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Capacity design (ductility class DCM) of a CLT building

AUTORE: Mauro Andreolli, engineer

ABSTRACT

This work illlustrates the procedure for the capacity design of a CLT building. It also presents a practical application to a case study: a two-storey structure is designed using the software TimberTech Buildings, of which the calculation report is totally reproduced.

Dissipative structural behaviour

Earthquake-resistant timber buildings should be designed considering either:

- **dissipative structural behaviour;**
- **low-dissipative structural behaviour.**

In the first concept the capability of parts of the structure (dissipative zones) to resist earthquake actions out of their elastic range is taken into account. Dissipative zones shall be located in joints and connections, whereas the timber members themselves shall be regarded as behaving elastically.

In the second concept the action effects are calculated on the basis of an elastic global analysis without taking into account non-linear material behaviour.

Ductility classes and overstrength factor

Depending on their ductile behaviour and energy dissipation capacity under seismic actions, buildings shall be assigned to one of the three following ductility classes:

- **DCH, high capacity to dissipate energy;**
- **DCM, medium capacity to dissipate energy;**
- **DCL, low capacity to dissipate energy.**

In DCH and DCM the European standard (UNI EN 1998-1 §8.1.3) requires the use of the capacity design procedure. The capacity design has the purpose of ensuring a ductile behaviour to the dissipative structure and operates as follows:

- distinguishes elements and mechanisms, both local and global, into ductile and fragile;
- aims to avoid local brittle ruptures and the activation of global brittle or unstable mechanisms;
- aims at locating the energy dissipations by hysteresis in areas of the ductile elements identified and designed for this purpose.

To ensure the correct behaviour of the structure, the seismic resistance of the local/global brittle elements/mechanisms must be designed to be grater than that of the ductile elements/mechanisms. To ensure compliance with this inequality, both locally and globally, the strength of the ductile elements/mechanisms is increased by means of a suitable coefficient γ_{Rd} known as the "overstrength factor"; starting from this increased capacity, the capacity of the brittle elements/mechanisms is sized. This coefficient is defined as equal to 1.3 for the ductility class DCM and 1.6 for the ductility class DCH.

The resistance demand evaluated with the capacity design criteria can be assumed not to exceed the strength demand evaluated for the non-dissipative structural behaviour.

Dissipative zones and non-dissipative zones

For CLT walls, the dissipative zones consist of:

- mechanical connections between walls;
- ductile elements of the traction connection (for example the nailing);
- ductile elements of the shear connection (for example the nailing).

The non-dissipative zones are instead represented by:

- brittle elements of the traction connection (for example the concrete anchors);
- brittle elements of the shear connection (for example the concrete anchors);
- timber elements.

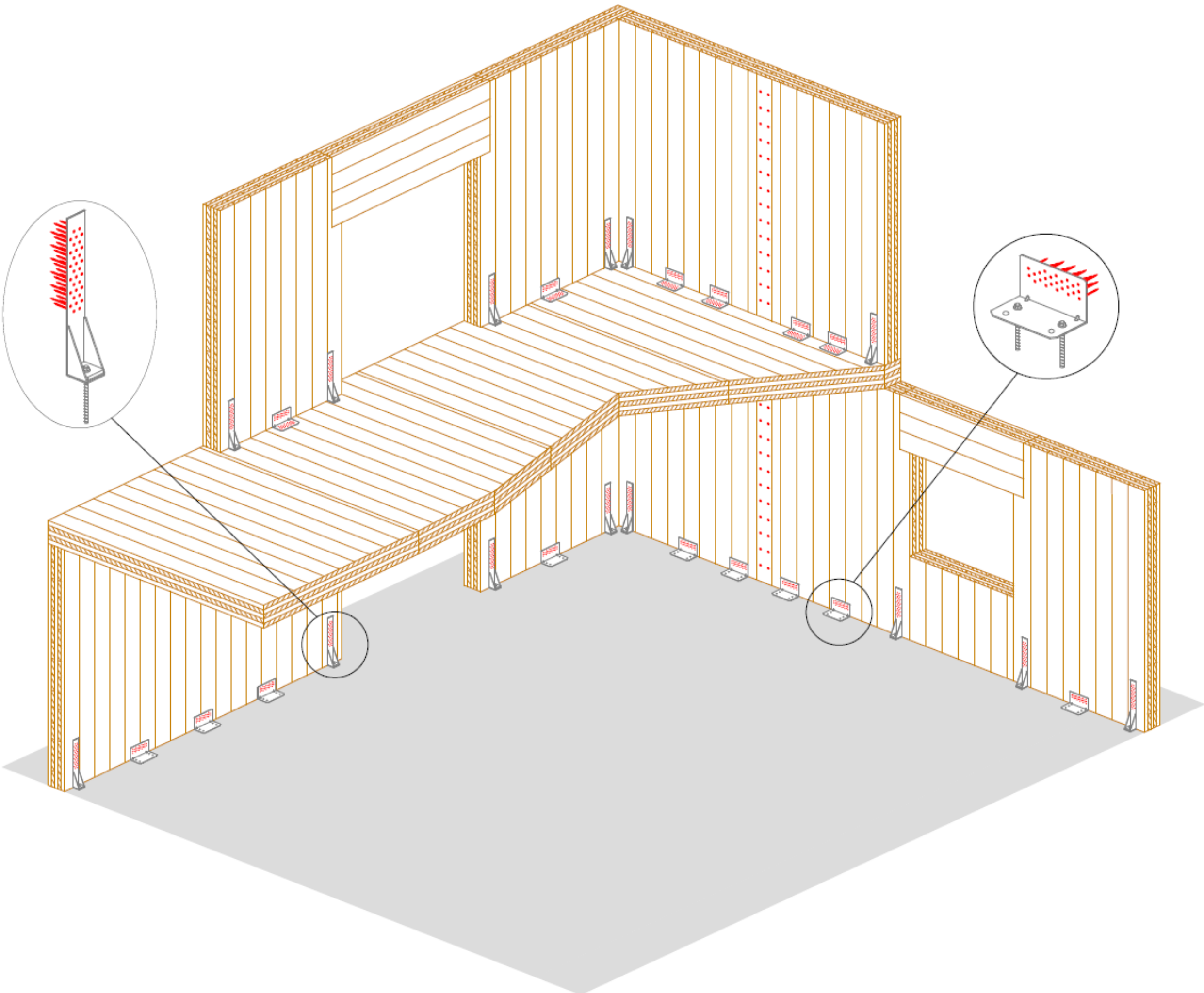

Figure 1 - *CLT building in ductility class DCM: dissipative zones*

Calculation procedure

Applying capacity design locally and globally

Planning according to capacity design procedures is therefore divided into two application "levels":

- **local level, related to the connection of the structure;**
- **global level, related to the walls and the building.**

The first has the purpose of avoiding the prevalence of brittle failure modes in dissipative connections. The second instead provides for the application of a series of rules aimed at avoiding non-dissipative collapse mechanisms and fragile breakages of the elements that make up the structure.

Calculation of design resistances

The design strength of the dissipative zones is defined by the following formula:

$$F_{Rd,ductile} = k_{R,deg} \cdot k_{mod} \cdot \frac{F_{Rk,ductile}}{\gamma_M}$$

where:

$F_{Rd,ductile}$ is the design value of the strength of the dissipative zones;

$k_{R,deg}$ is the strength reduction factor due to cyclic degradation;

k_{mod} is the modification factor for duration of load and moisture content;

$F_{Rk,ductile}$ is the characteristic value of the strength of the dissipative zones;

γ_M is the material partial factor.

The design resistance of the non-dissipative zones is defined by the following formula:

$$F_{Rd,brittle} = k_{mod} \cdot \frac{F_{Rk,brittle}}{\gamma_M}$$

where:

$F_{Rd,brittle}$ is the design value of the strength of the non-dissipative zones;

k_{mod} is the modification factor for duration of load and moisture content;

$F_{Rk,brittle}$ is the characteristic value of the strength of the non-dissipative zones;

γ_M is the material partial factor.

Evaluation of the degradation of strength due to seismic actions

First of all, the strength of materials can be reduced to take into account the degradation due to cyclic deformations.

The designer can therefor proceed by following two paths:

- if precise information is not available regarding the possible degradation of the strength of the materials due to cyclic deformations, it can apply the values of the partial safety coefficients on the materials adopted for the fundamental design situations;

- if, on the other hand, the degradation of strength is appropriately taken into account in the evaluation of the mechanical properties of materials, then it is possible to use the safety coefficients corresponding to accidental load combinations.

So the question is, what is the value of the strength degradation factor due to the effect of cyclic actions, indicated above with $k_{R,deg}$?

With reference to the specific case of timber structures, for ultimate limit state verifications of structures designed in accordance with the concept of dissipative behaviour, it is possible to assume the partial safety factors for the accidental load combinations taking into account the cycle degradation through a maximum 20% reduction of the resistance, which means that the coefficient $k_{R,deg}$ is equal to 0,8.

Checks

Check dissipative zones

The dissipative zones against the seismic actions calculated with the dissipative behavior factor need to be verified according to the following expression:

$$F_{Ed,ductile} \leq F_{Rd,ductile} = k_{R,deg} \cdot k_{mod} \cdot \frac{F_{Rk,ductile}}{\gamma_M}$$

where:

$F_{Ed,ductile}$ is the design value of the effect of actions of the dissipative zones;

$F_{Rd,ductile}$ is the design value of the strength of the dissipative zones;

$F_{Rk,ductile}$ is the characteristic value of the strength of the dissipative zones;

$k_{R,deg}$ is the strength reduction factor due to cyclic degradation;

k_{mod} is the modification factor for duration of load and moisture content;

γ_M is the material partial factor.

Check non-dissipative zones – Local level

In order to ensure compliance with the rules of capacity design at the local level (connection), it must be verified that the resistances associated with the brittle failure modes are over-resistant compared to the resistance associated with the ductile failure mode:

$$F_{Rd,brittle} \geq \frac{\gamma_{Rd}}{k_{R,deg}} \cdot F_{Rd,ductile}$$

where:

γ_{Rd} is the overstrength factor;

$k_{R,deg}$ is the resistance degradation coefficient due to cyclic actions;

$F_{Rd,ductile}$ is the design value of the strength of the dissipative zones;

$F_{Rd,brittle}$ is the design value of the strength of the non-dissipative zones.

Check non-dissipative zones – Global level

The non-dissipative zones need to be checked towards the actions deriving from the application of the capacity design rules. The design effect of the actions is obtained through the following relationship:

$$F_{Ed,brittle} = \Omega \cdot F_{Ed,brittle,E} + F_{Ed,brittle,G}$$

where:

$F_{Ed,brittle}$ is the design action effect in the non-dissipative connection or member;

Ω is the structure overstrength ratio (in both x and y directions);

$F_{Ed,brittle,E}$ is the action effect in the non-dissipative connection or member of the design seismic action;

$F_{Ed,brittle,G}$ is the action effect in the non-dissipative connection or member of the non-seismic actions in the design seismic situation.

The overstrength ratio for each floor of the building and for each direction is determined by the following expression:

$$\Omega_{i,j} = min\left\{\frac{\sum_{k=1}^{N_{i,j}} V_{Rd,i,j,k}^{CLT,CD}}{\sum_{k=1}^{N_{i,j}}\left|V_{Ed,i,j,k}\right|};\frac{\sum_{k=1}^{N_{i,j}} V_{Rd,i,j,k}^{ang,CD}}{\sum_{k=1}^{N_{i,j}}\left|V_{Ed,i,j,k}\right|};\frac{\sum_{k=1}^{N_{i,j}} M_{Rd,i,j,k}^{hd,CD}}{\sum_{k=1}^{N_{i,j}}\left|M_{Ed,i,j,k}\right|}\right\}$$

where:

$\sum_{k=1}^{N_{i,j}} V_{Rd,i,j,k}^{CLT,CD}$ is the sum of the design resistances related to the vertical mechanical connection between CLT walls of the j-th shear wall at the i-th storey, taking into account the overstrength factor through the ratio $\gamma_{Rd}/k_{R,deg}$;

$\sum_{k=1}^{N_{i,j}} V_{Rd,i,j,k}^{ang,CD}$ is the sum of the design lateral strength related to shear connections of the j-th shear wall at the i-th storey, taking into account the overstrength factor through the ratio $\gamma_{Rd}/k_{R,deg}$;

$\sum_{k=1}^{N_{i,j}} M_{Rd,i,j,k}^{hd,CD}$ is the sum of the design rocking strength of the j-th shear wall at the i-th storey, taking into account the overstrength factor through the ratio $\gamma_{Rd}/k_{R,deg}$;

$\sum_{k=1}^{N_{i,j}}\left|V_{Ed,i,j,k}\right|$ is the sum of the absolute values of the design global shear of the j-th shear wall at the i-th storey due to the seismic action;

$\sum_{k=1}^{N_{i,j}}\left|M_{Ed,i,j,k}\right|$ is the sum of the absolute values of the design rocking moment of the jth shear wall at the i-th storey due to the seismic action;

$N_{i,j}$ is the number of shear-walls parallel to the seismic action at the i-th storey.

Case study

The analyzed building, used for residential purpose, has two floors above ground with a maximum height at the ridge of 7.45 m and a rectangular plan measuring 10 x 11 m. It is a structure that has an almost symmetrical distribution of the walls in plan and it is regular both in plan and in height.

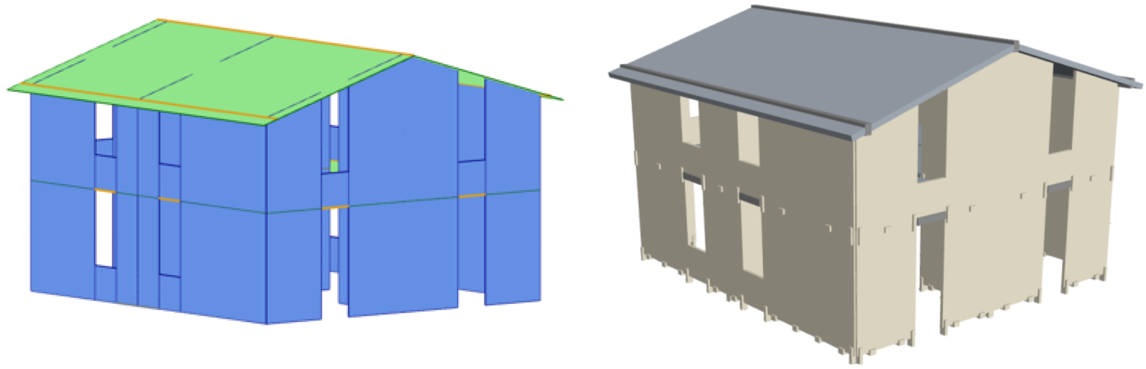

Figure 2 – *TimberTech Buildings model for the case study*

Attached is the complete calculation report generated using the TimberTech Buildings software, where all the verifications of the structure are present, including the application of capacity design.

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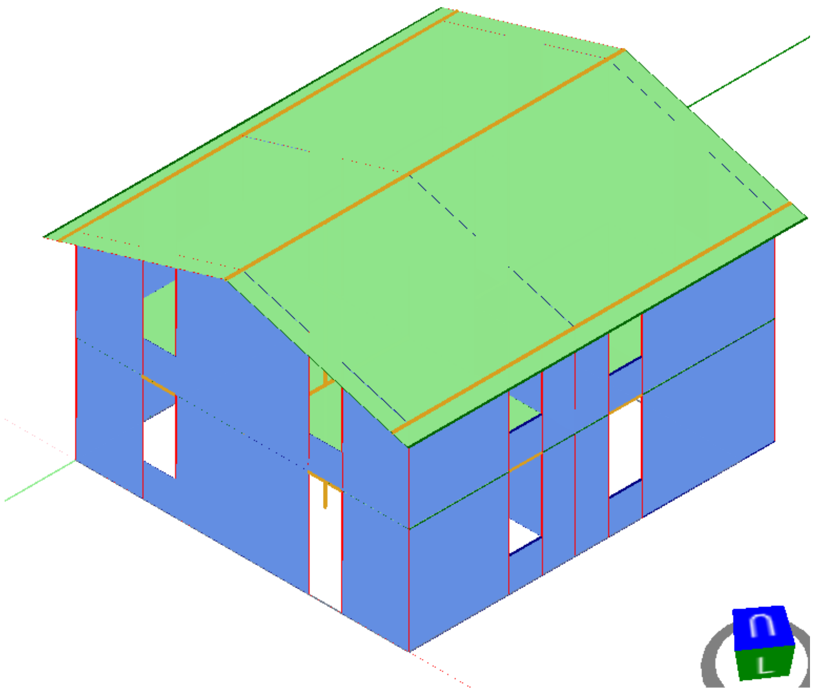
TECHNICAL DESIGN CALCULATION REPORT

Design of Timber Structures



Project: Capacity design (ductility class DCM) of a CLT building

Structural designer:

Ing. Mauro Andreolli

Date: Friday, April 7, 2023

Design codes and standards

The analysis are done according to: Eurocodes.

1. **EN 1990 – Eurocode 0**

   Basis of structural design

2. **EN 1993-1-1 – Eurocode 3**

   Design of steel structures - Part 1-1: General rules and rules for buildings

3. **EN 1993-1-5 – Eurocode 3**

   Design of steel structures - Part 1-5: Plated structural elements

4. **EN 1993-1-8 – Eurocode 3**

   Design of steel structures - Part 1-8: Design of joints

5. **EN 1995-1-1 – Eurocode 5**

   Design of timber structures - Part 1-1: General - Common rules and rules for buildings

6. **EN 1995-1-2 – Eurocode 5**

   Design of timber structures - Part 1-2: General – Structural fire design

7. **EN 1998-1-1 – Eurocode 8**

   Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings

8. **EN 338**

   Structural timber - Strength classes

9. **EN 14080**

   Timber structures - Glued laminated timber and glued solid timber - Requirements

10. **EN 10025**

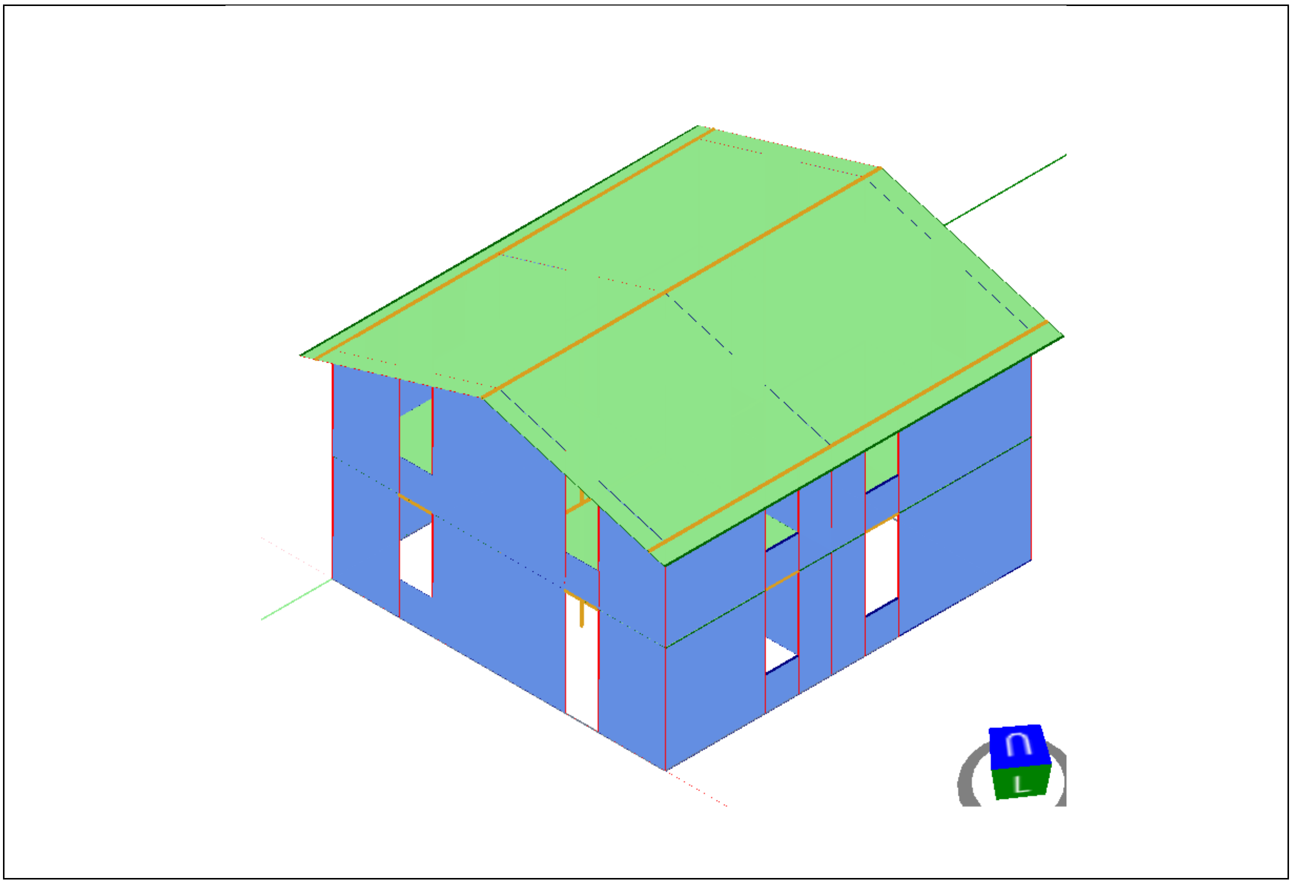
    Hot rolled products of structural steels

