength
- $k_{mod}$  Modification factor
- $f_{c,0,k}$  Characteristic compressive strength
- $\gamma_M$  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
- $\eta_1$  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
- $\eta_2$  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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{21.000 \text{ N/mm}^2}{1,30}$$

$$= 9.692 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 11.077 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta = \sqrt{\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,z,d}}{f_{m,z,d}}}$$

$$= \sqrt{\left(\frac{-0,258 \text{ N/mm}^2}{9.692 \text{ N/mm}^2}\right)^2 + \frac{-0,376 \text{ N/mm}^2}{11.077 \text{ N/mm}^2}}$$

$$= 0,035$$

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
- $\gamma_M$  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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{21.000 \text{ N/mm}^2}{1,30}$$

$$= 9.692 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 11.077 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta = \left| - \left( \frac{\sigma_{c,0,d}}{f_{c,0,d}} \right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right|$$

$$= \left| - \left( \frac{-0.122 \text{ N/mm}^2}{9.692 \text{ N/mm}^2} \right)^2 + \frac{-10.192 \text{ N/mm}^2}{11.077 \text{ N/mm}^2} \right|$$

$$= 0,920$$

6.2.4, Eq. 6.19

$$\eta = 0,920 \leq 1$$

- $f_{c,0,d}$  Design compressive strength
- $k_{mod}$  Modification factor
- $f_{c,0,k}$  Characteristic compressive strength
- $\gamma_M$  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

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M}$$

$$= 0,90 \cdot \frac{14.500 \text{ N/mm}^2}{1,30}$$

$$= 10.038 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M}$$

$$= 0,90 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 16.615 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M}$$

$$= 0,90 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 16.615 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta_1 = \left| \frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right|$$

$$= \left| \frac{0,083 \text{ N/mm}^2}{10.038 \text{ N/mm}^2} + \frac{4,692 \text{ N/mm}^2}{16.615 \text{ N/mm}^2} + 0,70 \cdot \frac{5,928 \text{ N/mm}^2}{16.615 \text{ N/mm}^2} \right|$$

$$= 0,540$$

6.2.3, Eq. 6.17

$$\eta_2 = \left| \frac{\sigma_{t,0,d}}{f_{t,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right|$$

$$= \left| \frac{0,083 \text{ N/mm}^2}{10.038 \text{ N/mm}^2} + 0,70 \cdot \frac{4,692 \text{ N/mm}^2}{16.615 \text{ N/mm}^2} + \frac{5,928 \text{ N/mm}^2}{16.615 \text{ N/mm}^2} \right|$$

$$= 0,563$$

6.2.3, Eq. 6.18

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

$$= \max(0,540, 0,563)$$

$$= 0,563$$

6.2.3

$$\eta = 0,563 \leq 1 \quad \checkmark$$

- $f_{t,0,d}$  Design tensile strength
- $k_{mod}$  Modification factor
- $f_{t,0,k}$  Characteristic tensile strength
- $\gamma_M$  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
- $\eta_1$  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
- $\eta_2$  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

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{14.500 \text{ N/mm}^2}{1,30}$$

$$= 6.692 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 11.077 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta = \left| \frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right|$$

$$= \left| \frac{0,053 \text{ N/mm}^2}{6.692 \text{ N/mm}^2} + \frac{0,427 \text{ N/mm}^2}{11.077 \text{ N/mm}^2} \right|$$

$$= 0,046$$

6.2.3, Eq. 6.18

$$\eta = 0,046 \leq 1 \quad \checkmark$$

- $f_{t,0,d}$  Design tensile strength
- $k_{mod}$  Modification factor
- $f_{t,0,k}$  Characteristic tensile strength
- $\gamma_M$  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

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M}$$

$$= 0,80 \cdot \frac{14.500 \text{ N/mm}^2}{1,30}$$

$$= 8.923 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M}$$

$$= 0,80 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 14.769 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta = \left| \frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \right|$$

$$= \left| \frac{0.176 \text{ N/mm}^2}{8.923 \text{ N/mm}^2} + \frac{5.529 \text{ N/mm}^2}{14.769 \text{ N/mm}^2} \right|$$

$$= 0.394$$

6.2.3, Eq. 6.17

$$\eta = 0.394 \leq 1$$

- $f_{t,0,d}$  Design tensile strength
- $k_{mod}$  Modification factor
- $f_{t,0,k}$  Characteristic tensile strength
- $\gamma_M$  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

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M}$$

$$= 0.80 \cdot \frac{24.000 \text{ N/mm}^2}{1.30}$$

$$= 14.769 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M}$$

$$= 0.80 \cdot \frac{24.000 \text{ N/mm}^2}{1.30}$$

$$= 14.769 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta_1 = \frac{\sigma_{m,y,d} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}}}{f_{m,y,d} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}}}$$

$$= \frac{1.727 \text{ N/mm}^2 + 0.70 \cdot \frac{1.009 \text{ N/mm}^2}{14.769 \text{ N/mm}^2}}{14.769 \text{ N/mm}^2 + 0.70 \cdot \frac{1.009 \text{ N/mm}^2}{14.769 \text{ N/mm}^2}}$$

$$= 0.165$$

6.1.6, Eq. 6.11

$$\eta_2 = \left| k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \right|$$

$$= \left| 0.70 \cdot \frac{1.727 \text{ N/mm}^2}{14.769 \text{ N/mm}^2} + \frac{1.009 \text{ N/mm}^2}{14.769 \text{ N/mm}^2} \right|$$

$$= 0.150$$

6.1.6, Eq. 6.12

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

$$= \max(0.165, 0.150)$$

$$= 0.165$$

6.1.6

$$\eta = 0.165 \leq 1 \quad \checkmark$$

- $f_{m,y,d}$  Design bending strength
- $k_{mod}$  Modification factor
- $f_{m,y,k}$  Characteristic bending strength
- $\gamma_M$  Partial factor
- $f_{m,z,d}$  Design bending strength
- $f_{m,z,k}$  Characteristic bending strength
- $\eta_1$  Design ratio 1
- $\sigma_{m,y,d}$  Design bending stress
- $k_m$  Redistribution factor
- $\sigma_{m,z,d}$  Design bending stress
- $\eta_2$  Design ratio 2



MODEL

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

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

$$\eta = \frac{|\sigma_{m,z,d}|}{f_{m,z,d}}$$
$$= \frac{|-0.183 \text{ N/mm}^2|}{11.077 \text{ N/mm}^2}$$
$$= 0.017$$

$$\eta = 0.017 \leq 1$$

2.4.1, Eq. 2.14

6.1.6, Eq. 6.12

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





MODEL

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

$$\eta = 0.127 \leq 1$$

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





MODEL

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

$$f_{v,y,d} = k_{mod} \frac{f_{v,y,k}}{\gamma_M}$$

$$= 0,90 \cdot \frac{4.000 \text{ N/mm}^2}{1,30}$$

$$= 2.769 \text{ N/mm}^2$$

$$\tau_{xy,d} = \frac{\tau_{xy}}{k_{cr}}$$

$$= \frac{0,272 \text{ N/mm}^2}{0,67}$$

$$= 0,405 \text{ N/mm}^2$$

$$\eta = \frac{|\tau_{xy,d}|}{f_{v,y,d}}$$

$$= \frac{|0,405 \text{ N/mm}^2|}{2.769 \text{ N/mm}^2}$$

$$= 0,146$$

$$\eta = 0,146 \leq 1$$

2.4.1, Eq. 2.14

6.1.7, Eq. 6.13

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





MODEL

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

$$f_{v,z,d} = k_{mod} \frac{f_{v,z,k}}{\gamma_M}$$

$$= 0,80 \cdot \frac{4.000 \text{ N/mm}^2}{1,30}$$

$$= 2.462 \text{ N/mm}^2$$

$$\tau_{xz,d} = \frac{\tau_{xz}}{k_{cr}}$$

$$= \frac{0,563 \text{ N/mm}^2}{0,67}$$

$$= 0,841 \text{ N/mm}^2$$

$$\eta = \frac{|\tau_{xz,d}|}{f_{v,z,d}}$$

$$= \frac{|0,841 \text{ N/mm}^2|}{2.462 \text{ N/mm}^2}$$

$$= 0,342$$

$$\eta = 0,342 \leq 1 \quad \checkmark$$

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

2.4.1, Eq. 2.14

6.1.7, Eq. 6.13





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

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M}$$

$$= 0,90 \cdot \frac{4.000 \text{ N/mm}^2}{1,30}$$

$$= 2.769 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M}$$

$$= 0,90 \cdot \frac{4.000 \text{ N/mm}^2}{1,30}$$

$$= 2.769 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$\eta = \frac{\tau_{tor,d}}{k_{shape} \cdot f_{v,d}}$$

$$= \frac{0.193 \text{ N/mm}^2}{1,05 \cdot 2.769 \text{ N/mm}^2}$$

$$= 0.066$$

6.1.8, Eq. 6.14

$$\eta = 0.066 \leq 1 \quad \checkmark$$

- $f_{v,z,d}$  Design shear strength
- $k_{mod}$  Modification factor
- $f_{v,z,k}$  Characteristic shear strength
- $\gamma_M$  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