General description of the building

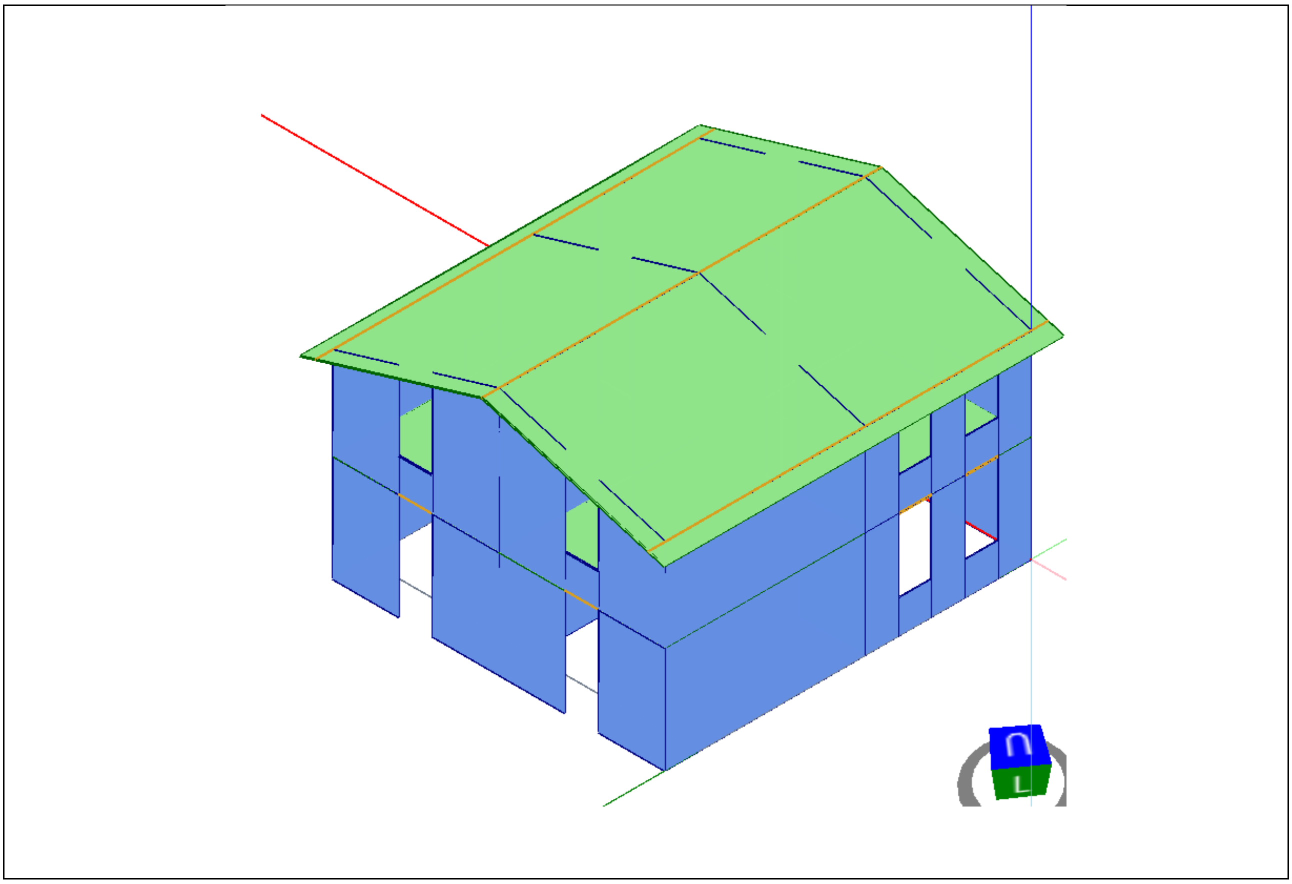
Description

Building length:	12 m
Building width:	10.96 m
Building height:	7.45 m

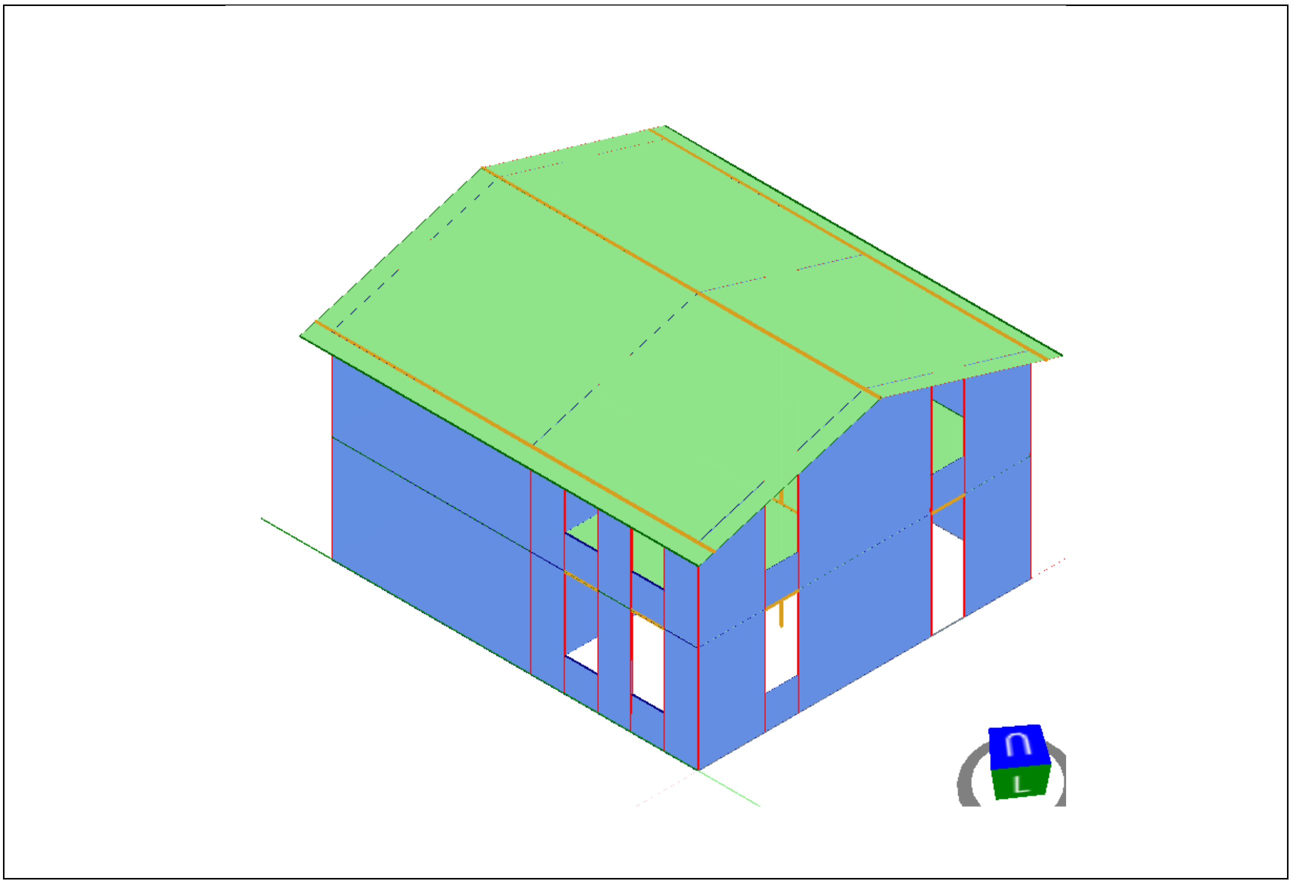
Three-dimensional view Southeast



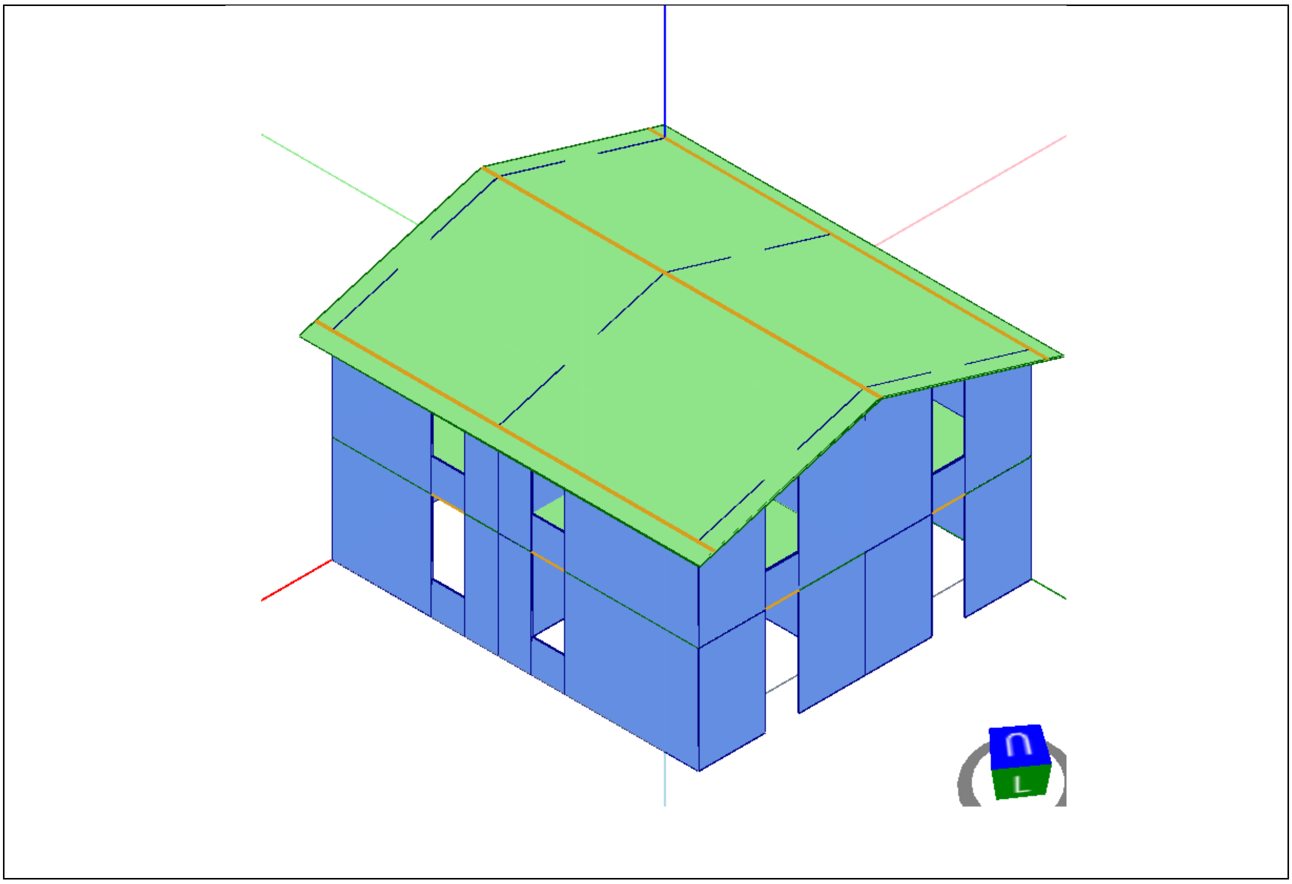
Three-dimensional view Northwest



Three-dimensional view Southwest



Three-dimensional view Northeast



Calculation software used

Calculation software features

The software used is *Timber Tech Buildings*, developed by Timber Tech srl, start up of the University of Trento (Italy).

Technical specifications

Name: Timber Tech Buildings

Version: 97

Software Producer: Timber Tech srl

Via della Villa, 22/A

I-38123 – Villazzano – Trento (TN) – Italy

www.timbertech.it

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Materials

Wooden materials

The materials used in the project are listed in the following tables.

Descr.	Description
$f_{m,k}$	Characteristic bending strength
$f_{t,0,k}$	Characteristic tensile strength along the grain
$f_{t,90,k}$	Characteristic tensile strength perpendicular to the grain
$f_{c,0,k}$	Characteristic compressive strength along the grain
$f_{c,90,k}$	Characteristic compressive strength perpendicular to the grain
$f_{v,k}$	Characteristic shear strength
$E_{0,mean}$	Mean value of modulus of elasticity along the grain
$E_{0,05}$	Fifth percentile value of modulus of elasticity along the grain
$E_{90,mean}$	Mean value of modulus of elasticity perpendicular to the grain
G_{mean}	Mean value of shear modulus
ρ_k	Characteristic density
$f_{v,k,inplane}$	Characteristic in-plane shear strength of CLT panel
$f_{R,k}$	Characteristic rolling shear strength
$f_{T,k}$	Torsional resistance of crossing surfaces
$G_{R,mean}$	Mean value of rolling shear modulus

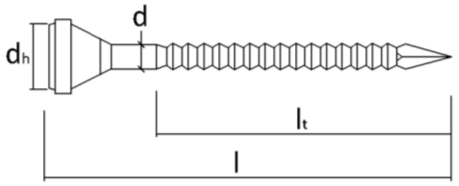
Homogeneous glued-laminated timber

Descr.	$f_{m,k}$ [MPa]	$f_{t,0,k}$ [MPa]	$f_{t,90,k}$ [MPa]	$f_{c,0,k}$ [MPa]	$f_{c,90,k}$ [MPa]	$f_{v,k}$ [MPa]	$E_{0,mean}$ [MPa]	$E_{0,05}$ [MPa]	$E_{90,mean}$ [MPa]	G_{mean} [MPa]	ρ_k [kg/m^3]
GL 24h - EN 14080	24	19.2	0.5	24	2.5	3.5	11500	9600	300	650	385

CLT

Descr	$f_{m,k}$ [MPa]	$f_{t,0,k}$ [MPa]	$f_{t,90,k}$ [MPa]	$f_{c,0,k}$ [MPa]	$f_{c,90,k}$ [MPa]	$f_{v,k,piast}$ [MPa]	$f_{R,k}$ [MPa]	$f_{v,k,lastr}$ [MPa]	$f_{T,k}$ [MPa]	$E_{0,mean}$ [MPa]	$E_{0,05}$ [MPa]	$E_{90,mean}$ [MPa]	G_{mean} [MPa]	$G_{R,mean}$ [MPa]	ρ_k [kg/m^3]
C 24 XLAM	24	14.5	0.4	21	2.5	4	0.8	4	2.5	11000	7400	370	690	50	350

Anker nails



Manufacturer	Code	Descr.	l [mm]	l_t [mm]	d [mm]	d_h [mm]
Rotho Blaas	PF601460	Anker nail - LBA 4,0 X 60	60	50	4	8

Concrete anchors

Manufacturer	Threaded-rod / Mechanical anchor code	Threaded-rod / Mechanical anchor descr.	Chemical anchor code	Chemical anchor descr.
Rotho Blaas	INA5816195	Threaded rod INA - 5.8 - M16 x 195	HYB420	Hybrid chemical anchor ETA-20/1285
Rotho Blaas	FE210115	Threaded rod INA - 5.8 - M12 x 130	FE400055	Vinylester chemical anchor ETA-09/0078

Calculation method and numerical model

Model Description

Hypothesis adopted for the elements

The timber walls are constrained at the base by means of connection systems capable of transmitting both in-plane and out-of-plane actions action on the wall.

In the analysis, in presence of horizontal loads, some elements may be defined as “secondary”: this mean that their strength and stiffness are neglected in the calculation of the response of the building. In the model these elements are represented in terms of mass and they are designed only for vertical loads.

Rigid body rocking – Forces on hold-down / tie-down

The hold-down or tie-down systems are used to prevent the rotation of the wall caused by the overturning moment of the horizontal force. The hold-down, placed on the in-tension edge of the wall, is loaded by a force equal to

$$T = \begin{cases} \left(\dfrac{M_{3-3}}{b} - \dfrac{N}{2}\right) \cdot \dfrac{1}{n_{anc}} & for\ active\ hold-down \\ 0 & for\ inactive\ hold-down \end{cases}$$

where:

b is the lever arm for the internal couple;

N is the axial vertical load acting on the wall;

M_{3-3} is the moment acting in the plane of the wall;

n_{anc} is the number of connections present at each end of the wall.

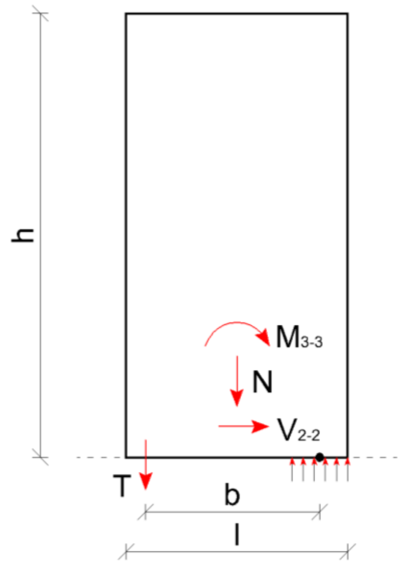


Figure: Calculation model of tensile force acting on the hold-down

Structural elements

The following table shows the positions of the individual walls. The last four columns show the coordinates of the ends of each wall.

X1 and Y1 indicate the coordinates of the starting point of the wall

X2 and Y2 indicate the coordinates of the end point of the wall

Wall name	Type of wall	Element resistant to horizontal loads	Height [m]	Length [m]	Altitude [m]	X1 [m]	Y1 [m]	X2 [m]	Y2 [m]
Parete 109	CLT	No	1.0	1	0	0	3	0	4
Parete 110	CLT	No	1.0	1	0	0	1	0	2
Parete 29	CLT	No	1.0	1	3.2	0	1	0	2
Parete 30	CLT	No	1.0	1	3.2	0	3	0	4
Parete 34	CLT	No	1.0	1	3.2	10	3	10	4
Parete 35	CLT	No	1.0	1	3.2	10	6	10	7
Parete 72	CLT	No	1.0	1	3.2	2	0	3	0
Parete 78	CLT	No	1.0	1	0	2	0	3	0
Parete 81	CLT	No	1.0	1	3.2	7	0	8	0
Parete 88	CLT	No	1.0	1	0	10	3	10	4
Parete 89	CLT	No	1.0	1	0	10	6	10	7
Parete 95	CLT	No	1.0	1	3.2	8	11	7	11
Parete 96	CLT	No	1.0	1	3.2	3	11	2	11
PX0-1	CLT	Yes	3.2	2	0	0	0	2	0
PX0-2	CLT	Yes	3.2	4	0	3	0	7	0
PX0-3	CLT	Yes	3.2	2	0	8	0	10	0
PX0-4	CLT	Yes	3.2	2	0	0	5	2	5
PX0-5	CLT	Yes	3.2	4	0	7	5	3	5
PX0-6	CLT	Yes	3.2	2	0	10	5	8	5
PX0-7	CLT	Yes	3.2	2	0	2	11	0	11
PX0-8	CLT	Yes	3.2	4	0	7	11	3	11
PX0-9	CLT	Yes	3.2	2	0	10	11	8	11
PX1-1	CLT	Yes	3.05	2	3.2	0	0	2	0
PX1-2	CLT	Yes	3.95	4	3.2	3	0	7	0
PX1-3	CLT	Yes	3.05	2	3.2	8	0	10	0
PX1-4	CLT	Yes	3.05	2	3.2	0	5	2	5
PX1-5	CLT	Yes	3.95	4	3.2	7	5	3	5
PX1-6	CLT	Yes	3.05	2	3.2	10	5	8	5
PX1-7	CLT	Yes	3.05	2	3.2	2	11	0	11
PX1-8	CLT	Yes	3.95	4	3.2	3	11	7	11
PX1-9	CLT	Yes	3.05	2	3.2	10	11	8	11
PY0-1	CLT	Yes	3.2	1	0	0	1	0	0
PY0-2	CLT	Yes	3.2	1	0	0	3	0	2
PY0-3	CLT	Yes	3.2	7	0	0	11	0	4
PY0-4	CLT	Yes	3.2	2	0	5	7	5	5
PY0-5	CLT	Yes	3.2	3	0	5	11	5	8
PY0-6	CLT	Yes	3.2	3	0	10	0	10	3
PY0-7	CLT	Yes	3.2	2	0	10	4	10	6
PY0-8	CLT	Yes	3.2	4	0	10	7	10	11
PY1-1	CLT	Yes	2.75	1	3.2	0	0	0	1
PY1-2	CLT	Yes	2.75	1	3.2	0	2	0	3
PY1-3	CLT	Yes	2.75	7	3.2	0	4	0	11
PY1-4	CLT	Yes	4.25	2	3.2	5	7	5	5
PY1-5	CLT	Yes	4.25	3	3.2	5	11	5	8
PY1-6	CLT	Yes	2.75	3	3.2	10	0	10	3
PY1-7	CLT	Yes	2.75	2	3.2	10	6	10	4
PY1-8	CLT	Yes	2.75	4	3.2	10	7	10	11

The following table shows the positions of the individual columns.

X and Y are the coordinates of the point where the column is located.

Column name	Height [m]	Altitude [m]	X [m]	Y [m]
Pilastro 12	3.2	0	5	2.5
Pilastro 5	4.25	3.2	5	2.5

Wall horizontal stiffness

The wall stiffness can be estimated considering the contributions of all the components, as shown below.

CLT walls

The overall stiffness of CLT walls is calculated taking into account the contribution of the following components:

- CLT panel (k_{XLAM})
- shear connections – angle brackets (k_a)
- hold-down or tie-down (k_h)

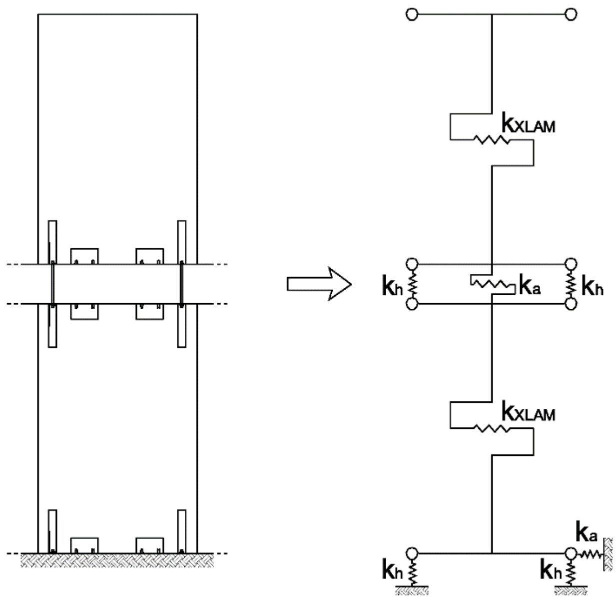


Figure: Mechanical model for CLT walls overall stiffness

The following table indicates the positions of the walls and their equivalent shear stiffness.

Wall name	Type of wall	Element resistant to horizontal loads	Heigth [m]	Length [m]	Equivalent shear stiffness [kN/m]
Parete 109	CLT	No	1.0	1	0
Parete 110	CLT	No	1.0	1	0
Parete 29	CLT	No	1.0	1	0
Parete 30	CLT	No	1.0	1	0
Parete 34	CLT	No	1.0	1	0
Parete 35	CLT	No	1.0	1	0
Parete 72	CLT	No	1.0	1	0
Parete 78	CLT	No	1.0	1	0
Parete 81	CLT	No	1.0	1	0
Parete 88	CLT	No	1.0	1	0
Parete 89	CLT	No	1.0	1	0
Parete 95	CLT	No	1.0	1	0
Parete 96	CLT	No	1.0	1	0
PX0-1	CLT	Yes	3.2	2	7148
PX0-2	CLT	Yes	3.2	4	22673
PX0-3	CLT	Yes	3.2	2	7148
PX0-4	CLT	Yes	3.2	2	7148
PX0-5	CLT	Yes	3.2	4	22673
PX0-6	CLT	Yes	3.2	2	7148
PX0-7	CLT	Yes	3.2	2	7148
PX0-8	CLT	Yes	3.2	4	22673
PX0-9	CLT	Yes	3.2	2	7148
PX1-1	CLT	Yes	3.05	2	3566
PX1-2	CLT	Yes	3.95	4	7935
PX1-3	CLT	Yes	3.05	2	3566
PX1-4	CLT	Yes	3.05	2	3566
PX1-5	CLT	Yes	3.95	4	7935

PX1-6	CLT	Yes	3.05	2	3566
PX1-7	CLT	Yes	3.05	2	3566
PX1-8	CLT	Yes	3.95	4	7935
PX1-9	CLT	Yes	3.05	2	3566
PY0-1	CLT	Yes	3.2	1	2055
PY0-2	CLT	Yes	3.2	1	2055
PY0-3	CLT	Yes	3.2	7	52986
PY0-4	CLT	Yes	3.2	2	7148
PY0-5	CLT	Yes	3.2	3	14226
PY0-6	CLT	Yes	3.2	3	14226
PY0-7	CLT	Yes	3.2	2	7148
PY0-8	CLT	Yes	3.2	4	22673
PY1-1	CLT	Yes	2.75	1	1246
PY1-2	CLT	Yes	2.75	1	1246
PY1-3	CLT	Yes	2.75	7	31204
PY1-4	CLT	Yes	4.25	2	1999
PY1-5	CLT	Yes	4.25	3	4031
PY1-6	CLT	Yes	2.75	3	7820
PY1-7	CLT	Yes	2.75	2	4233
PY1-8	CLT	Yes	2.75	4	13731

Types of structural elements and sign conventions

Linear elements

The linear elements are used to model beams and columns. They have a local reference system with respect to which stress/force components are shown. The sign convention adopted is shown in the figure below.

Force	Description	Unit of measure
N	Axial force	kN
M_{3-3}	Bending moment about local axis 3	kN m
V_2	Shear along local axis 2	kN
M_{2-2}	Bending moment about local axis 2	kN m
V_3	Shear along local axis 3	kN

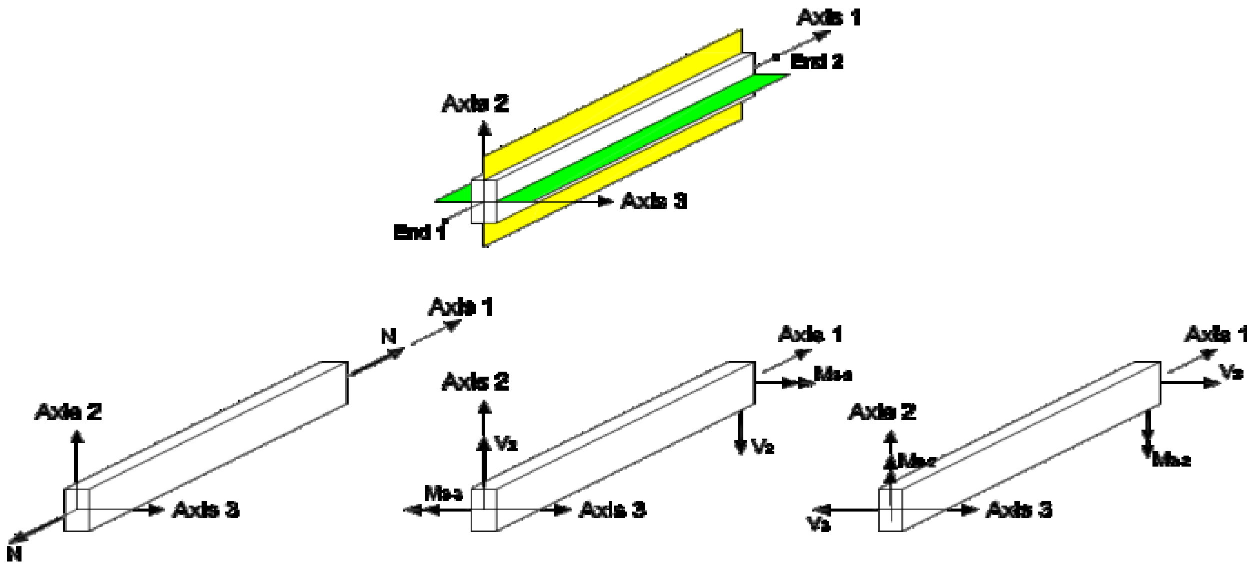


Figure: sign conventions for beams

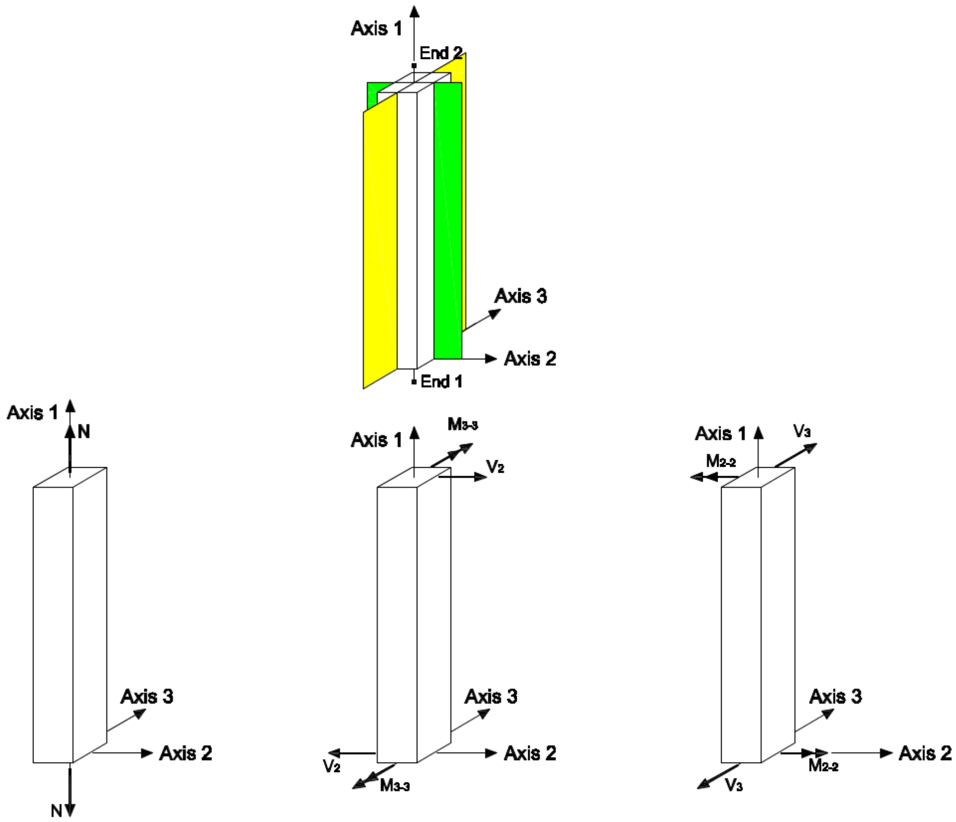


Figure: sign conventions for columns

Wall elements

The walls, regardless of type, have the following sign conventions.

	Actions per unit length	Description	Unit of measure
In-plane actions	**n**	Axial stress (per unit length)	kN/m
	$m_{3\text{-}3}$	Bending moment about local axis 3 (per unit length)	kNm/m
	v_2	Shear along local axis 2 (per unit length)	kN/m
Out-of-plane actions (plate)	**$m_{2\text{-}2}$**	Bending moment about local axis 2 (per unit length)	kNm/m
	v_3	Shear along local axis 3 (per unit length)	kN/m

	Actions	Description	Unit of measure
In-plane actions	**N**	Total axial force	kN
	$M_{3\text{-}3}$	Bending moment about local axis 3	kNm
	V_2	Shear along local axis 2	kN
Out-of-plane actions (plate)	**$M_{2\text{-}2}$**	Bending moment about local axis 3	kNm
	V_3	Shear along local axis 2	kN

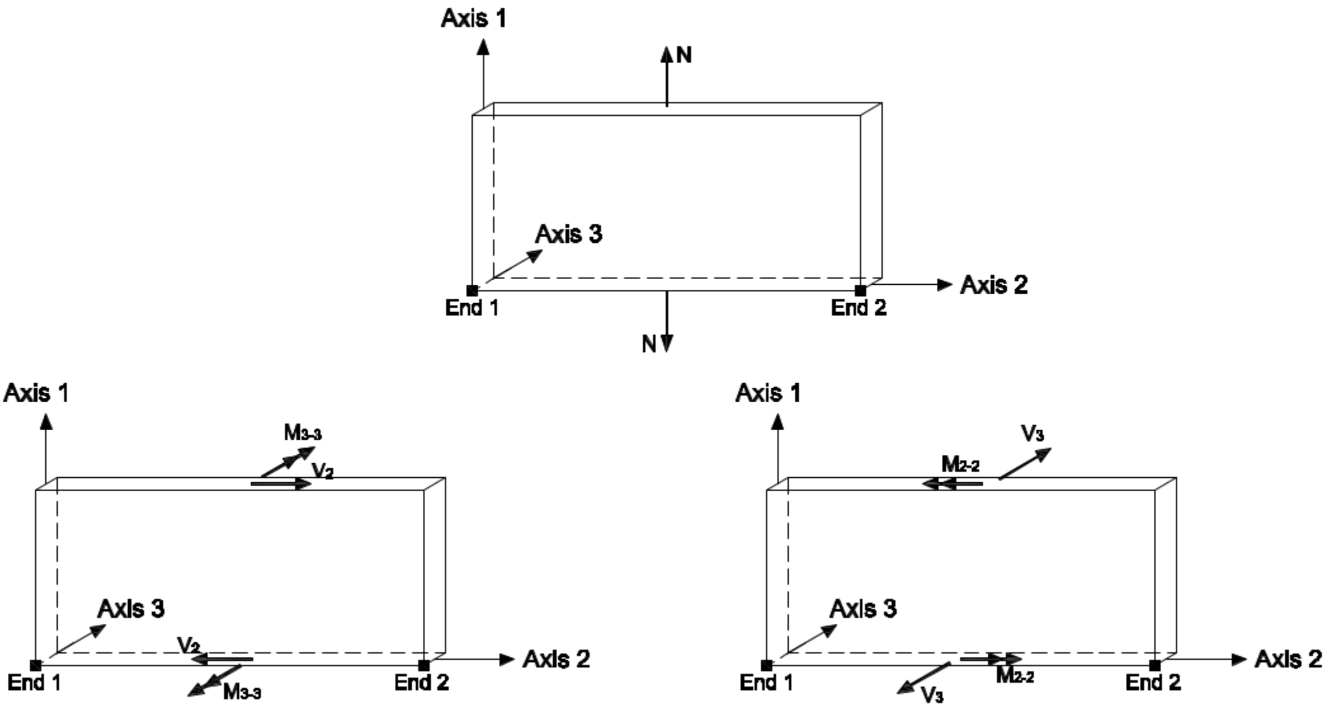


Figure: sign conventions for walls

Actions and design loads

Self-weight of structural materials

The weights of the structural materials are shown in the table below in kN/m^3

Description	Specific weight ɣ [kN/m^3]
GL 24h - EN 14080	5
C 24 XLAM	5

Wind action

The wind action is evaluated in accordance with the European standard EN 1-1-4. The wind action is represented by a simplified set of forces whose effects is equivalent to the extreme effects of the turbulent wind.

Project data

Terrain category: Terrain category 0

Basic wind velocity: 27 m/s

Mean wind

The mean wind velocity $v_m(z)$ at a height z above the terrain depends on the terrain roughness and orography and on the basic wind velocity according to the following expression:

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

where:

$c_r(z)$ is the roughness factor that depends on the terrain category and on the height z above the terrain of the relevant point;

$c_o(z)$ is the orography factor taken as 1;

v_b is the basic wind velocity.

According to section 4.3.2 of EN 1991-1-4, the roughness factor can be determined as follows:

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad for \quad z_{min} \le z \le z_{max}$$
$$c_r(z) = c_r(z_{min}) \quad for \quad z \le z_{min}$$

where:

z_0 and z_{min} are defined according to the terrain category:

	Terrain category	z_0	z_{min}
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15% of the surface is covered with buildings and their average height exceeds 15 m	1,0	10

k_r is the terrain factor calculated using:

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07}$$

with: $z_{0,II} = 0{,}05\ m$

Wind turbulence

The turbulence intensity $I_v(z)$ at a height z is defined as the standard deviation of the turbulence divided by the mean wind velocity and it can be determined as:

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{1}{c_o(z) \cdot \ln\left(\frac{z}{z_0}\right)} \quad for \quad z_{min} \le z \le z_{max}$$

$$I_v(z) = I_v(z_{min}) \qquad for \qquad z \le z_{min}$$

Peak velocity pressure

The peak velocity pressure $q_p(z)$ at a height z can be determined as:

$$q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \frac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b$$

where:

$I_v(z)$ is the turbulence intensity;

ρ is the air density taken as 1.25 kg/m^3;

$v_m(z)$ is the mean wind velocity;

$c_e(z)$ is the exposure factor defined as $c_e(z) = \frac{q_p(z)}{q_b}$;

q_b is the basic wind pressure defined as $q_b = \frac{1}{2} \cdot \rho \cdot v_b^2$.

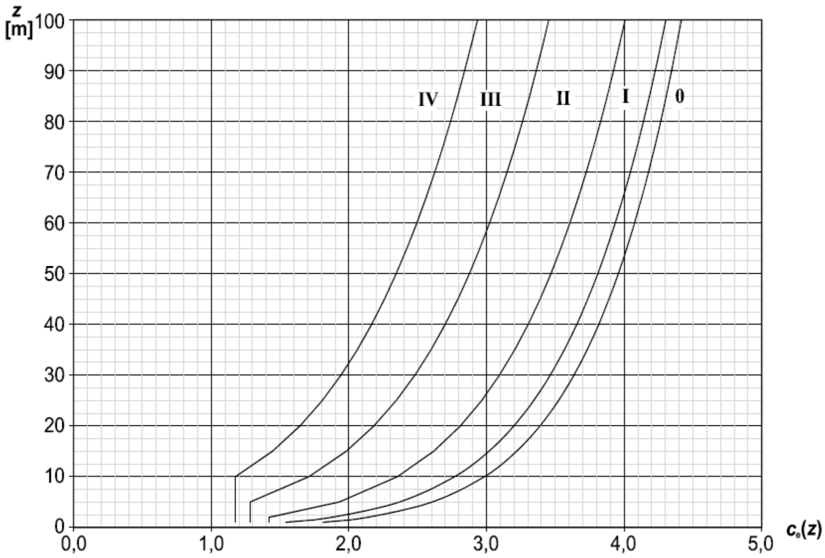


Figure 4.2 — Illustrations of the exposure factor $c_e(z)$ for c_O=1,0, k_l=1,0

The basic wind pressure results to be equal to:

q_b 455.63 N/m^2

Wind pressure on surfaces

The wind pressure acting on the external surfaces can be determined according to:

$$w_e(z_e) = q_p(z_e) \cdot c_{pe}$$

The wind pressure acting on the internal surfaces can be determined according to:

$$w_i(z_i) = q_p(z_i) \cdot c_{pi}$$

where:

c_{pe} is the pressure coefficient for the external pressure that can be calculated according to section 7.2 of EN 1991-1-4 or according to data supported by appropriate documentation or by experimental campaigns in wind tunnel;

c_{pi} is the pressure coefficient for the internal pressure.

The reference heights z_e to be considered in the calculation of the peak reference wind pressure are defined as follows:

- Windward surfaces of walls: the reference height changes along the structure height in accordance with point 7.2.2 on EN 1991-1-4;
- Leeward surfaces of walls: the reference height is equal to the maximum height of the building;
- Internal pressures: the reference height is equal to the maximum height of the building.

Wind forces

The wind forces for the whole structure or a structural component can be determined by calculating forces from surface pressures according to the following equations.

External forces:

$$F_{w,e} = c_s \cdot c_d \cdot \sum_{surfaces} w_e(z_e) \cdot A_{ref}$$

Internal forces:

$$F_{w,i} = \sum_{surfaces} w_i(z_i) \cdot A_{ref}$$

where:

c_s is the size factor that takes into account the effect on wind actions from the non-simultaneous occurrence of peak wind pressures on the surfaces. It is taken equal to 1;

c_d is the dynamic factor that takes into the effect of the vibrations of the structure due to turbulence. It is taken equal to 1.

Loads acting on the walls

The following table shows the loads acting on the walls.

Load name: Load ID

Position: Position of the wall: internal or external

$g_{1,k}$: Permanent action: self weight

$g_{2,k}$: Permanent action

$q_{,wind,k}$: Variable actions: wind load on windward, leeward and lateral surfaces

Wall name	Position	Load name	$g_{1,k}$ [kN/m^2]	$g_{2,k}$ [kN/m^2]	$q_{,wind,k}$ downwind [kN/m^2]	$q_{,wind,k}$ windward [kN/m^2]	$q_{,wind,k}$ lateral [kN/m^2]
PX1-1	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PY1-1	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PY1-2	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PX1-4	Internal	Carico pareti interne	0.5	0.6	0	0	0
PX1-3	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PY1-6	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PX1-6	Internal	Carico pareti interne	0.5	0.6	0	0	0
PY1-8	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PX1-9	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PY1-5	Internal	Carico pareti interne	0.5	0.6	0	0	0
PY1-4	Internal	Carico pareti interne	0.5	0.6	0	0	0
PX1-7	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
Parete 29	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
Parete 30	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
Parete 34	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
Parete 35	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PX1-8	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PY1-3	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PY1-7	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
Parete 72	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PX1-2	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PX0-1	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
Parete 78	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PX0-2	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PX0-3	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
Parete 81	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PY0-6	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PY0-7	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PY0-8	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
Parete 88	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
Parete 89	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PX1-5	Internal	Carico pareti interne	0.5	0.6	0	0	0
PX0-9	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PX0-8	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PX0-7	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
Parete 95	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
Parete 96	External	Carico pareti esterne	0.5	0.6	-0.77	1.35	-1.8
PY0-5	Internal	Carico pareti interne	0.5	0.6	0	0	0
PY0-4	Internal	Carico pareti interne	0.5	0.6	0	0	0
PX0-6	Internal	Carico pareti interne	0.5	0.6	0	0	0
PX0-5	Internal	Carico pareti interne	0.5	0.6	0	0	0
PX0-4	Internal	Carico pareti interne	0.5	0.6	0	0	0
PY0-3	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PY0-2	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
PY0-1	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
Parete 109	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8
Parete 110	External	Carico pareti esterne	0.5	0.6	-0.79	1.36	-1.8

Loads acting on the floors

The following table shows the characteristic values of the loads acting on the decks.

Load name: Load ID

Position: Position of the floor: internal or external

Environment: Load category

α: Roof pitch angle

$g_{1,k}$: Permanent action: self weight

$g_{2,k}$: Permanent action

$q_{,k}$: Variable actions

$q_{,snow,k}$: Variable actions: snow load

$q_{,wind,k}$: Variable actions: wind load

Floor name	Position	α [°]	Load name	Environment	$g_{1,k}$ [kN/m²]	$g_{2,k}$ [kN/m²]	$q_{,k}$ [kN/m²]	$q_{,snow,k}$ [kN/m²]	$q_{,wind,k}$ in depressure [kN/m²]	$q_{,wind,k}$ in pressure [kN/m²]
Solaio 12	Internal floor	0	Carico solaio residenziale	Imposed loads category A: floors	1	1.35	2	0	0	0
Solaio 13	Internal floor	0	Carico solaio residenziale	Imposed loads category A: floors	1	1.35	2	0	0	0
Solaio 20	Roof	17	Carico solaio copertura	Imposed loads category H	0.8	0.9	0.5	0	-1.8	0.64
Solaio 21	Roof	17	Carico solaio copertura	Imposed loads category H	0.8	0.9	0.5	0	-1.8	0.64
Solaio 22	Internal floor	0	Carico solaio residenziale	Imposed loads category A: floors	1	1.35	2	0	0	0
Solaio 23	Internal floor	0	Carico solaio residenziale	Imposed loads category A: floors	1	1.35	2	0	0	0

Line loads

The following table shows the characteristic values of the line loads acting on the beams and the decks.

Load name: Load ID

Position: Position of the element: internal or external

Environment: Load category

$G_{1,k}$: Permanent action: self weight

$G_{2,k}$: Permanent action

$Q_{,k}$: Variable actions

$Q_{,snow,k}$: Variable actions: snow load

$Q_{,wind,k}$: Variable actions: wind load

Element name	Position	Load name	Environment	$G_{1,k}$ [kN/m]	$G_{2,k}$ [kN/m]	$Q_{,k}$ [kN/m]	$Q_{,snow,k}$ [kN/m]	$Q_{,wind,k}$ In depressure [kN/m]	$Q_{,wind,k}$ In pressure [kN/m]
Trave 35	**Internal load**	**Carico solo permanente**	**-**	**0.28**	**0**	**-**	**0**	**0**	**0**
Trave 36	**Internal load**	**Carico solo permanente**	**-**	**0.2**	**0**	**-**	**0**	**0**	**0**

Trave 37	**Internal load**	**Carico solo permanente**	**-**	**0.2**	**0**	**-**	**0**	**0**	**0**
Trave 39	**Internal load**	**Carico solo permanente**	**-**	**0.2**	**0**	**-**	**0**	**0**	**0**
Trave 40	**Internal load**	**Carico solo permanente**	**-**	**0.2**	**0**	**-**	**0**	**0**	**0**
Trave 42	**Internal load**	**Carico solo permanente**	**-**	**0.2**	**0**	**-**	**0**	**0**	**0**
Trave 43	**Internal load**	**Carico solo permanente**	**-**	**0.2**	**0**	**-**	**0**	**0**	**0**
Trave 46	**Internal load**	**Carico solo permanente**	**-**	**0.2**	**0**	**-**	**0**	**0**	**0**
Trave 47	**Internal load**	**Carico solo permanente**	**-**	**0.2**	**0**	**-**	**0**	**0**	**0**
Trave 48	**Internal load**	**Carico solo permanente**	**-**	**0.32**	**0**	**-**	**0**	**0**	**0**
Trave 49	**Internal load**	**Carico solo permanente**	**-**	**0.32**	**0**	**-**	**0**	**0**	**0**
Trave 50	**Internal load**	**Carico solo permanente**	**-**	**0.28**	**0**	**-**	**0**	**0**	**0**
Trave 51	**Internal load**	**Carico solo permanente**	**-**	**0.28**	**0**	**-**	**0**	**0**	**0**
Trave 52	**Internal load**	**Carico solo permanente**	**-**	**0.28**	**0**	**-**	**0**	**0**	**0**
Trave 53	**Internal load**	**Carico solo permanente**	**-**	**0.28**	**0**	**-**	**0**	**0**	**0**

Seismic actions

The seismic actions are evaluated according to the Eurocode 8 and the National annex. The earthquake motion at a given point on the surface is represented by an elastic ground acceleration response spectrum.

The response spectra are calculated using the design ground acceleration a_g on type A ground: the acceleration is equal to a_{gR}, the value of the reference peak ground acceleration on type A ground, times the importance factor γ_I.

The response spectrum for the damage limit requirement is obtained multiplying the reduction of the design ground acceleration a_g by the reduction factor ν.

The parameters defining the design ground acceleration a_g on type A ground and the acceleration values for the ULS and DLS are reported below:

The reduction factor of the Damage limitation Limit State spectrum: 0.5

Importance factor: 1

Limit States	a_g[g]
ULS – Ultimate Limit State	0.261
DLS – Damage Limitation limit State	0.131

The value of the periods T_B, T_C, T_D and of the soil factor S defining the shape of the elastic response spectrum depend on the ground type and on the spectrum type. The parameters used are reported below:

Spectrum type: Type 1

Ground type: A

S soil factor: 1

T_B lower limit of the period of the constant spectral acceleration branch: 0.15 s

T_C upper limit of the period of the constant spectral acceleration branch: 0.4 s

T_D value defining the beginning of the constant displacement response range of the spectrum: 2 s

Horizontal elastic response spectrum

For the horizontal components of the seismic action, the elastic response spectrum $S_e(T)$ *is defined by the following expressions:*

$0 \leq T \leq T_B$ $$S_e(T) = a_g \times S \times \left[1 + \frac{T}{T_B} \times (\eta \times 2{,}5 - 1)\right]$$

$T_B \leq T \leq T_C$ $$S_e(T) = a_g \times S \times \eta \times 2{,}5$$

$T_C \leq T \leq T_D \qquad S_e(T) = a_g \times S \times \eta \times 2{,}5 \left[\frac{T_C}{T}\right]$

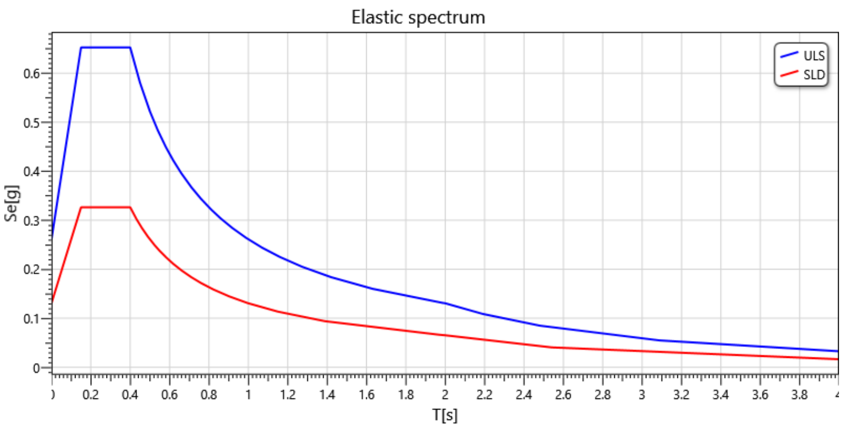
$T \leq T_D \qquad S_e(T) = a_g \times S \times \eta \times 2{,}5 \left[\frac{T_C T_D}{T^2}\right]$

Horizontal elastic response spectra are reported below; they are calculated using the following values of the parameters η and ξ

η 1

ξ 5%

η is the damping correction factor with a reference value of η = 1 for 5% viscous damping.



Design spectrum for elastic analysis (NO-COLLAPSE)

To avoid explicit inelastic structural analysis in design, the capacity of the structure to dissipate energy, through mainly ductile behavior of its elements and/or other mechanisms, is taken into account by performing an elastic analysis based on a response spectrum reduced with respect to the elastic one, henceforth called a "design spectrum". This reduction is accomplished by introducing the behavior factor q. The design spectrum is *defined by the following expressions:*

$0 \leq T \leq T_B \qquad S_d(T) = a_g \times S \times \left[\frac{2}{3} + \frac{T}{T_B} \times \left(\frac{2{,}5}{q} - \frac{2}{3}\right)\right]$

$T_B \leq T \leq T_C \qquad S_d(T) = a_g \times S \times \frac{2{,}5}{q}$

$T_C \leq T \leq T_D \qquad S_d(T) = \begin{cases} a_g \times S \times \frac{2{,}5}{q} \times \left[\frac{T_C}{T}\right] \\ \geq \beta \times a_g \end{cases}$

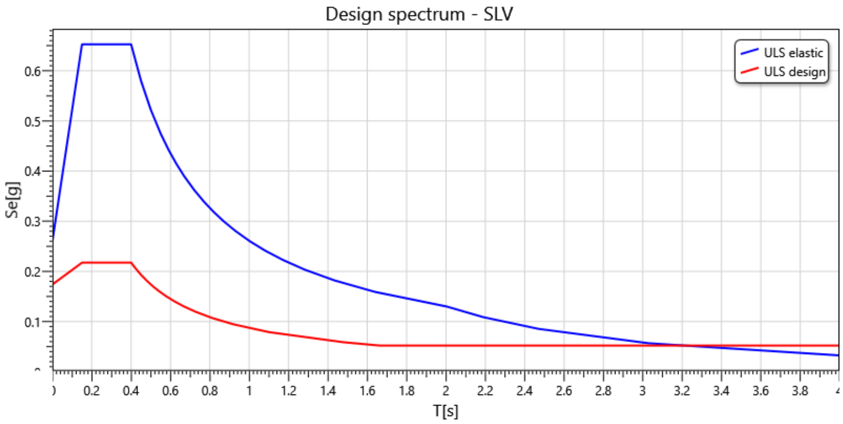
$T \leq T_D \qquad S_d(T) = \begin{cases} a_g \times S \times \frac{2{,}5}{q} \times \left[\frac{T_C T_D}{T^2}\right] \\ \geq \beta \times a_g \end{cases}$

where:

β is the lower bound factor for the horizontal design spectrum equal to 0.2;

q is the behaviour factor: 3.

The horizontal elastic response spectra and the horizontal design spectrum (Ultimate Limit State) are shown below:



Sections of the structural elements

CLT walls

The following table shows the CLT walls characteristics.

Section name	Manufacturer	Panel name	Material	Layers number	Thickness [mm]	Layers	Orientation of the outer layers
CLT wall	User defined	100 5s T	C 24 XLAM	5	100	20 - 20 - 20 - 20 - 20	Vertical

CLT floors

Floor geometric characteristic

h_b: CLT panel thickness

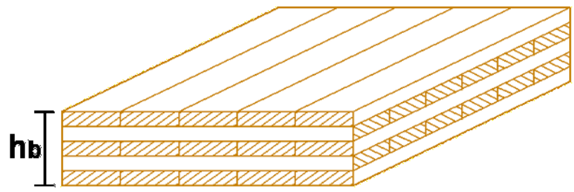


Figure: CLT floor geometric characteristics

The following table sets out the details concerning the CLT floors.

Section name	Manufacturer	CLT panel name	Material	Number of layers	Thickness h_b[mm]	Layers	External layers orientation
CLT floor	User defined	200 5s L	C 24 XLAM	5	200	40 - 40 - 40 - 40 - 40	Parallel to the calculation direction
CLT roof	User defined	160 5s L	C 24 XLAM	5	160	40 - 20 - 40 - 20 - 40	Parallel to the calculation direction

Cross section of timber linear elements

The following table sets out the details concerning the cross section of every linear element.