MODEL

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

$$f_{c,0,d} = k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$
$$= 0,80 \cdot \frac{21.000 \text{ N/mm}^2}{1,30}$$
$$= 12.923 \text{ N/mm}^2$$

$$\eta = \frac{|\sigma_{c,0,d}|}{f_{c,0,d}}$$
$$= \frac{|-0,997 \text{ N/mm}^2|}{12.923 \text{ N/mm}^2}$$
$$= 0,077$$

$$\eta = 0,077 \leq 1$$

2.4.1, Eq. 2.14

6.1.4, Eq. 6.2

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





MODEL

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

$$\begin{aligned} f_{t,0,d} &= k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M} \\ &= 0,80 \cdot \frac{14.500 \text{ N/mm}^2}{1,30} \\ &= 8.923 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \eta &= \frac{\sigma_{t,0,d}}{f_{t,0,d}} \\ &= \frac{0,284 \text{ N/mm}^2}{8,923 \text{ N/mm}^2} \\ &= 0,032 \end{aligned}$$

$$\eta = 0,032 \leq 1 \quad \checkmark$$

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

2.4.1, Eq. 2.14

6.1.2(1), Eq. 6.1







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

$$f_{t,0,d} = k_{mod} \cdot \frac{f_{t,0,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{14.500 \text{ N/mm}^2}{1,30}$$

$$= 6.692 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{v,z,d} = k_{mod} \cdot \frac{f_{v,z,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{4.000 \text{ N/mm}^2}{1,30}$$

$$= 1.846 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{v,y,d} = k_{mod} \cdot \frac{f_{v,y,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{4.000 \text{ N/mm}^2}{1,30}$$

$$= 1.846 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,y,d} = k_{mod} \cdot \frac{f_{m,y,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 11.077 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

$$f_{m,z,d} = k_{mod} \cdot \frac{f_{m,z,k}}{\gamma_M}$$

$$= 0,60 \cdot \frac{24.000 \text{ N/mm}^2}{1,30}$$

$$= 11.077 \text{ N/mm}^2$$

2.4.1, Eq. 2.14

Tension:

$$\eta_{\sigma_t} = \frac{\sigma_{t,0,d}}{f_{t,0,d}}$$

$$= \frac{0.000 \text{ N/mm}^2}{6.692 \text{ N/mm}^2}$$

$$= 0.000$$

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

$N_x$  is negligible.

Shear in y-axis:

$$\eta_{\tau_{xy}} = \frac{|\tau_{xy}|}{f_{v,y,d}}$$

$$= \frac{|0.000 \text{ N/mm}^2|}{1.846 \text{ N/mm}^2}$$

$$= 0.000$$

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

$\tau_{xy}$  is negligible.

Shear in z-axis:

$$\eta_{\tau_{xz}} = \frac{|\tau_{xz}|}{f_{v,z,d}}$$

$$= \frac{|0.000 \text{ N/mm}^2|}{1.846 \text{ N/mm}^2}$$

$$= 0.000$$

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



9.27 MEMBER NO. 8 | DS1 | CO1 | 3.748 M | SP0100

Timber Design

$\tau_{xz}$  is negligible.

Torsion:

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

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

$M_t$  is negligible.

Bending about y-axis:

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

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

$M_{Ed,y}$  is negligible.

Bending about z-axis:

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

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

$M_{Ed,z}$  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
- $\gamma_M$  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
- $\alpha_t$  Design component for tension
- $\alpha_{t,0,d}$  Design tensile stress
- $\eta_{\alpha_{t,lim}}$  Limit value of design ratio for tension
- $\eta_{\tau_{xy}}$  Design component for shear
- $\tau_{xy}$  Shear stress
- $\eta_{\tau_{xy,lim}}$  Limit value of design ratio for shear
- $\eta_{\tau_{xz}}$  Design component for shear
- $\tau_{xz}$  Shear stress
- $\eta_{\tau_{xz,lim}}$  Limit value of design ratio for shear
- $\eta_{\tau_{tor}}$  Design component for torsional moment



MODEL

9.27 MEMBER NO. 8 | DS1 | CO1 | 3.748 M | SP0100

Timber Design

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





MODEL

10 Design Overview

10.1 DESIGN OVERVIEW

Design Overview

Addon	Type	Objects		Location [m]	Design Situation	Loading No.	Design Check		Description
		No.					Ratio $\eta$ [-]	Type	
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'





RESULTS

10.1 DESIGN OVERVIEW

Design Overview

Addon	Type	Objects No.	Location [m]	Design Situation	Loading No.	Design Check Ratio $\eta$ [-]	Design Check Type	Description
Timber Design	Member	0-211,219-242 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 0-211,219-242	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 $C_z$ [m <sup>2</sup> ]	Tot. Volume $V_z$ [m <sup>3</sup> ]	Total Mass $M_z$ [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

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