Section name	Material	Width b [mm]	Height h [mm]	Area A [mm^2]	$J_{y\text{-}y}$ [mm^4]	$J_{z\text{-}z}$ [mm^4]
Column	GL 24h - EN 14080	200	200	40000	1.33E8	1.33E8
Ridge beam	GL 24h - EN 14080	200	280	56000	3.66E8	1.87E8
Architrave	GL 24h - EN 14080	200	200	40000	1.33E8	1.33E8
Internal beam	GL 24h - EN 14080	200	320	64000	5.46E8	2.13E8

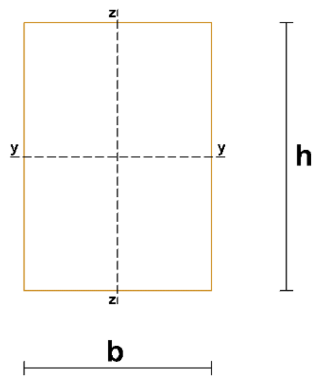


Figure: Geometric size of every timber cross section

Connections

Hold down

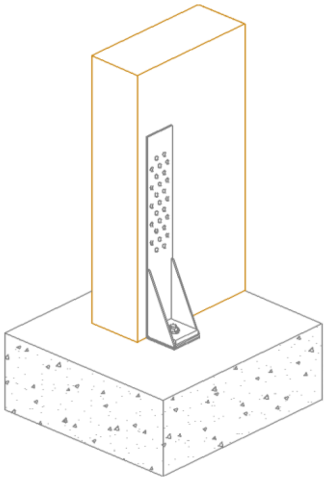


Figure: graphical representation of a hold down in a base connection (timber wall – foundation connection)

Connection name	Connection position	Manufacturer	Description	Fasteners	Threaded rods / Mechanical anchors	Chemical anchor	N° connection elements at each wall end
Ground traction connection - hold down	Ground connection	Rotho Blaas	WHT 440	20 x Anker nail - LBA 4,0 x 60	1 x Threaded rod INA - 5.8 - M16 x 195	Hybrid chemical anchor ETA-20/1285	1

Timber to concrete angle bracket

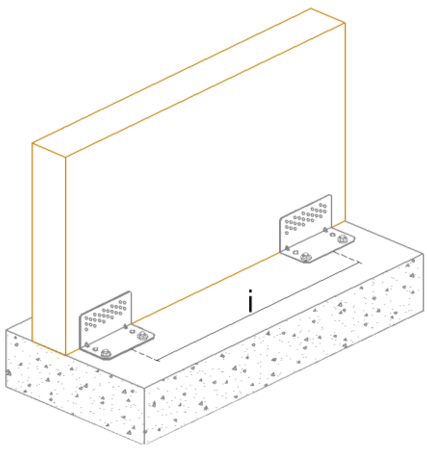


Figure: graphical representation of the shear connection with angle brackets

Connection name	Connection position	Manufacturer	Description	Fasteners	Threaded rods / Mechanical anchors	Chemical anchor	Number of sides	Spacing i [mm]
Ground shear connection - bracket	Ground connection	Rotho Blaas	Titan N - TCN 200	30 x Anker nail - LBA 4,0 X 60	2 x Threaded rod INA - 5.8 - M12 x 130	Vinylester chemical anchor ETA-09/0078	1	1000

Timber to timber tensile plate

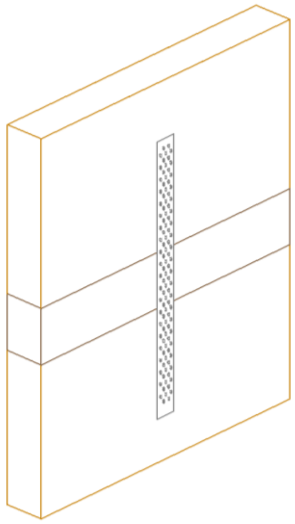


Figure: graphical representation of a punched strap

Connection name	Connection position	Manufacturer	Description	Width [mm]	Length [mm]	Thickness [mm]	Steel grade	Fasteners	N° connection elements at each wall end
Upper levels traction connection - tensile plate	Upper level	Rotho Blaas	Perforated strap 80 mm sp. 1,5 mm	80	25000	1.5	S350	12 x Anker nail - LBA 4,0 X 60	1

Timber to timber angle bracket

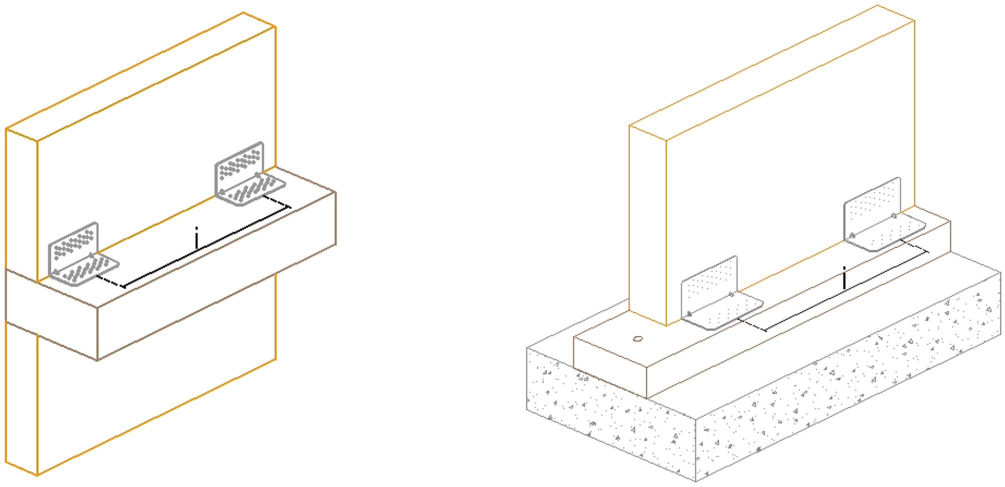


Figure: graphical representations of the timber to timber shear connection with angle brackets

Connection name	Connection position	Manufacturer	Description	Number of fasteners on the vertical plate	Number of fasteners on the horizontal plate	Number of sides	Spacing i [mm]
Upper levels shear connection - bracket	Upper level	Rotho Blaas	Titan TTN 240	36 x Anker nail - LBA 4,0 X 60	36 x Anker nail - LBA 4,0 X 60	1	2000

Combinations of actions

For each critical load case, the design values of the effects of actions shall be determined by combining the values of actions that are considered to occur simultaneously.

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+\gamma_{Q,1}Q_{k,1}+\sum_{i\geq 1}\gamma_{Q,i}\psi_{0,\mathrm{i}}Q_{k,i}=$$

$$=\gamma_{G1}\cdot G_1+\gamma_{G2}\cdot G_2+\gamma_Q\cdot Q_{k1}+\gamma_{Q2}\cdot\psi_{02}\cdot Q_{k2}+\gamma_{Q3}\cdot\psi_{03}\cdot Q_{k3}+\cdots$$

Combinations of actions for seismic design situations:

$$\sum_{j\geq 1}G_{k,j}+A_{Ed}+\sum_{i\geq 1}\psi_{2,\mathrm{i}}Q_{k,i}=$$

$$=G_1+G_2+A_{Ed}+\psi_{21}\cdot Q_{k1}+\psi_{22}\cdot Q_{k2}+\cdots$$

being:

G_1 permanent actions: self weight;

G_2 permanent actions;

Q_1 characteristic value of the main variable action;

Q_{ki} characteristic value of the i-th variable action;

γ_{G1} is the partial factor for the self-weight action;

γ_{G2} is the partial factor for the permanent actions action.

When permanent actions, as well as a portion of those, are fully defined in design process, it is possible to adopt the same partial factor employed for self-weight actions.

The following are the values of the combination coefficients used.

Action name	Description	Duration	ψ_0	ψ_1	ψ_2
Q cat.A	Category A: domestic, residential areas	Medium-term	0.7	0.5	0.3
Q cat.B	Category B: office areas	Medium-term	0.7	0.5	0.3
Q cat.C	Category C: congregation areas	Medium-term	0.7	0.7	0.6
Q cat.D	Category D: shopping areas	Medium-term	0.7	0.7	0.6
Q cat.E	Category E: storage areas	Long-term	1	0.9	0.8
Q cat.F	Category F: traffic area, vehicle weight ≤ 30 kN	Long-term	0.7	0.7	0.6
Q cat.G	Category G: traffic area, vehicle weight ≤ 160 kN	Long-term	0.7	0.5	0.3
Q cat.H	Category H: roofs	Medium-term	0	0	0
Q cat.I-A	Category I-A: practicable roofs of category A	Medium-term	0.7	0.5	0.3
Q cat.I-B	Category I-B: practicable roofs of category B	Medium-term	0.7	0.5	0.3
Q cat.I-C	Category I-C: practicable roofs of category C	Medium-term	0.7	0.7	0.6
Q cat.I-D	Category I-D: practicable roofs of category D	Medium-term	0.7	0.7	0.6

Q cat.I-E	Category I-E: practicable roofs of category E	Long-term	1	0.9	0.8
Ortho wind	Wind load	Instantaneous	0.6	0.2	0
Snow	Snow load (altitude <= 1000 mamsl)	Short-term	0.5	0.2	0
Snow	Snow load (altitude > 1000 mamsl)	Medium-term	0.7	0.5	0.2

Combinations of actions used

Vertical ULS loads combinations

The following table shows the ULS load combinations relevant for verifications in conditions of vertical load. The coefficient values listed correspond to the product of the partial safety factor γ_j and the combination factors ψ_{0j}.

The action of the wind is schematized with a uniform load orthogonal to each external wall.

Name	Duration	G1	G2	Q cat.A	Q cat.H	Snow	Ortho wind	Wind X	Wind Y	Dynamic SLV X	Dynamic SLV Y	Dynamic SLD X	Dynamic SLD Y
ULS 1	Permanent	1	1	0	0	0	0	0	0	0	0	0	0
ULS 2	Medium-term	1	1	1.5	0	0	0	0	0	0	0	0	0
ULS 3	Short-term	1	1	1.5	0	0.75	0	0	0	0	0	0	0
ULS 4	Instantaneous	1	1	1.5	0	0	0.9	0	0	0	0	0	0
ULS 5	Instantaneous	1	1	1.5	0	0.75	0.9	0	0	0	0	0	0
ULS 6	Medium-term	1	1	0	1.5	0	0	0	0	0	0	0	0
ULS 7	Medium-term	1	1	1.05	1.5	0	0	0	0	0	0	0	0
ULS 8	Short-term	1	1	0	1.5	0.75	0	0	0	0	0	0	0
ULS 9	Short-term	1	1	1.05	1.5	0.75	0	0	0	0	0	0	0
ULS 10	Instantaneous	1	1	0	1.5	0	0.9	0	0	0	0	0	0
ULS 11	Instantaneous	1	1	1.05	1.5	0	0.9	0	0	0	0	0	0
ULS 12	Instantaneous	1	1	0	1.5	0.75	0.9	0	0	0	0	0	0
ULS 13	Instantaneous	1	1	1.05	1.5	0.75	0.9	0	0	0	0	0	0
ULS 14	Short-term	1	1	0	0	1.5	0	0	0	0	0	0	0
ULS 15	Short-term	1	1	1.05	0	1.5	0	0	0	0	0	0	0
ULS 16	Instantaneous	1	1	0	0	1.5	0.9	0	0	0	0	0	0
ULS 17	Instantaneous	1	1	1.05	0	1.5	0.9	0	0	0	0	0	0
ULS 18	Instantaneous	1	1	0	0	0	1.5	0	0	0	0	0	0
ULS 19	Instantaneous	1	1	1.05	0	0	1.5	0	0	0	0	0	0
ULS 20	Instantaneous	1	1	0	0	0.75	1.5	0	0	0	0	0	0
ULS 21	Instantaneous	1	1	1.05	0	0.75	1.5	0	0	0	0	0	0
ULS 22	Permanent	1	1.35	0	0	0	0	0	0	0	0	0	0
ULS 23	Medium-term	1	1.35	1.5	0	0	0	0	0	0	0	0	0
ULS 24	Short-term	1	1.35	1.5	0	0.75	0	0	0	0	0	0	0
ULS 25	Instantaneous	1	1.35	1.5	0	0	0.9	0	0	0	0	0	0
ULS 26	Instantaneous	1	1.35	1.5	0	0.75	0.9	0	0	0	0	0	0
ULS 27	Medium-term	1	1.35	0	1.5	0	0	0	0	0	0	0	0
ULS 28	Medium-term	1	1.35	1.05	1.5	0	0	0	0	0	0	0	0
ULS 29	Short-term	1	1.35	0	1.5	0.75	0	0	0	0	0	0	0
ULS 30	Short-term	1	1.35	1.05	1.5	0.75	0	0	0	0	0	0	0
ULS 31	Instantaneous	1	1.35	0	1.5	0	0.9	0	0	0	0	0	0
ULS 32	Instantaneous	1	1.35	1.05	1.5	0	0.9	0	0	0	0	0	0
ULS 33	Instantaneous	1	1.35	0	1.5	0.75	0.9	0	0	0	0	0	0
ULS 34	Instantaneous	1	1.35	1.05	1.5	0.75	0.9	0	0	0	0	0	0
ULS 35	Short-term	1	1.35	0	0	1.5	0	0	0	0	0	0	0
ULS 36	Short-term	1	1.35	1.05	0	1.5	0	0	0	0	0	0	0
ULS 37	Instantaneous	1	1.35	0	0	1.5	0.9	0	0	0	0	0	0
ULS 38	Instantaneous	1	1.35	1.05	0	1.5	0.9	0	0	0	0	0	0
ULS 39	Instantaneous	1	1.35	0	0	0	1.5	0	0	0	0	0	0
ULS 40	Instantaneous	1	1.35	1.05	0	0	1.5	0	0	0	0	0	0
ULS 41	Instantaneous	1	1.35	0	0	0.75	1.5	0	0	0	0	0	0
ULS 42	Instantaneous	1	1.35	1.05	0	0.75	1.5	0	0	0	0	0	0
ULS 43	Permanent	1.35	1	0	0	0	0	0	0	0	0	0	0
ULS 44	Medium-term	1.35	1	1.5	0	0	0	0	0	0	0	0	0
ULS 45	Short-term	1.35	1	1.5	0	0.75	0	0	0	0	0	0	0
ULS 46	Instantaneous	1.35	1	1.5	0	0	0.9	0	0	0	0	0	0
ULS 47	Instantaneous	1.35	1	1.5	0	0.75	0.9	0	0	0	0	0	0
ULS 48	Medium-term	1.35	1	0	1.5	0	0	0	0	0	0	0	0
ULS 49	Medium-term	1.35	1	1.05	1.5	0	0	0	0	0	0	0	0
ULS 50	Short-term	1.35	1	0	1.5	0.75	0	0	0	0	0	0	0
ULS 51	Short-term	1.35	1	1.05	1.5	0.75	0	0	0	0	0	0	0
ULS 52	Instantaneous	1.35	1	0	1.5	0	0.9	0	0	0	0	0	0
ULS 53	Instantaneous	1.35	1	1.05	1.5	0	0.9	0	0	0	0	0	0
ULS 54	Instantaneous	1.35	1	0	1.5	0.75	0.9	0	0	0	0	0	0
ULS 55	Instantaneous	1.35	1	1.05	1.5	0.75	0.9	0	0	0	0	0	0
ULS 56	Short-term	1.35	1	0	0	1.5	0	0	0	0	0	0	0
ULS 57	Short-term	1.35	1	1.05	0	1.5	0	0	0	0	0	0	0
ULS 58	Instantaneous	1.35	1	0	0	1.5	0.9	0	0	0	0	0	0
ULS 59	Instantaneous	1.35	1	1.05	0	1.5	0.9	0	0	0	0	0	0
ULS 60	Instantaneous	1.35	1	0	0	0	1.5	0	0	0	0	0	0
ULS 61	Instantaneous	1.35	1	1.05	0	0	1.5	0	0	0	0	0	0
ULS 62	Instantaneous	1.35	1	0	0	0.75	1.5	0	0	0	0	0	0
ULS 63	Instantaneous	1.35	1	1.05	0	0.75	1.5	0	0	0	0	0	0
ULS 64	Permanent	1.35	1.35	0	0	0	0	0	0	0	0	0	0
ULS 65	Medium-term	1.35	1.35	1.5	0	0	0	0	0	0	0	0	0
ULS 66	Short-term	1.35	1.35	1.5	0	0.75	0	0	0	0	0	0	0
ULS 67	Instantaneous	1.35	1.35	1.5	0	0	0.9	0	0	0	0	0	0
ULS 68	Instantaneous	1.35	1.35	1.5	0	0.75	0.9	0	0	0	0	0	0
ULS 69	Medium-term	1.35	1.35	0	1.5	0	0	0	0	0	0	0	0
ULS 70	Medium-term	1.35	1.35	1.05	1.5	0	0	0	0	0	0	0	0
ULS 71	Short-term	1.35	1.35	0	1.5	0.75	0	0	0	0	0	0	0
ULS 72	Short-term	1.35	1.35	1.05	1.5	0.75	0	0	0	0	0	0	0
ULS 73	Instantaneous	1.35	1.35	0	1.5	0	0.9	0	0	0	0	0	0
ULS 74	Instantaneous	1.35	1.35	1.05	1.5	0	0.9	0	0	0	0	0	0
ULS 75	Instantaneous	1.35	1.35	0	1.5	0.75	0.9	0	0	0	0	0	0

ULS 76	Instantaneous	1.35	1.35	1.05	1.5	0.75	0.9	0	0	0	0	0	0
ULS 77	Short-term	1.35	1.35	0	0	1.5	0	0	0	0	0	0	0
ULS 78	Short-term	1.35	1.35	1.05	0	1.5	0	0	0	0	0	0	0
ULS 79	Instantaneous	1.35	1.35	0	0	1.5	0.9	0	0	0	0	0	0
ULS 80	Instantaneous	1.35	1.35	1.05	0	1.5	0.9	0	0	0	0	0	0
ULS 81	Instantaneous	1.35	1.35	0	0	0	1.5	0	0	0	0	0	0
ULS 82	Instantaneous	1.35	1.35	1.05	0	0	1.5	0	0	0	0	0	0
ULS 83	Instantaneous	1.35	1.35	0	0	0.75	1.5	0	0	0	0	0	0
ULS 84	Instantaneous	1.35	1.35	1.05	0	0.75	1.5	0	0	0	0	0	0

Horizontal ULS loads combinations

The following table shows the ULS load combinations relevant for verifications in conditions of vertical load. The coefficient values listed correspond to the product of the partial safety factor γ_j and the combination factors ψ_{0j}.

The action of the wind is schematized with a uniform load orthogonal to each external wall and it acts separately in the directions x, -x, y, -y.

Name	Duration	G1	G2	Q cat.A	Q cat.H	Snow	Ortho wind	Wind X	Wind Y	Dynamic SLV X	Dynamic SLV Y	Dynamic SLD X	Dynamic SLD Y
Horizontal ULS 1	Instantaneous	1	1	0	0	0	0	1.5	0	0	0	0	0
Horizontal ULS 2	Instantaneous	1	1	0	0	0	0	0	1.5	0	0	0	0
Horizontal ULS 3	Instantaneous	1	1	0	0	0	0	-1.5	0	0	0	0	0
Horizontal ULS 4	Instantaneous	1	1	0	0	0	0	0	-1.5	0	0	0	0
Horizontal ULS 5	Instantaneous	1.35	1.35	1.05	0	0.75	0	1.5	0	0	0	0	0
Horizontal ULS 6	Instantaneous	1.35	1.35	1.05	0	0.75	0	0	1.5	0	0	0	0
Horizontal ULS 7	Instantaneous	1.35	1.35	1.05	0	0.75	0	-1.5	0	0	0	0	0
Horizontal ULS 8	Instantaneous	1.35	1.35	1.05	0	0.75	0	0	-1.5	0	0	0	0

Combination of actions for rare SLS

Name	Duration	G1	G2	Q cat.A	Q cat.H	Snow	Ortho wind	Wind X	Wind Y	Dynamic SLV X	Dynamic SLV Y	Dynamic SLD X	Dynamic SLD Y
SLS characteristic 1	Permanent	1	1	0	0	0	0	0	0	0	0	0	0
SLS characteristic 2	Medium-term	1	1	1	0	0	0	0	0	0	0	0	0
SLS characteristic 3	Short-term	1	1	1	0	0.5	0	0	0	0	0	0	0
SLS characteristic 4	Instantaneous	1	1	1	0	0	0.6	0	0	0	0	0	0
SLS characteristic 5	Instantaneous	1	1	1	0	0.5	0.6	0	0	0	0	0	0
SLS characteristic 6	Medium-term	1	1	0	1	0	0	0	0	0	0	0	0
SLS characteristic 7	Medium-term	1	1	0.7	1	0	0	0	0	0	0	0	0
SLS characteristic 8	Short-term	1	1	0	1	0.5	0	0	0	0	0	0	0
SLS characteristic 9	Short-term	1	1	0.7	1	0.5	0	0	0	0	0	0	0
SLS characteristic 10	Instantaneous	1	1	0	1	0	0.6	0	0	0	0	0	0
SLS characteristic 11	Instantaneous	1	1	0.7	1	0	0.6	0	0	0	0	0	0
SLS characteristic 12	Instantaneous	1	1	0	1	0.5	0.6	0	0	0	0	0	0
SLS characteristic 13	Instantaneous	1	1	0.7	1	0.5	0.6	0	0	0	0	0	0
SLS characteristic 14	Short-term	1	1	0	0	1	0	0	0	0	0	0	0

SLS characteristic 15	Short-term	1	1	0.7	0	1	0	0	0	0	0	0	0
SLS characteristic 16	Instantaneous	1	1	0	0	1	0.6	0	0	0	0	0	0
SLS characteristic 17	Instantaneous	1	1	0.7	0	1	0.6	0	0	0	0	0	0
SLS characteristic 18	Instantaneous	1	1	0	0	0	1	0	0	0	0	0	0
SLS characteristic 19	Instantaneous	1	1	0.7	0	0	1	0	0	0	0	0	0
SLS characteristic 20	Instantaneous	1	1	0	0	0.5	1	0	0	0	0	0	0
SLS characteristic 21	Instantaneous	1	1	0.7	0	0.5	1	0	0	0	0	0	0

Seismic load combinations

The action effects due to the combination of the horizontal components of the seismic action are computed using the following combinations:

$$E_{Edx} + 0{,}3 \cdot E_{Edy}$$

$$0{,}3 \cdot E_{Edx} + E_{Edy}$$

Combinations of actions for Damage Limit State (SLD)

Name	Duration	G1	G2	Q cat.A	Q cat.H	Snow	Ortho wind	Wind X	Wind Y	Dynamic SLV X	Dynamic SLV Y	Dynamic SLD X	Dynamic SLD Y
Dynamic SLD 1 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	1	0.3
Dynamic SLD 1 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	1	0.3
Dynamic SLD 1 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	1	0.3
Dynamic SLD 1 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	1	0.3
Dynamic SLD 2 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	1	-0.3
Dynamic SLD 2 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	1	-0.3
Dynamic SLD 2 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	1	-0.3
Dynamic SLD 2 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	1	-0.3
Dynamic SLD 3 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-1	0.3
Dynamic SLD 3 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-1	0.3
Dynamic SLD 3 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-1	0.3
Dynamic SLD 3 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-1	0.3
Dynamic SLD 4 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-1	-0.3
Dynamic SLD 4 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-1	-0.3
Dynamic SLD 4 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-1	-0.3
Dynamic SLD 4 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-1	-0.3
Dynamic SLD 5 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	0.3	1
Dynamic SLD 5 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	0.3	1
Dynamic SLD 5 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	0.3	1
Dynamic SLD 5 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	0.3	1
Dynamic SLD 6 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	0.3	-1
Dynamic SLD 6 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	0.3	-1
Dynamic SLD 6 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	0.3	-1
Dynamic SLD 6 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	0.3	-1
Dynamic SLD 7 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-0.3	1

Dynamic SLD 7 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-0.3	1
Dynamic SLD 7 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-0.3	1
Dynamic SLD 7 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-0.3	1
Dynamic SLD 8 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-0.3	-1
Dynamic SLD 8 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-0.3	-1
Dynamic SLD 8 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-0.3	-1
Dynamic SLD 8 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0	0	-0.3	-1

Combinations of actions for Life Safety Limit State (SLV)

Name	Duration	G1	G2	Q cat.A	Q cat.H	Snow	Ortho wind	Wind X	Wind Y	Dynamic SLV X	Dynamic SLV Y	Dynamic SLD X	Dynamic SLD Y
Dynamic SLV 1 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	1	0.3	0	0
Dynamic SLV 1 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	1	0.3	0	0
Dynamic SLV 1 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	1	0.3	0	0
Dynamic SLV 1 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	1	0.3	0	0
Dynamic SLV 2 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	1	-0.3	0	0
Dynamic SLV 2 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	1	-0.3	0	0
Dynamic SLV 2 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	1	-0.3	0	0
Dynamic SLV 2 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	1	-0.3	0	0
Dynamic SLV 3 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	-1	0.3	0	0
Dynamic SLV 3 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	-1	0.3	0	0
Dynamic SLV 3 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	-1	0.3	0	0
Dynamic SLV 3 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	-1	0.3	0	0
Dynamic SLV 4 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	-1	-0.3	0	0
Dynamic SLV 4 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	-1	-0.3	0	0
Dynamic SLV 4 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	-1	-0.3	0	0
Dynamic SLV 4 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	-1	-0.3	0	0
Dynamic SLV 5 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0.3	1	0	0
Dynamic SLV 5 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0.3	1	0	0
Dynamic SLV 5 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0.3	1	0	0
Dynamic SLV 5 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0.3	1	0	0
Dynamic SLV 6 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0.3	-1	0	0
Dynamic SLV 6 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0.3	-1	0	0
Dynamic SLV 6 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	0.3	-1	0	0

Dynamic SLV 6 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	0.3	-1	0	0
Dynamic SLV 7 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	-0.3	1	0	0
Dynamic SLV 7 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	-0.3	1	0	0
Dynamic SLV 7 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	-0.3	1	0	0
Dynamic SLV 7 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	-0.3	1	0	0
Dynamic SLV 8 ex+ ey+	Instantaneous	1	1	0.3	0	0	0	0	0	-0.3	-1	0	0
Dynamic SLV 8 ex+ ey-	Instantaneous	1	1	0.3	0	0	0	0	0	-0.3	-1	0	0
Dynamic SLV 8 ex- ey+	Instantaneous	1	1	0.3	0	0	0	0	0	-0.3	-1	0	0
Dynamic SLV 8 ex- ey-	Instantaneous	1	1	0.3	0	0	0	0	0	-0.3	-1	0	0

Horizontal actions

Modal analysis

The modal analysis is used to determine the vibration modes of the structure, useful to understand the seismic behaviour of the building and to proceed with the linear dynamic analysis.

The modal analysis involves the solution of the generalized eigenvalue problem:

$$[\boldsymbol{K} - \boldsymbol{\Omega}^2 \boldsymbol{M}]\boldsymbol{\Phi} = \boldsymbol{0}$$

where $\boldsymbol{K}$ is the stiffness matrix, $\boldsymbol{M}$ the mass matrix, $\boldsymbol{\Omega}^2$ is the diagonal matrix of the eigenvalues and $\boldsymbol{\Phi}$ is the corresponding matrix of eigenvectors or modal shapes (normalized with respect to the mass matrix); the seismic masses of the diaphragms are calculated with the following combination of vertical loads:

$$\sum G_{k,j} + \sum \psi_{\mathrm{Ei}} \cdot \mathrm{Q_{ki}} = \mathrm{G_1} + \mathrm{G_2} + \sum \psi_{\mathrm{Ei}} \cdot \mathrm{Q_{ki}}$$

where ψ_{Ei} is the combination coefficient for variable action *i.* The combination coefficients shall be computed from the following expression:

$$\psi_{\mathrm{Ei}} = \varphi \cdot \psi_{\mathrm{2i}}$$

Type of variable action	Storey	φ
Categories A-C (as defined in EN 1991-1-1)	Roof Storeys with correlated occupancies Independently occupied storeys	1 0.8 0.5
Categories D-F (as defined in EN 1991-1-1)		1

The base shear forces for DLS and ULS and the respective acceleration values are given below.

The eigenvalue, obtained by the solution of the generalized eigenvalue problem, is the square of the circular frequency $\boldsymbol{\omega}$ related to the period, *T*, and to the frequency, *f*, by the following equations:

$$T = \frac{1}{f} \text{ and } f = \frac{\omega}{2\pi}$$

The participating mass ratio for the mode *i-th*, corresponding to an acceleration in the global axis X and Y and to a rotational acceleration around the vertical axis Z, is given by:

$$M_x^i = \frac{m_x^i}{\sum m_{x,j}} \, [\%]$$

$$M_y^i = \frac{m_y^i}{\sum m_{y,j}} \, [\%]$$

$$M_z^i = \frac{m_z^i}{\sum I_{z,j}} \ [\%]$$

where:

$$m_x^i = \frac{\left([\boldsymbol{\Phi}^i]^T \boldsymbol{M}\, \boldsymbol{R}_x\right)^2}{[\boldsymbol{\Phi}^i]^T \boldsymbol{M}\, \boldsymbol{\Phi}^i}$$

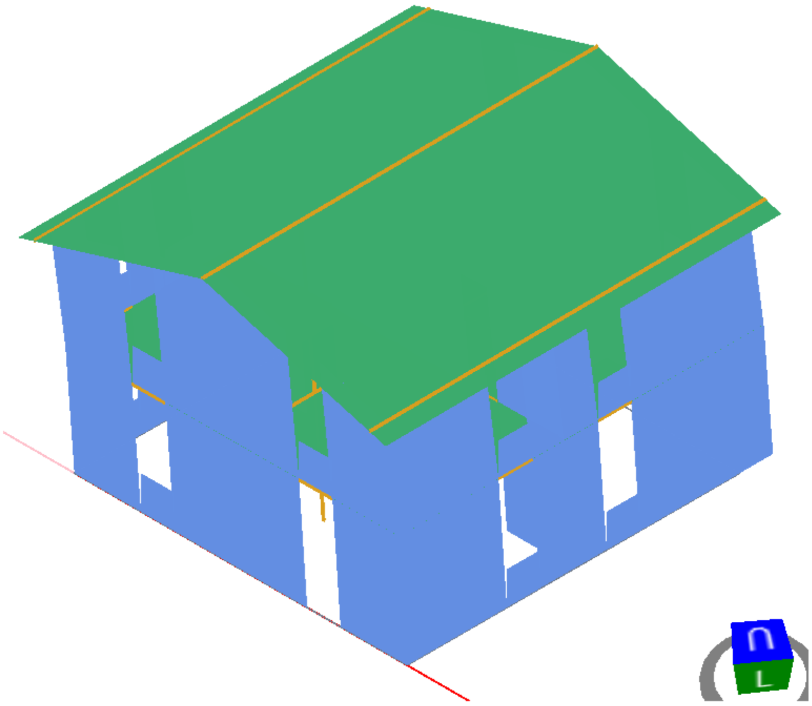
$$m_y^i = \frac{\left([\boldsymbol{\Phi}^i]^T \boldsymbol{M}\, \boldsymbol{R}_y\right)^2}{[\boldsymbol{\Phi}^i]^T \boldsymbol{M}\, \boldsymbol{\Phi}^i}$$

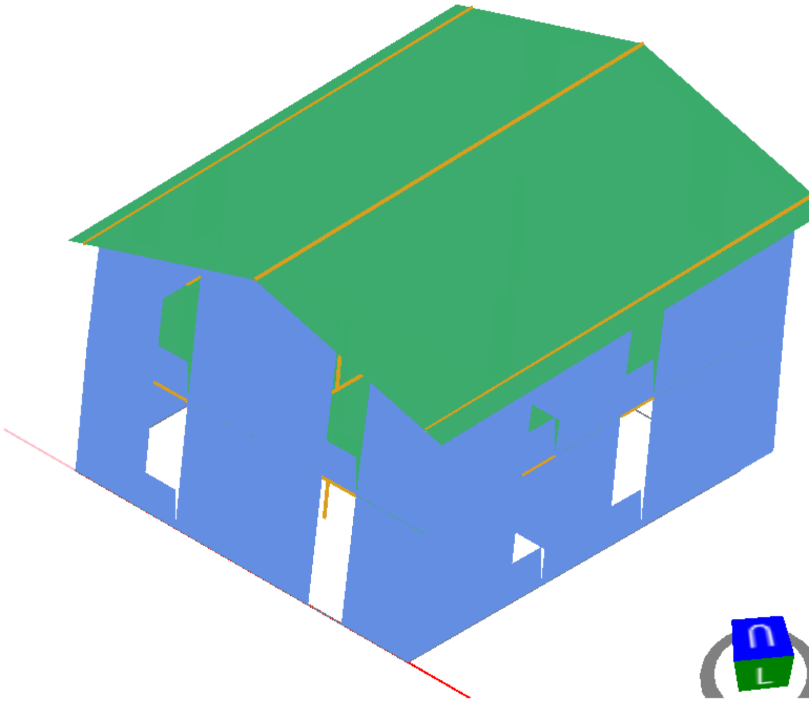
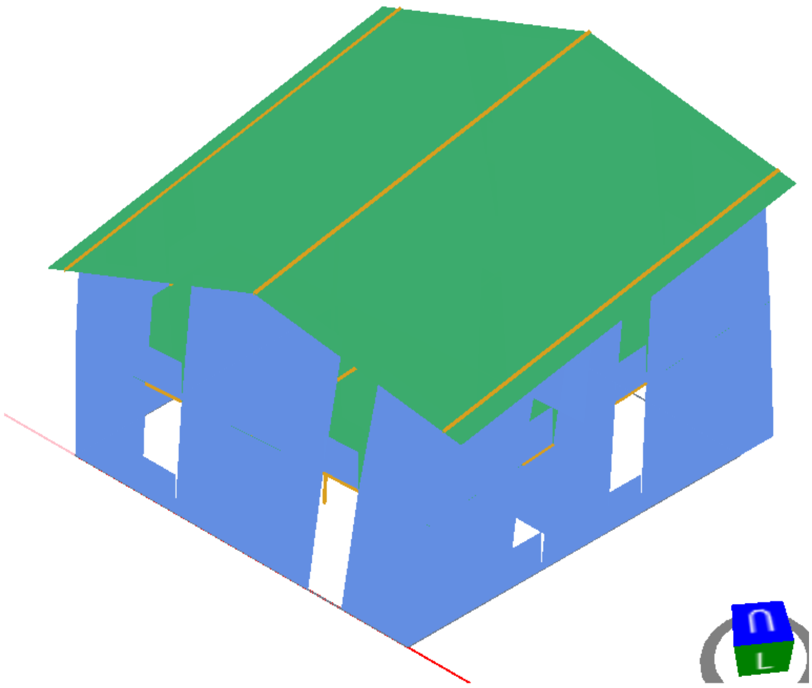
$$m_z^i = \frac{\left([\boldsymbol{\Phi}^i]^T \boldsymbol{M}\, \boldsymbol{R}_z\right)^2}{[\boldsymbol{\Phi}^i]^T \boldsymbol{M}\, \boldsymbol{\Phi}^i}$$

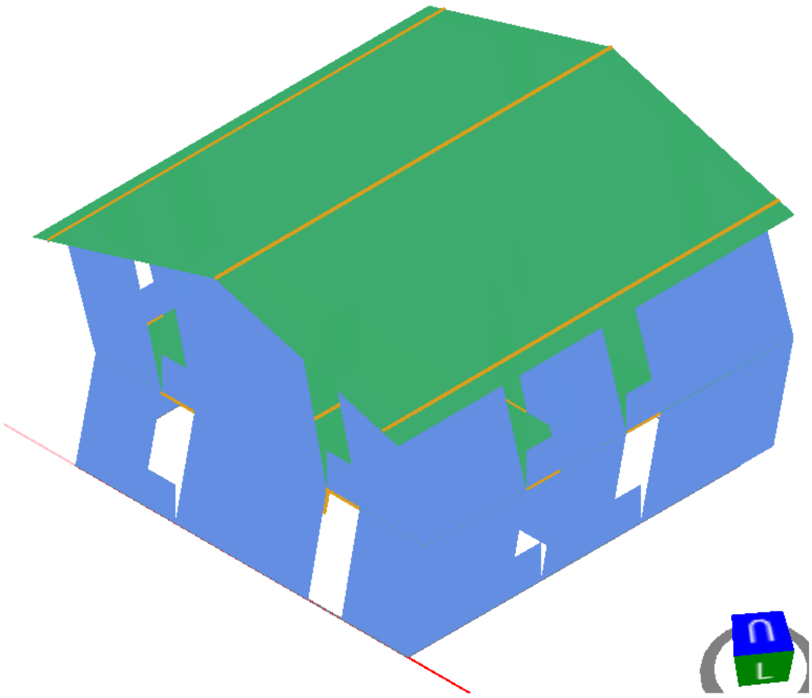
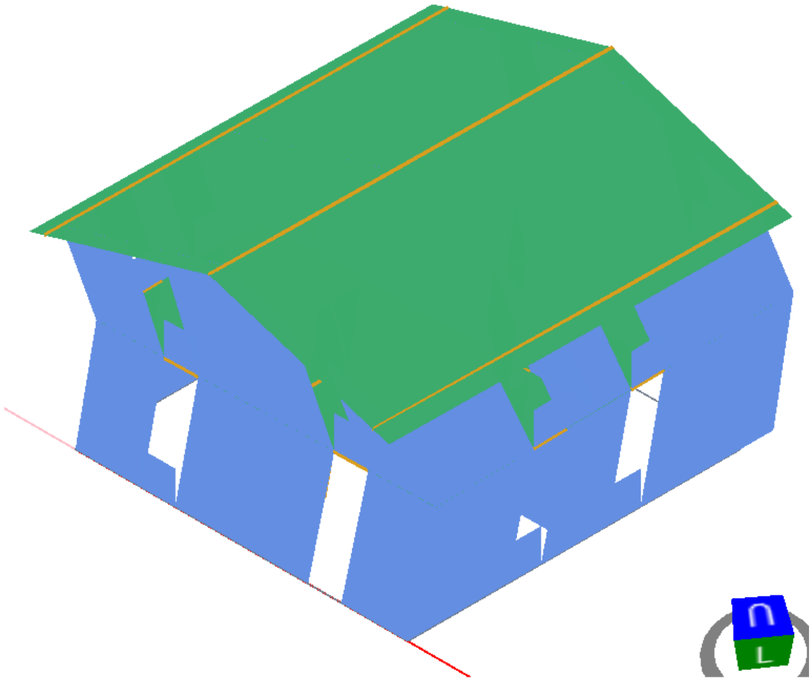
and where $\sum m_{x,j}$, $\sum m_{y,j}$ and $\sum I_{z,j}$ are the total masses acting in the axis X, Y and the total rotational inertia about the axis Z of the unrestrained *j-th* degrees of freedom.

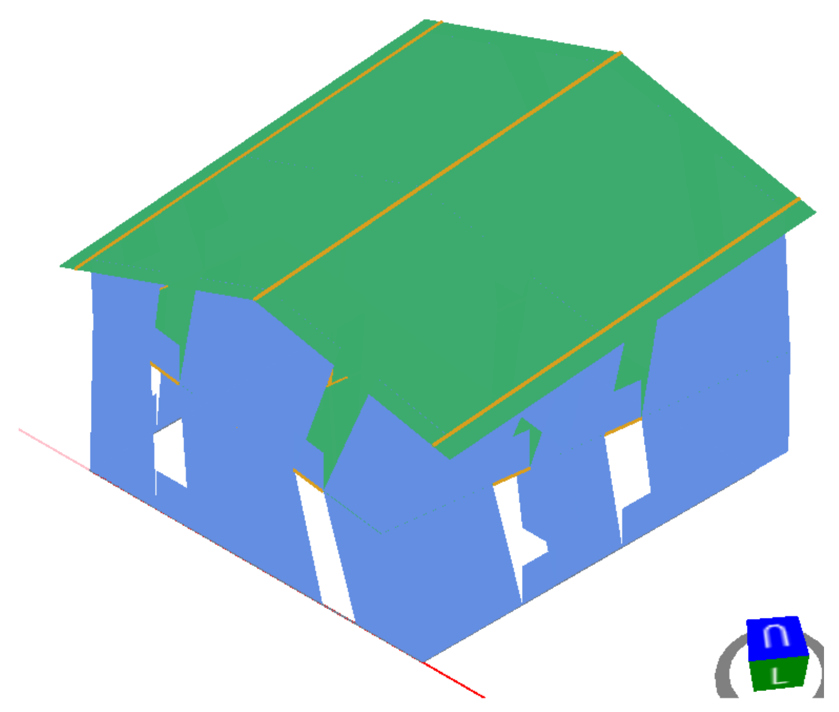
Mode	Period [s]	Frequency [Hz]	M_X [%]	Sum M_X [%]	M_Y [%]	Sum M_Y [%]	M_Z [%]	Sum M_Z [%]
Mode 1	0.22	4.61	81.51	81.51	0.09	0.09	0.28	0.28
Mode 2	0.20	5.11	0.14	81.65	84.77	84.87	2.47	2.75
Mode 3	0.15	6.67	0.18	81.83	2.70	87.57	83.35	86.10
Mode 4	0.10	9.88	18.11	99.93	0.01	87.58	0.02	86.12
Mode 5	0.09	11.09	0.03	99.96	12.07	99.65	0.52	86.64
Mode 6	0.07	14.58	0.04	100.00	0.35	100.00	13.36	100.00

The table shows, limited to the first six modes of vibration, the corresponding period and the modal deformed shape.

Mode	Period [s]	Modal deformed shape
Mode 1	0.22	

Mode 2	0.20	
Mode 3	0.15	

Mode 4	0.10	
Mode 5	0.09	

Mode 6	0.07	

Dynamic linear analysis

The dynamic linear analysis consists of:

- the calculation of the seismic effects (the seismic action is represented by the design response spectrum), of each of the vibration modes calculated in the modal analysis;
- combination of these effects.

The seismic effects of the structural model are obtained by the application of the following external loads:

$$\boldsymbol{F_x^i} = \Gamma_x^i S_d(T_i)\boldsymbol{M\Phi^i}$$

and

$$\boldsymbol{F_y^i} = \Gamma_y^i S_d(T_i)\boldsymbol{M\Phi^i}$$

where:

$\boldsymbol{F_x^i}$ and $\boldsymbol{F_y^i}$ are the external loads of the *i-th vibration mode* due to seismic action along X and Y;

$\boldsymbol{S_d}(\boldsymbol{T_i})$ is the spectrum value corresponding to the *i-th* period;

$\boldsymbol{\Phi^i}$ is the *i-th modal shape;*

Γ_x^i and Γ_y^i are the participating modal factor of the *i-th mode* given by:

$$\Gamma_x^i = \frac{[\boldsymbol{\Phi^i}]^{\boldsymbol{T}}\boldsymbol{M}\,\boldsymbol{R_x}}{[\boldsymbol{\Phi^i}]^{\boldsymbol{T}}\boldsymbol{M}\,\boldsymbol{\Phi^i}}\ and\ \Gamma_y^i = \frac{[\boldsymbol{\Phi^i}]^{\boldsymbol{T}}\boldsymbol{M}\,\boldsymbol{R_y}}{[\boldsymbol{\Phi^i}]^{\boldsymbol{T}}\boldsymbol{M}\,\boldsymbol{\Phi^i}}$$

The effects for a given direction of acceleration (along X or Y) and for each of the vibration modes are combined with the Complete Quadratic Combination technique defined as:

$$E = \left(\sum_j \sum_i \rho_{ij} \cdot E_i \cdot E_j\right)^{1/2}$$

where:

E_j is the effect of the j-th vibration mode;

ρ_{ij} is the correlation coefficient of the *i-th* mode and the *j-th* mode, given by:

$$\rho_{ij} = \frac{8\,\xi^2\beta_{ij}^{3/2}}{(1+\beta_{ij})\left[(1-\beta_{ij})\right]}$$

ξ is the damping ratio in the i-th and j-th modes;

$\beta_{ij} = T_j/T_i)$.

The following table provides the diaphragms properties.

Diaphragm	Height above the base of the timber structure [m]	xG [m]	yG [m]	Accidental eccentricity ex [m]	Accidental eccentricity ey [m]	Mass i [kg]
1	3.20	5.00	5.61	0.50	0.55	46813
2	6.63	5.00	5.60	0.55	0.60	32901

The following table provides, for each of the vibration mode, the corresponding period and value of the response spectrum, both SLV value and the SLD value.

Mode	Period [s]	SLV spectrum value [g]	SLD spectrum value [g]
Mode 1	0.22	0.22	0.33
Mode 2	0.20	0.22	0.33
Mode 3	0.14	0.22	0.32
Mode 4	0.10	0.20	0.26
Mode 5	0.09	0.20	0.25
Mode 6	0.07	0.19	0.22

Wind

The table below illustrates the horizontal forces acting on the storeys due to the wind action and the coordinates of their respective application points.

Diaphragm	Height above the reference plane [m]	xG,wind [m]	yG,wind [m]	Fx [kN]	Fy [kN]
1	3.20	5.00	5.50	47.42	42.24
2	6.63	5.00	5.50	29.31	26.23

The action effects

In this chapter are reported the internal stresses present in the structural elements and their connections caused by the different loads.

Walls

Wall name: Wall ID

N: Total axial force

V2: Shear force (in-plane)

V3: Shear force (out-of-plane)

M2-2: Bending moment (out-of-plane)

M3-3: Bending moment (in-plane)

dr: Interstory drift

Load	Wall name	N [kN]	V2 [kN]	V3 [kN]	M2-2 [kNm]	M3-3 [kNm]	dr [mm]
G1	PX1-1	3.75	0.00	0.00	0.00	0.00	0.00
G1	PY1-1	6.26	0.00	0.00	0.00	0.00	0.00
G1	PY1-2	6.96	0.00	0.00	0.00	0.00	0.00
G1	PX1-4	3.05	0.00	0.00	0.00	0.00	0.00
G1	PX1-3	3.75	0.00	0.00	0.00	0.00	0.00
G1	PY1-6	14.59	0.00	0.00	0.00	0.00	0.00
G1	PX1-6	3.05	0.00	0.00	0.00	0.00	0.00
G1	PY1-8	18.75	0.00	0.00	0.00	0.00	0.00
G1	PX1-9	3.75	0.00	0.00	0.00	0.00	0.00
G1	PY1-5	22.96	0.00	0.00	0.00	0.00	0.00
G1	PY1-4	17.88	0.00	0.00	0.00	0.00	0.00
G1	PX1-7	3.75	0.00	0.00	0.00	0.00	0.00
G1	Parete 29	0.50	0.00	0.00	0.00	0.00	N/D
G1	Parete 30	0.50	0.00	0.00	0.00	0.00	N/D
G1	Parete 34	0.50	0.00	0.00	0.00	0.00	N/D
G1	Parete 35	0.50	0.00	0.00	0.00	0.00	N/D
G1	PX1-8	9.01	0.00	0.00	0.00	0.00	0.00
G1	PY1-3	31.25	0.00	0.00	0.00	0.00	0.00
G1	PY1-7	11.12	0.00	0.00	0.00	0.00	0.00
G1	Parete 72	0.50	0.00	0.00	0.00	0.00	N/D
G1	PX1-2	14.68	0.00	0.00	0.00	0.00	0.00
G1	PX0-1	7.30	0.00	0.00	0.00	0.00	0.00
G1	Parete 78	0.50	0.00	0.00	0.00	0.00	N/D
G1	PX0-2	26.78	0.00	0.00	0.00	0.00	0.00
G1	PX0-3	7.30	0.00	0.00	0.00	0.00	0.00
G1	Parete 81	0.50	0.00	0.00	0.00	0.00	N/D
G1	PY0-6	28.52	0.00	0.00	0.00	0.00	0.00
G1	PY0-7	18.78	0.00	0.00	0.00	0.00	0.00
G1	PY0-8	25.50	0.00	0.00	0.00	0.00	0.00
G1	Parete 88	0.50	0.00	0.00	0.00	0.00	N/D
G1	Parete 89	0.50	0.00	0.00	0.00	0.00	N/D
G1	PX1-5	10.47	0.00	0.00	0.00	0.00	0.00
G1	PX0-9	14.82	0.00	0.00	0.00	0.00	0.00
G1	PX0-8	31.15	0.00	0.00	0.00	0.00	0.00
G1	PX0-7	14.82	0.00	0.00	0.00	0.00	0.00
G1	Parete 95	0.50	0.00	0.00	0.00	0.00	N/D
G1	Parete 96	0.50	0.00	0.00	0.00	0.00	N/D
G1	PY0-5	27.92	0.00	0.00	0.00	0.00	0.00
G1	PY0-4	23.73	0.00	0.00	0.00	0.00	0.00
G1	PX0-6	13.89	0.00	0.00	0.00	0.00	0.00
G1	PX0-5	34.65	0.00	0.00	0.00	0.00	0.00
G1	PX0-4	13.89	0.00	0.00	0.00	0.00	0.00
G1	PY0-3	46.55	0.00	0.00	0.00	0.00	0.00
G1	PY0-2	14.26	0.00	0.00	0.00	0.00	0.00
G1	PY0-1	11.96	0.00	0.00	0.00	0.00	0.00
G1	Parete 109	0.50	0.00	0.00	0.00	0.00	N/D
G1	Parete 110	0.50	0.00	0.00	0.00	0.00	N/D
G2	PX1-1	4.36	0.00	0.00	0.00	0.00	0.00
G2	PY1-1	6.59	0.00	0.00	0.00	0.00	0.00
G2	PY1-2	7.30	0.00	0.00	0.00	0.00	0.00
G2	PX1-4	3.66	0.00	0.00	0.00	0.00	0.00
G2	PX1-3	4.37	0.00	0.00	0.00	0.00	0.00

G2	PY1-6	15.54	0.00	0.00	0.00	0.00	0.00
G2	PX1-6	3.66	0.00	0.00	0.00	0.00	0.00
G2	PY1-8	20.01	0.00	0.00	0.00	0.00	0.00
G2	PX1-9	4.36	0.00	0.00	0.00	0.00	0.00
G2	PY1-5	25.13	0.00	0.00	0.00	0.00	0.00
G2	PY1-4	19.46	0.00	0.00	0.00	0.00	0.00
G2	PX1-7	4.37	0.00	0.00	0.00	0.00	0.00
G2	Parete 29	0.60	0.00	0.00	0.00	0.00	N/D
G2	Parete 30	0.60	0.00	0.00	0.00	0.00	N/D
G2	Parete 34	0.60	0.00	0.00	0.00	0.00	N/D
G2	Parete 35	0.60	0.00	0.00	0.00	0.00	N/D
G2	PX1-8	10.65	0.00	0.00	0.00	0.00	0.00
G2	PY1-3	33.43	0.00	0.00	0.00	0.00	0.00
G2	PY1-7	11.77	0.00	0.00	0.00	0.00	0.00
G2	Parete 72	0.60	0.00	0.00	0.00	0.00	N/D
G2	PX1-2	16.62	0.00	0.00	0.00	0.00	0.00
G2	PX0-1	8.50	0.00	0.00	0.00	0.00	0.00
G2	Parete 78	0.60	0.00	0.00	0.00	0.00	N/D
G2	PX0-2	31.25	0.00	0.00	0.00	0.00	0.00
G2	PX0-3	8.51	0.00	0.00	0.00	0.00	0.00
G2	Parete 81	0.60	0.00	0.00	0.00	0.00	N/D
G2	PY0-6	33.45	0.00	0.00	0.00	0.00	0.00
G2	PY0-7	21.29	0.00	0.00	0.00	0.00	0.00
G2	PY0-8	27.99	0.00	0.00	0.00	0.00	0.00
G2	Parete 88	0.60	0.00	0.00	0.00	0.00	N/D
G2	Parete 89	0.60	0.00	0.00	0.00	0.00	N/D
G2	PX1-5	12.19	0.00	0.00	0.00	0.00	0.00
G2	PX0-9	18.66	0.00	0.00	0.00	0.00	0.00
G2	PX0-8	39.23	0.00	0.00	0.00	0.00	0.00
G2	PX0-7	18.66	0.00	0.00	0.00	0.00	0.00
G2	Parete 95	0.60	0.00	0.00	0.00	0.00	N/D
G2	Parete 96	0.60	0.00	0.00	0.00	0.00	N/D
G2	PY0-5	30.89	0.00	0.00	0.00	0.00	0.00
G2	PY0-4	26.47	0.00	0.00	0.00	0.00	0.00
G2	PX0-6	17.63	0.00	0.00	0.00	0.00	0.00
G2	PX0-5	43.29	0.00	0.00	0.00	0.00	0.00
G2	PX0-4	17.63	0.00	0.00	0.00	0.00	0.00
G2	PY0-3	52.24	0.00	0.00	0.00	0.00	0.00
G2	PY0-2	16.57	0.00	0.00	0.00	0.00	0.00
G2	PY0-1	13.88	0.00	0.00	0.00	0.00	0.00
G2	Parete 109	0.60	0.00	0.00	0.00	0.00	N/D
G2	Parete 110	0.60	0.00	0.00	0.00	0.00	N/D
Q cat.A	PX1-1	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY1-1	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY1-2	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX1-4	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX1-3	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY1-6	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX1-6	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY1-8	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX1-9	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY1-5	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY1-4	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX1-7	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	PX1-8	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY1-3	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY1-7	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	PX1-2	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX0-1	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	PX0-2	9.39	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX0-3	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	PY0-6	17.56	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY0-7	7.53	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY0-8	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	PX1-5	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX0-9	15.04	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX0-8	30.09	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX0-7	15.04	0.00	0.00	0.00	0.00	0.00
Q cat.A	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	PY0-5	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY0-4	4.70	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX0-6	15.01	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX0-5	34.71	0.00	0.00	0.00	0.00	0.00
Q cat.A	PX0-4	15.01	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY0-3	7.50	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY0-2	10.01	0.00	0.00	0.00	0.00	0.00
Q cat.A	PY0-1	7.50	0.00	0.00	0.00	0.00	0.00
Q cat.A	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.A	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	PX1-1	0.39	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY1-1	2.75	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY1-2	3.14	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX1-4	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX1-3	0.39	0.00	0.00	0.00	0.00	0.00

Q cat.H	PY1-6	5.88	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX1-6	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY1-8	7.45	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX1-9	0.39	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY1-5	9.71	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY1-4	7.98	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX1-7	0.39	0.00	0.00	0.00	0.00	0.00
Q cat.H	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	PX1-8	0.65	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY1-3	12.16	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY1-7	4.71	0.00	0.00	0.00	0.00	0.00
Q cat.H	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	PX1-2	3.97	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX0-1	0.39	0.00	0.00	0.00	0.00	0.00
Q cat.H	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	PX0-2	3.97	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX0-3	0.39	0.00	0.00	0.00	0.00	0.00
Q cat.H	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	PY0-6	5.88	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY0-7	4.71	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY0-8	7.45	0.00	0.00	0.00	0.00	0.00
Q cat.H	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	PX1-5	1.50	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX0-9	0.39	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX0-8	0.65	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX0-7	0.39	0.00	0.00	0.00	0.00	0.00
Q cat.H	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	PY0-5	9.71	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY0-4	7.98	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX0-6	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX0-5	1.50	0.00	0.00	0.00	0.00	0.00
Q cat.H	PX0-4	0.00	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY0-3	12.16	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY0-2	3.14	0.00	0.00	0.00	0.00	0.00
Q cat.H	PY0-1	2.75	0.00	0.00	0.00	0.00	0.00
Q cat.H	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Q cat.H	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D
Snow	PX1-1	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY1-1	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY1-2	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX1-4	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX1-3	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY1-6	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX1-6	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY1-8	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX1-9	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY1-5	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY1-4	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX1-7	0.00	0.00	0.00	0.00	0.00	0.00
Snow	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Snow	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Snow	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Snow	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Snow	PX1-8	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY1-3	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY1-7	0.00	0.00	0.00	0.00	0.00	0.00
Snow	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Snow	PX1-2	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX0-1	0.00	0.00	0.00	0.00	0.00	0.00
Snow	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Snow	PX0-2	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX0-3	0.00	0.00	0.00	0.00	0.00	0.00
Snow	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Snow	PY0-6	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY0-7	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY0-8	0.00	0.00	0.00	0.00	0.00	0.00
Snow	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Snow	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Snow	PX1-5	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX0-9	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX0-8	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX0-7	0.00	0.00	0.00	0.00	0.00	0.00
Snow	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Snow	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Snow	PY0-5	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY0-4	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX0-6	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX0-5	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PX0-4	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY0-3	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY0-2	0.00	0.00	0.00	0.00	0.00	0.00
Snow	PY0-1	0.00	0.00	0.00	0.00	0.00	0.00
Snow	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Snow	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D
Ortho wind	PX1-1	-1.47	0.00	5.49	4.18	0.00	0.00
Ortho wind	PY1-1	-10.31	0.00	2.47	1.70	0.00	0.00
Ortho wind	PY1-2	-11.79	0.00	2.47	1.70	0.00	0.00
Ortho wind	PX1-4	0.00	0.00	0.00	0.00	0.00	0.00
Ortho wind	PX1-3	-1.47	0.00	5.49	4.18	0.00	0.00

Ortho wind	PY1-6	-22.09	0.00	7.42	5.10	0.00	0.00
Ortho wind	PX1-6	0.00	0.00	0.00	0.00	0.00	0.00
Ortho wind	PY1-8	-27.98	0.00	9.89	6.80	0.00	0.00
Ortho wind	PX1-9	-1.47	0.00	5.49	4.18	0.00	0.00
Ortho wind	PY1-5	-36.48	0.00	0.00	0.00	0.00	0.00
Ortho wind	PY1-4	-29.97	0.00	0.00	0.00	0.00	0.00
Ortho wind	PX1-7	-1.47	0.00	5.49	4.18	0.00	0.00
Ortho wind	Parete 29	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	Parete 30	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	Parete 34	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	Parete 35	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	PX1-8	-2.43	0.00	14.21	14.03	0.00	0.00
Ortho wind	PY1-3	-45.67	0.00	17.31	11.90	0.00	0.00
Ortho wind	PY1-7	-17.68	0.00	4.95	3.40	0.00	0.00
Ortho wind	Parete 72	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	PX1-2	-14.91	0.00	14.21	14.03	0.00	0.00
Ortho wind	PX0-1	-1.47	0.00	5.76	4.61	0.00	0.00
Ortho wind	Parete 78	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	PX0-2	-14.92	0.00	11.51	9.21	0.00	0.00
Ortho wind	PX0-3	-1.47	0.00	5.76	4.61	0.00	0.00
Ortho wind	Parete 81	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	PY0-6	-22.09	0.00	8.63	6.91	0.00	0.00
Ortho wind	PY0-7	-17.68	0.00	5.76	4.61	0.00	0.00
Ortho wind	PY0-8	-27.98	0.00	11.51	9.21	0.00	0.00
Ortho wind	Parete 88	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	Parete 89	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	PX1-5	-5.65	0.00	0.00	0.00	0.00	0.00
Ortho wind	PX0-9	-1.47	0.00	5.76	4.61	0.00	0.00
Ortho wind	PX0-8	-2.43	0.00	11.51	9.21	0.00	0.00
Ortho wind	PX0-7	-1.47	0.00	5.76	4.61	0.00	0.00
Ortho wind	Parete 95	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	Parete 96	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	PY0-5	-36.48	0.00	0.00	0.00	0.00	0.00
Ortho wind	PY0-4	-29.96	0.00	0.00	0.00	0.00	0.00
Ortho wind	PX0-6	0.00	0.00	0.00	0.00	0.00	0.00
Ortho wind	PX0-5	-5.64	0.00	0.00	0.00	0.00	0.00
Ortho wind	PX0-4	0.00	0.00	0.00	0.00	0.00	0.00
Ortho wind	PY0-3	-45.67	0.00	20.15	16.12	0.00	0.00
Ortho wind	PY0-2	-11.79	0.00	2.88	2.30	0.00	0.00
Ortho wind	PY0-1	-10.31	0.00	2.88	2.30	0.00	0.00
Ortho wind	Parete 109	0.00	0.00	0.90	0.22	0.00	N/D
Ortho wind	Parete 110	0.00	0.00	0.90	0.22	0.00	N/D
Wind X	PX1-1	0.00	2.27	0.00	0.00	6.93	0.64
Wind X	PY1-1	0.00	0.01	0.00	0.00	0.03	0.01
Wind X	PY1-2	0.00	0.01	0.00	0.00	0.03	0.01
Wind X	PX1-4	0.00	2.31	0.00	0.00	7.05	0.65
Wind X	PX1-3	0.00	2.27	0.00	0.00	6.93	0.64
Wind X	PY1-6	0.00	0.09	0.00	0.00	0.25	0.01
Wind X	PX1-6	0.00	2.31	0.00	0.00	7.05	0.65
Wind X	PY1-8	0.00	0.16	0.00	0.00	0.43	0.01
Wind X	PX1-9	0.00	2.35	0.00	0.00	7.18	0.66
Wind X	PY1-5	0.00	0.01	0.00	0.00	0.02	0.00
Wind X	PY1-4	0.00	0.00	0.00	0.00	0.01	0.00
Wind X	PX1-7	0.00	2.35	0.00	0.00	7.18	0.66
Wind X	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	PX1-8	0.00	5.24	0.00	0.00	20.69	0.66
Wind X	PY1-3	0.00	0.28	0.00	0.00	0.78	0.01
Wind X	PY1-7	0.00	0.05	0.00	0.00	0.13	0.01
Wind X	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	PX1-2	0.00	5.06	0.00	0.00	19.98	0.64
Wind X	PX0-1	0.00	4.84	0.00	0.00	22.43	0.68
Wind X	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	PX0-2	0.00	15.36	0.00	0.00	69.14	0.68
Wind X	PX0-3	0.00	4.84	0.00	0.00	22.43	0.68
Wind X	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	PY0-6	0.00	0.21	0.00	0.00	0.93	0.01
Wind X	PY0-7	0.00	0.11	0.00	0.00	0.48	0.01
Wind X	PY0-8	0.00	0.34	0.00	0.00	1.52	0.01
Wind X	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	PX1-5	0.00	5.14	0.00	0.00	20.30	0.65
Wind X	PX0-9	0.00	5.05	0.00	0.00	23.36	0.71
Wind X	PX0-8	0.00	16.03	0.00	0.00	72.00	0.71
Wind X	PX0-7	0.00	5.05	0.00	0.00	23.36	0.71
Wind X	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	PY0-5	0.00	0.02	0.00	0.00	0.09	0.00
Wind X	PY0-4	0.00	0.01	0.00	0.00	0.04	0.00
Wind X	PX0-6	0.00	4.94	0.00	0.00	22.85	0.69
Wind X	PX0-5	0.00	15.67	0.00	0.00	70.44	0.69
Wind X	PX0-4	0.00	4.94	0.00	0.00	22.85	0.69
Wind X	PY0-3	0.00	0.64	0.00	0.00	2.82	0.01
Wind X	PY0-2	0.00	0.02	0.00	0.00	0.11	0.01
Wind X	PY0-1	0.00	0.02	0.00	0.00	0.11	0.01
Wind X	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Wind X	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	PX1-1	0.00	0.13	0.00	0.00	0.39	0.04
Wind Y	PY1-1	0.00	0.46	0.00	0.00	1.27	0.37
Wind Y	PY1-2	0.00	0.46	0.00	0.00	1.27	0.37
Wind Y	PX1-4	0.00	0.01	0.00	0.00	0.02	0.00
Wind Y	PX1-3	0.00	0.13	0.00	0.00	0.39	0.04

Wind Y	PY1-6	0.00	3.42	0.00	0.00	9.41	0.44
Wind Y	PX1-6	0.00	0.01	0.00	0.00	0.02	0.00
Wind Y	PY1-8	0.00	6.01	0.00	0.00	16.53	0.44
Wind Y	PX1-9	0.00	0.13	0.00	0.00	0.41	0.04
Wind Y	PY1-5	0.00	1.63	0.00	0.00	6.93	0.40
Wind Y	PY1-4	0.00	0.81	0.00	0.00	3.43	0.40
Wind Y	PX1-7	0.00	0.13	0.00	0.00	0.41	0.04
Wind Y	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	PX1-8	0.00	0.30	0.00	0.00	1.18	0.04
Wind Y	PY1-3	0.00	11.58	0.00	0.00	31.84	0.37
Wind Y	PY1-7	0.00	1.85	0.00	0.00	5.10	0.44
Wind Y	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	PX1-2	0.00	0.28	0.00	0.00	1.11	0.04
Wind Y	PX0-1	0.00	0.29	0.00	0.00	1.33	0.04
Wind Y	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	PX0-2	0.00	0.93	0.00	0.00	4.09	0.04
Wind Y	PX0-3	0.00	0.29	0.00	0.00	1.33	0.04
Wind Y	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	PY0-6	0.00	8.56	0.00	0.00	36.79	0.60
Wind Y	PY0-7	0.00	4.30	0.00	0.00	18.85	0.60
Wind Y	PY0-8	0.00	13.64	0.00	0.00	60.17	0.60
Wind Y	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	PX1-5	0.00	0.02	0.00	0.00	0.07	0.00
Wind Y	PX0-9	0.00	0.31	0.00	0.00	1.41	0.04
Wind Y	PX0-8	0.00	0.99	0.00	0.00	4.35	0.04
Wind Y	PX0-7	0.00	0.31	0.00	0.00	1.41	0.04
Wind Y	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	PY0-5	0.00	8.01	0.00	0.00	32.56	0.56
Wind Y	PY0-4	0.00	4.02	0.00	0.00	16.31	0.56
Wind Y	PX0-6	0.00	0.02	0.00	0.00	0.08	0.00
Wind Y	PX0-5	0.00	0.06	0.00	0.00	0.26	0.00
Wind Y	PX0-4	0.00	0.02	0.00	0.00	0.08	0.00
Wind Y	PY0-3	0.00	27.79	0.00	0.00	120.77	0.52
Wind Y	PY0-2	0.00	1.08	0.00	0.00	4.72	0.52
Wind Y	PY0-1	0.00	1.08	0.00	0.00	4.72	0.52
Wind Y	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Wind Y	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	PX1-1	0.00	5.73	0.00	0.00	17.48	1.61
Dynamic SLV X	PY1-1	0.00	0.36	0.00	0.00	0.98	0.29
Dynamic SLV X	PY1-2	0.00	0.36	0.00	0.00	0.98	0.29
Dynamic SLV X	PX1-4	0.00	6.81	0.00	0.00	20.76	1.91
Dynamic SLV X	PX1-3	0.00	5.73	0.00	0.00	17.48	1.61
Dynamic SLV X	PY1-6	0.00	4.57	0.00	0.00	12.56	0.58
Dynamic SLV X	PX1-6	0.00	6.81	0.00	0.00	20.76	1.91
Dynamic SLV X	PY1-8	0.00	8.02	0.00	0.00	22.05	0.58
Dynamic SLV X	PX1-9	0.00	8.15	0.00	0.00	24.87	2.29
Dynamic SLV X	PY1-5	0.00	1.23	0.00	0.00	5.25	0.31
Dynamic SLV X	PY1-4	0.00	0.61	0.00	0.00	2.60	0.31
Dynamic SLV X	PX1-7	0.00	8.15	0.00	0.00	24.87	2.29
Dynamic SLV X	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	PX1-8	0.00	18.14	0.00	0.00	71.67	2.29
Dynamic SLV X	PY1-3	0.00	8.92	0.00	0.00	24.53	0.29
Dynamic SLV X	PY1-7	0.00	2.47	0.00	0.00	6.80	0.58
Dynamic SLV X	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	PX1-2	0.00	12.75	0.00	0.00	50.37	1.61
Dynamic SLV X	PX0-1	0.00	7.04	0.00	0.00	39.16	0.99
Dynamic SLV X	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	PX0-2	0.00	22.34	0.00	0.00	119.30	0.99
Dynamic SLV X	PX0-3	0.00	7.04	0.00	0.00	39.16	0.99
Dynamic SLV X	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	PY0-6	0.00	6.70	0.00	0.00	33.43	0.47
Dynamic SLV X	PY0-7	0.00	3.37	0.00	0.00	17.27	0.47
Dynamic SLV X	PY0-8	0.00	10.68	0.00	0.00	55.27	0.47
Dynamic SLV X	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	PX1-5	0.00	15.15	0.00	0.00	59.83	1.91
Dynamic SLV X	PX0-9	0.00	10.76	0.00	0.00	58.13	1.51
Dynamic SLV X	PX0-8	0.00	34.14	0.00	0.00	177.38	1.51
Dynamic SLV X	PX0-7	0.00	10.76	0.00	0.00	58.13	1.51
Dynamic SLV X	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	PY0-5	0.00	3.75	0.00	0.00	16.99	0.26
Dynamic SLV X	PY0-4	0.00	1.88	0.00	0.00	8.50	0.26
Dynamic SLV X	PX0-6	0.00	8.68	0.00	0.00	47.56	1.21
Dynamic SLV X	PX0-5	0.00	27.54	0.00	0.00	144.99	1.21
Dynamic SLV X	PX0-4	0.00	8.68	0.00	0.00	47.56	1.21
Dynamic SLV X	PY0-3	0.00	12.68	0.00	0.00	64.03	0.24
Dynamic SLV X	PY0-2	0.00	0.49	0.00	0.00	2.51	0.24
Dynamic SLV X	PY0-1	0.00	0.49	0.00	0.00	2.51	0.24
Dynamic SLV X	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV X	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	PX1-1	0.00	2.83	0.00	0.00	8.64	0.79
Dynamic SLV Y	PY1-1	0.00	1.21	0.00	0.00	3.32	0.97
Dynamic SLV Y	PY1-2	0.00	1.21	0.00	0.00	3.32	0.97
Dynamic SLV Y	PX1-4	0.00	1.61	0.00	0.00	4.91	0.45
Dynamic SLV Y	PX1-3	0.00	2.83	0.00	0.00	8.64	0.79

Dynamic SLV Y	PY1-6	0.00	13.31	0.00	0.00	36.61	1.70
Dynamic SLV Y	PX1-6	0.00	1.61	0.00	0.00	4.91	0.45
Dynamic SLV Y	PY1-8	0.00	23.37	0.00	0.00	64.28	1.70
Dynamic SLV Y	PX1-9	0.00	1.69	0.00	0.00	5.14	0.47
Dynamic SLV Y	PY1-5	0.00	5.28	0.00	0.00	22.45	1.31
Dynamic SLV Y	PY1-4	0.00	2.62	0.00	0.00	11.13	1.31
Dynamic SLV Y	PX1-7	0.00	1.69	0.00	0.00	5.14	0.47
Dynamic SLV Y	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	PX1-8	0.00	3.75	0.00	0.00	14.82	0.47
Dynamic SLV Y	PY1-3	0.00	30.28	0.00	0.00	83.28	0.97
Dynamic SLV Y	PY1-7	0.00	7.21	0.00	0.00	19.82	1.70
Dynamic SLV Y	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	PX1-2	0.00	6.31	0.00	0.00	24.91	0.79
Dynamic SLV Y	PX0-1	0.00	4.05	0.00	0.00	21.36	0.57
Dynamic SLV Y	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	PX0-2	0.00	12.85	0.00	0.00	65.28	0.57
Dynamic SLV Y	PX0-3	0.00	4.05	0.00	0.00	21.36	0.57
Dynamic SLV Y	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	PY0-6	0.00	20.73	0.00	0.00	101.70	1.46
Dynamic SLV Y	PY0-7	0.00	10.42	0.00	0.00	52.49	1.46
Dynamic SLV Y	PY0-8	0.00	33.04	0.00	0.00	167.89	1.46
Dynamic SLV Y	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	PX1-5	0.00	3.58	0.00	0.00	14.15	0.45
Dynamic SLV Y	PX0-9	0.00	2.54	0.00	0.00	13.06	0.35
Dynamic SLV Y	PX0-8	0.00	8.04	0.00	0.00	39.96	0.35
Dynamic SLV Y	PX0-7	0.00	2.54	0.00	0.00	13.06	0.35
Dynamic SLV Y	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	PY0-5	0.00	16.41	0.00	0.00	74.13	1.15
Dynamic SLV Y	PY0-4	0.00	8.24	0.00	0.00	37.10	1.15
Dynamic SLV Y	PX0-6	0.00	2.05	0.00	0.00	11.34	0.29
Dynamic SLV Y	PX0-5	0.00	6.49	0.00	0.00	34.56	0.29
Dynamic SLV Y	PX0-4	0.00	2.05	0.00	0.00	11.34	0.29
Dynamic SLV Y	PY0-3	0.00	47.03	0.00	0.00	230.96	0.89
Dynamic SLV Y	PY0-2	0.00	1.82	0.00	0.00	9.05	0.89
Dynamic SLV Y	PY0-1	0.00	1.82	0.00	0.00	9.05	0.89
Dynamic SLV Y	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLV Y	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	PX1-1	0.00	8.56	0.00	0.00	26.10	2.40
Dynamic SLD X	PY1-1	0.00	0.53	0.00	0.00	1.45	0.42
Dynamic SLD X	PY1-2	0.00	0.53	0.00	0.00	1.45	0.42
Dynamic SLD X	PX1-4	0.00	10.16	0.00	0.00	31.00	2.85
Dynamic SLD X	PX1-3	0.00	8.56	0.00	0.00	26.10	2.40
Dynamic SLD X	PY1-6	0.00	6.81	0.00	0.00	18.72	0.87
Dynamic SLD X	PX1-6	0.00	10.16	0.00	0.00	31.00	2.85
Dynamic SLD X	PY1-8	0.00	11.95	0.00	0.00	32.86	0.87
Dynamic SLD X	PX1-9	0.00	12.17	0.00	0.00	37.12	3.41
Dynamic SLD X	PY1-5	0.00	1.84	0.00	0.00	7.82	0.46
Dynamic SLD X	PY1-4	0.00	0.91	0.00	0.00	3.88	0.46
Dynamic SLD X	PX1-7	0.00	12.17	0.00	0.00	37.12	3.41
Dynamic SLD X	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	PX1-8	0.00	27.08	0.00	0.00	106.97	3.41
Dynamic SLD X	PY1-3	0.00	13.24	0.00	0.00	36.41	0.42
Dynamic SLD X	PY1-7	0.00	3.68	0.00	0.00	10.13	0.87
Dynamic SLD X	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	PX1-2	0.00	19.04	0.00	0.00	75.22	2.40
Dynamic SLD X	PX0-1	0.00	10.49	0.00	0.00	58.72	1.47
Dynamic SLD X	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	PX0-2	0.00	33.28	0.00	0.00	178.84	1.47
Dynamic SLD X	PX0-3	0.00	10.49	0.00	0.00	58.72	1.47
Dynamic SLD X	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	PY0-6	0.00	10.02	0.00	0.00	50.14	0.70
Dynamic SLD X	PY0-7	0.00	5.03	0.00	0.00	25.91	0.70
Dynamic SLD X	PY0-8	0.00	15.97	0.00	0.00	82.88	0.70
Dynamic SLD X	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	PX1-5	0.00	22.62	0.00	0.00	89.33	2.85
Dynamic SLD X	PX0-9	0.00	16.06	0.00	0.00	87.19	2.25
Dynamic SLD X	PX0-8	0.00	50.94	0.00	0.00	266.01	2.25
Dynamic SLD X	PX0-7	0.00	16.06	0.00	0.00	87.19	2.25
Dynamic SLD X	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	PY0-5	0.00	5.60	0.00	0.00	25.48	0.39
Dynamic SLD X	PY0-4	0.00	2.82	0.00	0.00	12.75	0.39
Dynamic SLD X	PX0-6	0.00	12.95	0.00	0.00	71.32	1.81
Dynamic SLD X	PX0-5	0.00	41.07	0.00	0.00	217.42	1.81
Dynamic SLD X	PX0-4	0.00	12.95	0.00	0.00	71.32	1.81
Dynamic SLD X	PY0-3	0.00	18.91	0.00	0.00	95.77	0.36
Dynamic SLD X	PY0-2	0.00	0.73	0.00	0.00	3.76	0.36
Dynamic SLD X	PY0-1	0.00	0.73	0.00	0.00	3.76	0.36
Dynamic SLD X	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD X	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	PX1-1	0.00	4.23	0.00	0.00	12.89	1.18
Dynamic SLD Y	PY1-1	0.00	1.80	0.00	0.00	4.95	1.45
Dynamic SLD Y	PY1-2	0.00	1.80	0.00	0.00	4.95	1.45
Dynamic SLD Y	PX1-4	0.00	2.41	0.00	0.00	7.34	0.67
Dynamic SLD Y	PX1-3	0.00	4.23	0.00	0.00	12.89	1.18

Dynamic SLD Y	PY1-6	0.00	19.87	0.00	0.00	54.63	2.54
Dynamic SLD Y	PX1-6	0.00	2.41	0.00	0.00	7.34	0.67
Dynamic SLD Y	PY1-8	0.00	34.88	0.00	0.00	95.93	2.54
Dynamic SLD Y	PX1-9	0.00	2.51	0.00	0.00	7.67	0.71
Dynamic SLD Y	PY1-5	0.00	7.88	0.00	0.00	33.50	1.96
Dynamic SLD Y	PY1-4	0.00	3.91	0.00	0.00	16.61	1.96
Dynamic SLD Y	PX1-7	0.00	2.51	0.00	0.00	7.67	0.71
Dynamic SLD Y	Parete 29	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	Parete 30	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	Parete 34	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	Parete 35	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	PX1-8	0.00	5.60	0.00	0.00	22.10	0.71
Dynamic SLD Y	PY1-3	0.00	45.10	0.00	0.00	124.04	1.45
Dynamic SLD Y	PY1-7	0.00	10.75	0.00	0.00	29.57	2.54
Dynamic SLD Y	Parete 72	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	PX1-2	0.00	9.40	0.00	0.00	37.14	1.18
Dynamic SLD Y	PX0-1	0.00	6.04	0.00	0.00	31.97	0.85
Dynamic SLD Y	Parete 78	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	PX0-2	0.00	19.17	0.00	0.00	97.70	0.85
Dynamic SLD Y	PX0-3	0.00	6.04	0.00	0.00	31.97	0.85
Dynamic SLD Y	Parete 81	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	PY0-6	0.00	31.00	0.00	0.00	152.53	2.18
Dynamic SLD Y	PY0-7	0.00	15.58	0.00	0.00	78.73	2.18
Dynamic SLD Y	PY0-8	0.00	49.41	0.00	0.00	251.83	2.18
Dynamic SLD Y	Parete 88	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	Parete 89	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	PX1-5	0.00	5.35	0.00	0.00	21.14	0.67
Dynamic SLD Y	PX0-9	0.00	3.78	0.00	0.00	19.54	0.53
Dynamic SLD Y	PX0-8	0.00	12.01	0.00	0.00	59.80	0.53
Dynamic SLD Y	PX0-7	0.00	3.78	0.00	0.00	19.54	0.53
Dynamic SLD Y	Parete 95	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	Parete 96	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	PY0-5	0.00	24.53	0.00	0.00	111.14	1.72
Dynamic SLD Y	PY0-4	0.00	12.33	0.00	0.00	55.63	1.72
Dynamic SLD Y	PX0-6	0.00	3.06	0.00	0.00	17.00	0.43
Dynamic SLD Y	PX0-5	0.00	9.70	0.00	0.00	51.81	0.43
Dynamic SLD Y	PX0-4	0.00	3.06	0.00	0.00	17.00	0.43
Dynamic SLD Y	PY0-3	0.00	70.22	0.00	0.00	345.86	1.33
Dynamic SLD Y	PY0-2	0.00	2.72	0.00	0.00	13.55	1.33
Dynamic SLD Y	PY0-1	0.00	2.72	0.00	0.00	13.55	1.33
Dynamic SLD Y	Parete 109	0.00	0.00	0.00	0.00	0.00	N/D
Dynamic SLD Y	Parete 110	0.00	0.00	0.00	0.00	0.00	N/D

Columns

Column name: Column ID

N: Total axial force

Load	Column name	N [kN]
G1	Pilastro 5	13.27
G1	Pilastro 12	30.57
G2	Pilastro 5	13.09
G2	Pilastro 12	34.22
Q cat.A	Pilastro 5	0.00
Q cat.A	Pilastro 12	31.31
Q cat.H	Pilastro 5	7.27
Q cat.H	Pilastro 12	7.27
Snow	Pilastro 5	0.00
Snow	Pilastro 12	0.00
Ortho wind	Pilastro 5	-27.31
Ortho wind	Pilastro 12	-27.31
Wind X	Pilastro 5	0.00
Wind X	Pilastro 12	0.00
Wind Y	Pilastro 5	0.00
Wind Y	Pilastro 12	0.00
Dynamic SLV X	Pilastro 5	0.00
Dynamic SLV X	Pilastro 12	0.00
Dynamic SLV Y	Pilastro 5	0.00
Dynamic SLV Y	Pilastro 12	0.00
Dynamic SLD X	Pilastro 5	0.00
Dynamic SLD X	Pilastro 12	0.00
Dynamic SLD Y	Pilastro 5	0.00
Dynamic SLD Y	Pilastro 12	0.00

Floors

Floor name: Floor ID

V2: Maximum shear stress along the local axis 2 for the most stressed element of the floor

M3-3: Maximum bending moment around local axis 3 for the most stressed element of the floor

w_{ist}: Maximum deformation for the most stressed element of the floor

Load	Floor name	V2 [kN]	M3-3 [kNm]	w_{ist} [mm]
G1	Solaio 12	2.49	3.13	1.59
G1	Solaio 13	2.49	3.13	1.59
G1	Solaio 20	2.01	2.56	0.00
G1	Solaio 21	2.01	2.57	0.00
G1	Solaio 22	2.99	4.50	3.18
G1	Solaio 23	2.99	4.50	3.18
G2	Solaio 12	3.36	4.22	2.15
G2	Solaio 13	3.36	4.22	2.15
G2	Solaio 20	2.26	2.88	0.00
G2	Solaio 21	2.26	2.89	0.00
G2	Solaio 22	4.04	6.08	4.29
G2	Solaio 23	4.04	6.08	4.29
Q cat.A	Solaio 12	4.98	6.26	3.18
Q cat.A	Solaio 13	4.98	6.26	3.18
Q cat.A	Solaio 20	0.00	0.00	0.00
Q cat.A	Solaio 21	0.00	0.00	0.00
Q cat.A	Solaio 22	5.98	9.01	6.36
Q cat.A	Solaio 23	5.98	9.01	6.36
Q cat.H	Solaio 12	0.00	0.00	0.00
Q cat.H	Solaio 13	0.00	0.00	0.00
Q cat.H	Solaio 20	1.26	1.60	0.00
Q cat.H	Solaio 21	1.26	1.60	0.00
Q cat.H	Solaio 22	0.00	0.00	0.00
Q cat.H	Solaio 23	0.00	0.00	0.00
Snow	Solaio 12	0.00	0.00	0.00
Snow	Solaio 13	0.00	0.00	0.00
Snow	Solaio 20	0.00	0.00	0.00
Snow	Solaio 21	0.00	0.00	0.00
Snow	Solaio 22	0.00	0.00	0.00
Snow	Solaio 23	0.00	0.00	0.00
Ortho wind	Solaio 12	0.00	0.00	0.00
Ortho wind	Solaio 13	0.00	0.00	0.00
Ortho wind	Solaio 20	4.72	6.02	1.67
Ortho wind	Solaio 21	4.73	6.03	1.67
Ortho wind	Solaio 22	0.00	0.00	0.00
Ortho wind	Solaio 23	0.00	0.00	0.00
Wind X	Solaio 12	0.00	0.00	0.00
Wind X	Solaio 13	0.00	0.00	0.00
Wind X	Solaio 20	0.00	0.00	0.00
Wind X	Solaio 21	0.00	0.00	0.00
Wind X	Solaio 22	0.00	0.00	0.00
Wind X	Solaio 23	0.00	0.00	0.00
Wind Y	Solaio 12	0.00	0.00	0.00
Wind Y	Solaio 13	0.00	0.00	0.00
Wind Y	Solaio 20	0.00	0.00	0.00
Wind Y	Solaio 21	0.00	0.00	0.00
Wind Y	Solaio 22	0.00	0.00	0.00
Wind Y	Solaio 23	0.00	0.00	0.00
Dynamic SLV X	Solaio 12	0.00	0.00	0.00
Dynamic SLV X	Solaio 13	0.00	0.00	0.00
Dynamic SLV X	Solaio 20	0.00	0.00	0.00
Dynamic SLV X	Solaio 21	0.00	0.00	0.00
Dynamic SLV X	Solaio 22	0.00	0.00	0.00
Dynamic SLV X	Solaio 23	0.00	0.00	0.00
Dynamic SLV Y	Solaio 12	0.00	0.00	0.00
Dynamic SLV Y	Solaio 13	0.00	0.00	0.00
Dynamic SLV Y	Solaio 20	0.00	0.00	0.00
Dynamic SLV Y	Solaio 21	0.00	0.00	0.00
Dynamic SLV Y	Solaio 22	0.00	0.00	0.00
Dynamic SLV Y	Solaio 23	0.00	0.00	0.00

Dynamic SLD X	Solaio 12	0.00	0.00	0.00
Dynamic SLD X	Solaio 13	0.00	0.00	0.00
Dynamic SLD X	Solaio 20	0.00	0.00	0.00
Dynamic SLD X	Solaio 21	0.00	0.00	0.00
Dynamic SLD X	Solaio 22	0.00	0.00	0.00
Dynamic SLD X	Solaio 23	0.00	0.00	0.00
Dynamic SLD Y	Solaio 12	0.00	0.00	0.00
Dynamic SLD Y	Solaio 13	0.00	0.00	0.00
Dynamic SLD Y	Solaio 20	0.00	0.00	0.00
Dynamic SLD Y	Solaio 21	0.00	0.00	0.00
Dynamic SLD Y	Solaio 22	0.00	0.00	0.00
Dynamic SLD Y	Solaio 23	0.00	0.00	0.00

Beams

Beam name: Beam ID

V2: Maximum shear stress along the local axis 2

M3-3: Maximum bending moment around local axis 3

w_{ist}: Maximum deformation for the most stressed element of the floor

Load	Beam name	V2 [kN]	M3-3 [kNm]	w_{ist} [mm]
G1	Trave 35	6.45	2.96	-0.13
G1	Trave 36	0.34	0.09	0.01
G1	Trave 37	0.34	0.09	0.01
G1	Trave 39	1.57	0.40	0.03
G1	Trave 40	0.34	0.09	0.01
G1	Trave 42	1.82	0.46	0.03
G1	Trave 43	1.82	0.46	0.03
G1	Trave 46	1.57	0.40	0.03
G1	Trave 47	1.57	0.40	0.03
G1	Trave 48	8.27	4.16	0.18
G1	Trave 49	0.16	0.04	0.00
G1	Trave 50	1.40	0.35	0.01
G1	Trave 51	1.39	0.35	0.01
G1	Trave 52	1.61	0.41	0.01
G1	Trave 53	1.61	0.41	0.01
G2	Trave 35	6.80	3.12	-0.14
G2	Trave 36	0.29	0.07	0.01
G2	Trave 37	0.29	0.07	0.01
G2	Trave 39	1.95	0.50	0.03
G2	Trave 40	0.29	0.07	0.01
G2	Trave 42	2.28	0.58	0.04
G2	Trave 43	2.28	0.58	0.04
G2	Trave 46	1.95	0.50	0.03
G2	Trave 47	1.95	0.50	0.03
G2	Trave 48	10.50	5.28	0.23
G2	Trave 49	0.00	0.00	0.00
G2	Trave 50	1.41	0.35	0.01
G2	Trave 51	1.41	0.35	0.01
G2	Trave 52	1.99	0.51	0.01
G2	Trave 53	1.99	0.51	0.01
Q cat.A	Trave 35	0.00	0.00	0.00
Q cat.A	Trave 36	0.00	0.00	0.00
Q cat.A	Trave 37	0.00	0.00	0.00
Q cat.A	Trave 39	2.46	0.63	0.04
Q cat.A	Trave 40	0.00	0.00	0.00
Q cat.A	Trave 42	2.95	0.75	0.05
Q cat.A	Trave 43	2.95	0.75	0.05
Q cat.A	Trave 46	2.45	0.63	0.04
Q cat.A	Trave 47	2.45	0.63	0.04
Q cat.A	Trave 48	15.56	7.83	0.34
Q cat.A	Trave 49	0.00	0.00	0.00
Q cat.A	Trave 50	0.00	0.00	0.00
Q cat.A	Trave 51	0.00	0.00	0.00
Q cat.A	Trave 52	2.94	0.75	0.02
Q cat.A	Trave 53	2.94	0.75	0.02
Q cat.H	Trave 35	3.78	1.73	-0.08
Q cat.H	Trave 36	0.00	0.00	0.00
Q cat.H	Trave 37	0.00	0.00	0.00
Q cat.H	Trave 39	0.00	0.00	0.00
Q cat.H	Trave 40	0.00	0.00	0.00
Q cat.H	Trave 42	0.00	0.00	0.00
Q cat.H	Trave 43	0.00	0.00	0.00
Q cat.H	Trave 46	0.00	0.00	0.00
Q cat.H	Trave 47	0.00	0.00	0.00

Q cat.H	Trave 48	0.00	0.00	0.00
Q cat.H	Trave 49	0.00	0.00	0.00
Q cat.H	Trave 50	0.78	0.20	0.00
Q cat.H	Trave 51	0.78	0.20	0.00
Q cat.H	Trave 52	0.00	0.00	0.00
Q cat.H	Trave 53	0.00	0.00	0.00
Snow	Trave 35	0.00	0.00	0.00
Snow	Trave 36	0.00	0.00	0.00
Snow	Trave 37	0.00	0.00	0.00
Snow	Trave 39	0.00	0.00	0.00
Snow	Trave 40	0.00	0.00	0.00
Snow	Trave 42	0.00	0.00	0.00
Snow	Trave 43	0.00	0.00	0.00
Snow	Trave 46	0.00	0.00	0.00
Snow	Trave 47	0.00	0.00	0.00
Snow	Trave 48	0.00	0.00	0.00
Snow	Trave 49	0.00	0.00	0.00
Snow	Trave 50	0.00	0.00	0.00
Snow	Trave 51	0.00	0.00	0.00
Snow	Trave 52	0.00	0.00	0.00
Snow	Trave 53	0.00	0.00	0.00
Ortho wind	Trave 35	14.18	6.52	0.29
Ortho wind	Trave 36	0.00	0.00	0.00
Ortho wind	Trave 37	0.00	0.00	0.00
Ortho wind	Trave 39	0.00	0.00	0.00
Ortho wind	Trave 40	0.00	0.00	0.00
Ortho wind	Trave 42	0.00	0.00	0.00
Ortho wind	Trave 43	0.00	0.00	0.00
Ortho wind	Trave 46	0.00	0.00	0.00
Ortho wind	Trave 47	0.00	0.00	0.00
Ortho wind	Trave 48	0.00	0.00	0.00
Ortho wind	Trave 49	0.00	0.00	0.00
Ortho wind	Trave 50	2.95	0.74	-0.01
Ortho wind	Trave 51	2.95	0.74	-0.01
Ortho wind	Trave 52	0.00	0.00	0.00
Ortho wind	Trave 53	0.00	0.00	0.00
Wind X	Trave 35	0.00	0.00	0.00
Wind X	Trave 36	0.00	0.00	0.00
Wind X	Trave 37	0.00	0.00	0.00
Wind X	Trave 39	0.00	0.00	0.00
Wind X	Trave 40	0.00	0.00	0.00
Wind X	Trave 42	0.00	0.00	0.00
Wind X	Trave 43	0.00	0.00	0.00
Wind X	Trave 46	0.00	0.00	0.00
Wind X	Trave 47	0.00	0.00	0.00
Wind X	Trave 48	0.00	0.00	0.00
Wind X	Trave 49	0.00	0.00	0.00
Wind X	Trave 50	0.00	0.00	0.00
Wind X	Trave 51	0.00	0.00	0.00
Wind X	Trave 52	0.00	0.00	0.00
Wind X	Trave 53	0.00	0.00	0.00
Wind Y	Trave 35	0.00	0.00	0.00
Wind Y	Trave 36	0.00	0.00	0.00
Wind Y	Trave 37	0.00	0.00	0.00
Wind Y	Trave 39	0.00	0.00	0.00
Wind Y	Trave 40	0.00	0.00	0.00
Wind Y	Trave 42	0.00	0.00	0.00
Wind Y	Trave 43	0.00	0.00	0.00
Wind Y	Trave 46	0.00	0.00	0.00
Wind Y	Trave 47	0.00	0.00	0.00
Wind Y	Trave 48	0.00	0.00	0.00
Wind Y	Trave 49	0.00	0.00	0.00
Wind Y	Trave 50	0.00	0.00	0.00
Wind Y	Trave 51	0.00	0.00	0.00
Wind Y	Trave 52	0.00	0.00	0.00
Wind Y	Trave 53	0.00	0.00	0.00
Dynamic SLV X	Trave 35	0.00	0.00	0.00
Dynamic SLV X	Trave 36	0.00	0.00	0.00
Dynamic SLV X	Trave 37	0.00	0.00	0.00
Dynamic SLV X	Trave 39	0.00	0.00	0.00
Dynamic SLV X	Trave 40	0.00	0.00	0.00
Dynamic SLV X	Trave 42	0.00	0.00	0.00
Dynamic SLV X	Trave 43	0.00	0.00	0.00
Dynamic SLV X	Trave 46	0.00	0.00	0.00
Dynamic SLV X	Trave 47	0.00	0.00	0.00
Dynamic SLV X	Trave 48	0.00	0.00	0.00
Dynamic SLV X	Trave 49	0.00	0.00	0.00
Dynamic SLV X	Trave 50	0.00	0.00	0.00
Dynamic SLV X	Trave 51	0.00	0.00	0.00
Dynamic SLV X	Trave 52	0.00	0.00	0.00
Dynamic SLV X	Trave 53	0.00	0.00	0.00
Dynamic SLV Y	Trave 35	0.00	0.00	0.00
Dynamic SLV Y	Trave 36	0.00	0.00	0.00
Dynamic SLV Y	Trave 37	0.00	0.00	0.00
Dynamic SLV Y	Trave 39	0.00	0.00	0.00
Dynamic SLV Y	Trave 40	0.00	0.00	0.00
Dynamic SLV Y	Trave 42	0.00	0.00	0.00
Dynamic SLV Y	Trave 43	0.00	0.00	0.00
Dynamic SLV Y	Trave 46	0.00	0.00	0.00
Dynamic SLV Y	Trave 47	0.00	0.00	0.00

Dynamic SLV Y	Trave 48	0.00	0.00	0.00
Dynamic SLV Y	Trave 49	0.00	0.00	0.00
Dynamic SLV Y	Trave 50	0.00	0.00	0.00
Dynamic SLV Y	Trave 51	0.00	0.00	0.00
Dynamic SLV Y	Trave 52	0.00	0.00	0.00
Dynamic SLV Y	Trave 53	0.00	0.00	0.00
Dynamic SLD X	Trave 35	0.00	0.00	0.00
Dynamic SLD X	Trave 36	0.00	0.00	0.00
Dynamic SLD X	Trave 37	0.00	0.00	0.00
Dynamic SLD X	Trave 39	0.00	0.00	0.00
Dynamic SLD X	Trave 40	0.00	0.00	0.00
Dynamic SLD X	Trave 42	0.00	0.00	0.00
Dynamic SLD X	Trave 43	0.00	0.00	0.00
Dynamic SLD X	Trave 46	0.00	0.00	0.00
Dynamic SLD X	Trave 47	0.00	0.00	0.00
Dynamic SLD X	Trave 48	0.00	0.00	0.00
Dynamic SLD X	Trave 49	0.00	0.00	0.00
Dynamic SLD X	Trave 50	0.00	0.00	0.00
Dynamic SLD X	Trave 51	0.00	0.00	0.00
Dynamic SLD X	Trave 52	0.00	0.00	0.00
Dynamic SLD X	Trave 53	0.00	0.00	0.00
Dynamic SLD Y	Trave 35	0.00	0.00	0.00
Dynamic SLD Y	Trave 36	0.00	0.00	0.00
Dynamic SLD Y	Trave 37	0.00	0.00	0.00
Dynamic SLD Y	Trave 39	0.00	0.00	0.00
Dynamic SLD Y	Trave 40	0.00	0.00	0.00
Dynamic SLD Y	Trave 42	0.00	0.00	0.00
Dynamic SLD Y	Trave 43	0.00	0.00	0.00
Dynamic SLD Y	Trave 46	0.00	0.00	0.00
Dynamic SLD Y	Trave 47	0.00	0.00	0.00
Dynamic SLD Y	Trave 48	0.00	0.00	0.00
Dynamic SLD Y	Trave 49	0.00	0.00	0.00
Dynamic SLD Y	Trave 50	0.00	0.00	0.00
Dynamic SLD Y	Trave 51	0.00	0.00	0.00
Dynamic SLD Y	Trave 52	0.00	0.00	0.00
Dynamic SLD Y	Trave 53	0.00	0.00	0.00

Forces and moments acting at the base of the structure

In this chapter are reported the values of actions acting at the base of the walls and columns of the ground floor. With regard to the walls the first row of the table shows the values of the actions related to the ULS combination that maximizes the axial force, the second row shows the values of the actions related to the seismic or horizontal ULS combination that that maximizes the moment acting in the plane of the wall M3-3 and the shear force V2 (also acting in the plane of the wall) and that, at the same time, minimizes the axial force N. Following is instead reported the actions at the foot of the walls associated with the different loads considered individually.

Walls

Wall name: Wall ID

N: Total axial force

V2: Shear force (in-plane)

V3: Shear force (out-of-plane)

M2-2: Bending moment (out-of-plane)

M3-3: Bending moment (in-plane)

Wall name	Length [m]	Load / Comb.	N [kN]	V2 [kN]	V3 [kN]	M2-2 [kNm]	M3-3 [kNm]
PX0-1	2.00	ULS 71	21.92	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey-	15.80	10.62	0.00	0.00	57.60
		G1	7.30	0.00	0.00	0.00	0.00
		G2	8.50	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	0.39	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-1.47	0.00	5.76	0.00	0.00
		Wind X	0.00	4.84	0.00	0.00	22.43
		Wind Y	0.00	0.29	0.00	0.00	1.33
		Dynamic SLV X	0.00	7.04	0.00	0.00	39.16
		Dynamic SLV Y	0.00	4.05	0.00	0.00	21.36
		Dynamic SLD X	0.00	10.49	0.00	0.00	58.72
		Dynamic SLD Y	0.00	6.04	0.00	0.00	31.97
Parete 78	1.00	ULS 71	1.49	0.00	0.00	0.00	0.00
		Horizontal ULS 1	1.10	0.00	0.00	0.00	0.00
		G1	0.50	0.00	0.00	0.00	0.00
		G2	0.60	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	0.00	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	0.00	0.00	0.90	0.00	0.00
		Wind X	0.00	0.00	0.00	0.00	0.00
		Wind Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD Y	0.00	0.00	0.00	0.00	0.00
PX0-2	4.00	ULS 70	94.17	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey-	60.85	33.69	0.00	0.00	175.72
		G1	26.78	0.00	0.00	0.00	0.00
		G2	31.25	0.00	0.00	0.00	0.00
		Q cat.A	9.39	0.00	0.00	0.00	0.00
		Q cat.H	3.97	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-14.92	0.00	11.51	0.00	0.00
		Wind X	0.00	15.36	0.00	0.00	69.14
		Wind Y	0.00	0.93	0.00	0.00	4.09
		Dynamic SLV X	0.00	22.34	0.00	0.00	119.30
		Dynamic SLV Y	0.00	12.85	0.00	0.00	65.28
		Dynamic SLD X	0.00	33.28	0.00	0.00	178.84
		Dynamic SLD Y	0.00	19.17	0.00	0.00	97.70

PX0-3	2.00	ULS 71	21.93	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey-	15.81	10.62	0.00	0.00	57.60
		G1	7.30	0.00	0.00	0.00	0.00
		G2	8.51	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	0.39	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-1.47	0.00	5.76	0.00	0.00
		Wind X	0.00	4.84	0.00	0.00	22.43
		Wind Y	0.00	0.29	0.00	0.00	1.33
		Dynamic SLV X	0.00	7.04	0.00	0.00	39.16
		Dynamic SLV Y	0.00	4.05	0.00	0.00	21.36
		Dynamic SLD X	0.00	10.49	0.00	0.00	58.72
		Dynamic SLD Y	0.00	6.04	0.00	0.00	31.97
PY0-6	3.00	ULS 70	110.91	0.00	0.00	0.00	0.00
		Dynamic SLV 5 ex+ ey+	67.23	22.74	0.00	0.00	111.73
		G1	28.52	0.00	0.00	0.00	0.00
		G2	33.45	0.00	0.00	0.00	0.00
		Q cat.A	17.56	0.00	0.00	0.00	0.00
		Q cat.H	5.88	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-22.09	0.00	8.63	0.00	0.00
		Wind X	0.00	0.21	0.00	0.00	0.93
		Wind Y	0.00	8.56	0.00	0.00	36.79
		Dynamic SLV X	0.00	6.70	0.00	0.00	33.43
		Dynamic SLV Y	0.00	20.73	0.00	0.00	101.70
		Dynamic SLD X	0.00	10.02	0.00	0.00	50.14
		Dynamic SLD Y	0.00	31.00	0.00	0.00	152.53
PY0-7	2.00	ULS 70	69.06	0.00	0.00	0.00	0.00
		Dynamic SLV 5 ex+ ey+	42.33	11.43	0.00	0.00	57.67
		G1	18.78	0.00	0.00	0.00	0.00
		G2	21.29	0.00	0.00	0.00	0.00
		Q cat.A	7.53	0.00	0.00	0.00	0.00
		Q cat.H	4.71	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-17.68	0.00	5.76	0.00	0.00
		Wind X	0.00	0.11	0.00	0.00	0.48
		Wind Y	0.00	4.30	0.00	0.00	18.85
		Dynamic SLV X	0.00	3.37	0.00	0.00	17.27
		Dynamic SLV Y	0.00	10.42	0.00	0.00	52.49
		Dynamic SLD X	0.00	5.03	0.00	0.00	25.91
		Dynamic SLD Y	0.00	15.58	0.00	0.00	78.73
PY0-8	4.00	ULS 71	83.39	0.00	0.00	0.00	0.00
		Dynamic SLV 5 ex+ ey+	53.49	36.24	0.00	0.00	184.47
		G1	25.50	0.00	0.00	0.00	0.00
		G2	27.99	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	7.45	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-27.98	0.00	11.51	0.00	0.00
		Wind X	0.00	0.34	0.00	0.00	1.52
		Wind Y	0.00	13.64	0.00	0.00	60.17
		Dynamic SLV X	0.00	10.68	0.00	0.00	55.27
		Dynamic SLV Y	0.00	33.04	0.00	0.00	167.89
		Dynamic SLD X	0.00	15.97	0.00	0.00	82.88
		Dynamic SLD Y	0.00	49.41	0.00	0.00	251.83
Parete 88	1.00	ULS 71	1.49	0.00	0.00	0.00	0.00
		Horizontal ULS 1	1.10	0.00	0.00	0.00	0.00
		G1	0.50	0.00	0.00	0.00	0.00
		G2	0.60	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	0.00	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	0.00	0.00	0.90	0.00	0.00
		Wind X	0.00	0.00	0.00	0.00	0.00
		Wind Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD Y	0.00	0.00	0.00	0.00	0.00
Parete 89	1.00	ULS 71	1.49	0.00	0.00	0.00	0.00
		Horizontal ULS 1	1.10	0.00	0.00	0.00	0.00
		G1	0.50	0.00	0.00	0.00	0.00
		G2	0.60	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	0.00	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	0.00	0.00	0.90	0.00	0.00
		Wind X	0.00	0.00	0.00	0.00	0.00
		Wind Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD Y	0.00	0.00	0.00	0.00	0.00

PX0-9	2.00	ULS 66	67.75	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey+	37.99	11.52	0.00	0.00	62.05
		G1	14.82	0.00	0.00	0.00	0.00
		G2	18.66	0.00	0.00	0.00	0.00
		Q cat.A	15.04	0.00	0.00	0.00	0.00
		Q cat.H	0.39	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-1.47	0.00	5.76	0.00	0.00
		Wind X	0.00	5.05	0.00	0.00	23.36
		Wind Y	0.00	0.31	0.00	0.00	1.41
		Dynamic SLV X	0.00	10.76	0.00	0.00	58.13
		Dynamic SLV Y	0.00	2.54	0.00	0.00	13.06
		Dynamic SLD X	0.00	16.06	0.00	0.00	87.19
		Dynamic SLD Y	0.00	3.78	0.00	0.00	19.54
PX0-8	4.00	ULS 66	140.15	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey+	79.41	36.55	0.00	0.00	189.37
		G1	31.15	0.00	0.00	0.00	0.00
		G2	39.23	0.00	0.00	0.00	0.00
		Q cat.A	30.09	0.00	0.00	0.00	0.00
		Q cat.H	0.65	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-2.43	0.00	11.51	0.00	0.00
		Wind X	0.00	16.03	0.00	0.00	72.00
		Wind Y	0.00	0.99	0.00	0.00	4.35
		Dynamic SLV X	0.00	34.14	0.00	0.00	177.38
		Dynamic SLV Y	0.00	8.04	0.00	0.00	39.96
		Dynamic SLD X	0.00	50.94	0.00	0.00	266.01
		Dynamic SLD Y	0.00	12.01	0.00	0.00	59.80
PX0-7	2.00	ULS 66	67.77	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey+	38.00	11.52	0.00	0.00	62.05
		G1	14.82	0.00	0.00	0.00	0.00
		G2	18.66	0.00	0.00	0.00	0.00
		Q cat.A	15.04	0.00	0.00	0.00	0.00
		Q cat.H	0.39	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-1.47	0.00	5.76	0.00	0.00
		Wind X	0.00	5.05	0.00	0.00	23.36
		Wind Y	0.00	0.31	0.00	0.00	1.41
		Dynamic SLV X	0.00	10.76	0.00	0.00	58.13
		Dynamic SLV Y	0.00	2.54	0.00	0.00	13.06
		Dynamic SLD X	0.00	16.06	0.00	0.00	87.19
		Dynamic SLD Y	0.00	3.78	0.00	0.00	19.54
PY0-5	3.00	ULS 71	93.97	0.00	0.00	0.00	0.00
		Dynamic SLV 8 ex- ey+	58.82	17.61	0.00	0.00	79.39
		G1	27.92	0.00	0.00	0.00	0.00
		G2	30.89	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	9.71	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-36.48	0.00	0.00	0.00	0.00
		Wind X	0.00	0.02	0.00	0.00	0.09
		Wind Y	0.00	8.01	0.00	0.00	32.56
		Dynamic SLV X	0.00	3.75	0.00	0.00	16.99
		Dynamic SLV Y	0.00	16.41	0.00	0.00	74.13
		Dynamic SLD X	0.00	5.60	0.00	0.00	25.48
		Dynamic SLD Y	0.00	24.53	0.00	0.00	111.14
PY0-4	2.00	ULS 70	84.67	0.00	0.00	0.00	0.00
		Dynamic SLV 8 ex- ey+	51.61	8.85	0.00	0.00	39.73
		G1	23.73	0.00	0.00	0.00	0.00
		G2	26.47	0.00	0.00	0.00	0.00
		Q cat.A	4.70	0.00	0.00	0.00	0.00
		Q cat.H	7.98	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-29.96	0.00	0.00	0.00	0.00
		Wind X	0.00	0.01	0.00	0.00	0.04
		Wind Y	0.00	4.02	0.00	0.00	16.31
		Dynamic SLV X	0.00	1.88	0.00	0.00	8.50
		Dynamic SLV Y	0.00	8.24	0.00	0.00	37.10
		Dynamic SLD X	0.00	2.82	0.00	0.00	12.75
		Dynamic SLD Y	0.00	12.33	0.00	0.00	55.63
PX0-6	2.00	ULS 67	65.06	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey-	36.02	9.39	0.00	0.00	51.46
		G1	13.89	0.00	0.00	0.00	0.00
		G2	17.63	0.00	0.00	0.00	0.00
		Q cat.A	15.01	0.00	0.00	0.00	0.00
		Q cat.H	0.00	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	0.00	0.00	0.00	0.00	0.00
		Wind X	0.00	4.94	0.00	0.00	22.85
		Wind Y	0.00	0.02	0.00	0.00	0.08
		Dynamic SLV X	0.00	8.68	0.00	0.00	47.56
		Dynamic SLV Y	0.00	2.05	0.00	0.00	11.34
		Dynamic SLD X	0.00	12.95	0.00	0.00	71.32
		Dynamic SLD Y	0.00	3.06	0.00	0.00	17.00

PX0-5	4.00	ULS 66	157.29	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey-	88.35	29.79	0.00	0.00	156.91
		G1	34.65	0.00	0.00	0.00	0.00
		G2	43.29	0.00	0.00	0.00	0.00
		Q cat.A	34.71	0.00	0.00	0.00	0.00
		Q cat.H	1.50	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-5.64	0.00	0.00	0.00	0.00
		Wind X	0.00	15.67	0.00	0.00	70.44
		Wind Y	0.00	0.06	0.00	0.00	0.26
		Dynamic SLV X	0.00	27.54	0.00	0.00	144.99
		Dynamic SLV Y	0.00	6.49	0.00	0.00	34.56
		Dynamic SLD X	0.00	41.07	0.00	0.00	217.42
		Dynamic SLD Y	0.00	9.70	0.00	0.00	51.81
PX0-4	2.00	ULS 67	65.06	0.00	0.00	0.00	0.00
		Dynamic SLV 1 ex+ ey-	36.02	9.39	0.00	0.00	51.46
		G1	13.89	0.00	0.00	0.00	0.00
		G2	17.63	0.00	0.00	0.00	0.00
		Q cat.A	15.01	0.00	0.00	0.00	0.00
		Q cat.H	0.00	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	0.00	0.00	0.00	0.00	0.00
		Wind X	0.00	4.94	0.00	0.00	22.85
		Wind Y	0.00	0.02	0.00	0.00	0.08
		Dynamic SLV X	0.00	8.68	0.00	0.00	47.56
		Dynamic SLV Y	0.00	2.05	0.00	0.00	11.34
		Dynamic SLD X	0.00	12.95	0.00	0.00	71.32
		Dynamic SLD Y	0.00	3.06	0.00	0.00	17.00
PY0-3	7.00	ULS 70	159.48	0.00	0.00	0.00	0.00
		Dynamic SLV 8 ex- ey+	101.04	68.44	0.00	0.00	339.53
		G1	46.55	0.00	0.00	0.00	0.00
		G2	52.24	0.00	0.00	0.00	0.00
		Q cat.A	7.50	0.00	0.00	0.00	0.00
		Q cat.H	12.16	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-45.67	0.00	20.15	0.00	0.00
		Wind X	0.00	0.64	0.00	0.00	2.82
		Wind Y	0.00	27.79	0.00	0.00	120.77
		Dynamic SLV X	0.00	12.68	0.00	0.00	64.03
		Dynamic SLV Y	0.00	47.03	0.00	0.00	230.96
		Dynamic SLD X	0.00	18.91	0.00	0.00	95.77
		Dynamic SLD Y	0.00	70.22	0.00	0.00	345.86
PY0-2	1.00	ULS 70	56.83	0.00	0.00	0.00	0.00
		Dynamic SLV 8 ex- ey+	33.83	2.65	0.00	0.00	13.31
		G1	14.26	0.00	0.00	0.00	0.00
		G2	16.57	0.00	0.00	0.00	0.00
		Q cat.A	10.01	0.00	0.00	0.00	0.00
		Q cat.H	3.14	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-11.79	0.00	2.88	0.00	0.00
		Wind X	0.00	0.02	0.00	0.00	0.11
		Wind Y	0.00	1.08	0.00	0.00	4.72
		Dynamic SLV X	0.00	0.49	0.00	0.00	2.51
		Dynamic SLV Y	0.00	1.82	0.00	0.00	9.05
		Dynamic SLD X	0.00	0.73	0.00	0.00	3.76
		Dynamic SLD Y	0.00	2.72	0.00	0.00	13.55
PY0-1	1.00	ULS 70	46.88	0.00	0.00	0.00	0.00
		Dynamic SLV 8 ex- ey+	28.09	2.65	0.00	0.00	13.31
		G1	11.96	0.00	0.00	0.00	0.00
		G2	13.88	0.00	0.00	0.00	0.00
		Q cat.A	7.50	0.00	0.00	0.00	0.00
		Q cat.H	2.75	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	-10.31	0.00	2.88	0.00	0.00
		Wind X	0.00	0.02	0.00	0.00	0.11
		Wind Y	0.00	1.08	0.00	0.00	4.72
		Dynamic SLV X	0.00	0.49	0.00	0.00	2.51
		Dynamic SLV Y	0.00	1.82	0.00	0.00	9.05
		Dynamic SLD X	0.00	0.73	0.00	0.00	3.76
		Dynamic SLD Y	0.00	2.72	0.00	0.00	13.55
Parete 109	1.00	ULS 71	1.49	0.00	0.00	0.00	0.00
		Horizontal ULS 1	1.10	0.00	0.00	0.00	0.00
		G1	0.50	0.00	0.00	0.00	0.00
		G2	0.60	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	0.00	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	0.00	0.00	0.90	0.00	0.00
		Wind X	0.00	0.00	0.00	0.00	0.00
		Wind Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD Y	0.00	0.00	0.00	0.00	0.00

Parete 110	1.00	ULS 71	1.49	0.00	0.00	0.00	0.00
		Horizontal ULS 1	1.10	0.00	0.00	0.00	0.00
		G1	0.50	0.00	0.00	0.00	0.00
		G2	0.60	0.00	0.00	0.00	0.00
		Q cat.A	0.00	0.00	0.00	0.00	0.00
		Q cat.H	0.00	0.00	0.00	0.00	0.00
		Snow	0.00	0.00	0.00	0.00	0.00
		Ortho wind	0.00	0.00	0.90	0.00	0.00
		Wind X	0.00	0.00	0.00	0.00	0.00
		Wind Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLV Y	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD X	0.00	0.00	0.00	0.00	0.00
		Dynamic SLD Y	0.00	0.00	0.00	0.00	0.00

Columns

Column name: Column ID

N: Total axial force

Column name	Load / Comb.	N [kN]
Pilastro 12	ULS 66	134.44
	G1	30.57
	G2	34.22
	Q cat.A	31.31
	Q cat.H	7.27
	Snow	0.00
	Ortho wind	-27.31
	Wind X	0.00
	Wind Y	0.00
	Dynamic SLV X	0.00
	Dynamic SLV Y	0.00
	Dynamic SLD X	0.00
	Dynamic SLD Y	0.00

Capacity design

Dissipative structural behavior

Earthquake-resistant timber buildings should be designed considering either:

- **dissipative structural behaviour;**
- **low-dissipative structural behaviour.**

In the first concept the capability of parts of the structure (dissipative zones) to resist earthquake actions out of their elastic range is taken into account. Dissipative zones shall be located in joints and connections, whereas the timber members themselves shall be regarded as behaving elastically.

In the second concept the action effects are calculated on the basis of an elastic global analysis without taking into account non-linear material behaviour.

Ductility classes

Depending on their ductile behaviour and energy dissipation capacity under seismic actions, buildings shall be assigned to one of the three following ductility classes:

- **DCH, high capacity to dissipate energy;**
- **DCM, medium capacity to dissipate energy;**
- **DCL, low capacity to dissipate energy.**

In DCH and DCM the European standard (UNI EN 1998-1 §8.1.3) requires the use of the capacity design procedure.

The capacity design has the purpose of ensuring a ductile behaviour to the dissipative structure and operates as follows:

- distinguishes elements and mechanisms, both local and global, into ductile and fragile;
- aims to avoid local brittle ruptures and the activation of global brittle or unstable mechanisms;
- aims at locating the energy dissipations by hysteresis in areas of the ductile elements identified and designed for this purpose.

Overstrength factor

To ensure the correct behaviour of the structure, the seismic resistance of the local/global brittle elements/mechanisms must be designed to be grater than that of the ductile elements/mechanisms. To ensure compliance with this inequality, both locally and globally, the strength of the ductile elements/mechanisms is increased by means of a suitable coefficient γ_{Rd} known as the “overstrength factor". Starting from this increased capacity, the capacity of the brittle elements/mechanisms is sized.

Limitation of the stresses to the values determined in the non-dissipative case

The resistance demand evaluated with the capacity design criteria can be assumed not to exceed the strength demand evaluated for the non-dissipative structural behaviour.

Calculation procedure

Applying capacity design locally and globally

The capacity design imposes, as a preliminary step, the definition of which are the dissipative zones and which are the non-dissipative zones. These zones depend on the ductility class adopted and on the structural typology

Planning according to capacity design procedures is therefore divided into two application "levels":

- **local level, related to the connection of the structure;**
- **global level, related to the walls and the building.**

The first has the purpose of avoiding the prevalence of brittle failure modes in dissipative connections. The second instead provides for the application of a series of rules aimed at avoiding non-dissipative collapse mechanisms and fragile breakages of the elements that make up the structure.

Calculation of design resistances

The design strength of the dissipative zones is defined by the following formula:

$$F_{Rd,ductile} = k_{R,deg} \cdot k_{mod} \cdot \frac{F_{Rk,ductile}}{\gamma_M}$$

where:

$F_{Rd,ductile}$ is the design value of the strength of the dissipative zones;

$k_{R,deg}$ is the strength reduction factor due to cyclic degradation;

k_{mod} is the modification factor for duration of load and moisture content;

$F_{Rk,ductile}$ is the characteristic value of the strength of the dissipative zones;

γ_M is the material partial factor.

The design strength of the non-dissipative zones is defined by the following formula:

$$F_{Rd,brittle} = k_{mod} \cdot \frac{F_{Rk,brittle}}{\gamma_M}$$

where:

$F_{Rd,brittle}$ is the design value of the strength of the non-dissipative zones;

k_{mod} is the modification factor for duration of load and moisture content;

$F_{Rk,brittle}$ is the characteristic value of the strength of the non-dissipative zones;

γ_M is the material partial factor.

Check dissipative zones

The dissipative zones against the seismic actions calculated with the dissipative behavior factor need to be verified according to the following expression:

$$F_{Ed,ductile} \leq F_{Rd,ductile} = k_{R,deg} \cdot k_{mod} \cdot \frac{F_{Rk,ductile}}{\gamma_M}$$

where:

$F_{Ed,ductile}$ is the design value of the effect of actions of the dissipative zones;

$F_{Rd,ductile}$ is the design value of the strength of the dissipative zones;

$F_{Rk,ductile}$ is the characteristic value of the strength of the dissipative zones;

$k_{R,deg}$ is the strength reduction factor due to cyclic degradation;

k_{mod} is the modification factor for duration of load and moisture content;

γ_M is the material partial factor.

Check non-dissipative zones – Local level

In order to ensure compliance with the rules of capacity design at the local level (connection), it must be verified that the resistances associated with the brittle failure modes are over-resistant compared to the resistance associated with the ductile failure mode:

$$F_{Rd,brittle} \geq \frac{\gamma_{Rd}}{k_{R,deg}} \cdot F_{Rd,ductile}$$

where:

γ_{Rd} is the overstrength factor;

$k_{R,deg}$ is the resistance degradation coefficient due to cyclic actions;

$F_{Rd,ductile}$ is the design value of the strength of the dissipative zones;

$F_{Rd,brittle}$ is the design value of the strength of the non-dissipative zones.

In other words, the fragile elements of the dissipative connections must be verified for a stress equal to:

$$F_{Ed,brittle} = \frac{\gamma_{Rd}}{k_{R,deg}} \cdot F_{Rd,ductile}$$

where:

γ_{Rd} is the overstrength factor;

$k_{R,deg}$ is the resistance degradation coefficient due to cyclic actions;

$F_{Ed,brittle}$ is the design value of the effect of actions of the non-dissipative zones;

$F_{Rd,ductile}$ is the design value of the strength of the dissipative zones;

Check non-dissipative zones – Global level

The non-dissipative zones need to be checked towards the actions deriving from the application of the capacity design rules. The design effect of the actions is obtained through the following relationship:

$$F_{Ed,brittle} = \Omega \cdot F_{Ed,brittle,E} + F_{Ed,brittle,G}$$

where:

$F_{Ed,brittle}$ is the design action effect in the non-dissipative connection or member;

Ω is the structure overstrength ratio (in both x and y directions);

$F_{Ed,brittle,E}$ is the action effect in the non-dissipative connection or member of the design seismic action;

$F_{Ed,brittle,G}$ is the action effect in the non-dissipative connection or member of the non-seismic actions in the design seismic situation.

Dissipative zones and non-dissipative zones

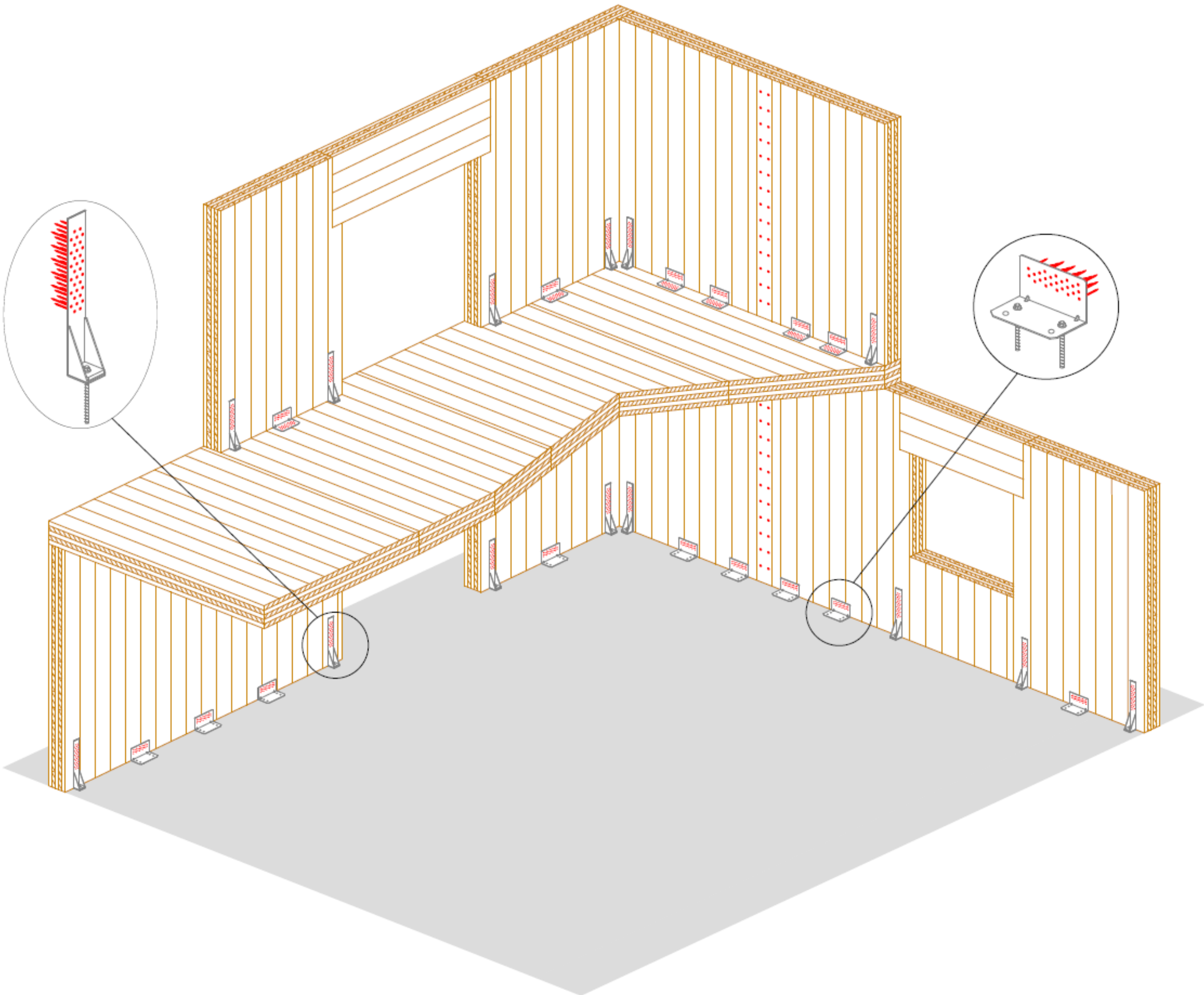
For CLT walls, the dissipative zones consist of:

- mechanical connections between walls;
- ductile elements of the traction connection (for example the nailing);
- ductile elements of the shear connection (for example the nailing).

The non-dissipative zones are instead represented by:

- brittle elements of the traction connection (for example the concrete anchors);
- brittle elements of the shear connection (for example the concrete anchors);

- timber elements.



Determination of the overstrength ratio

The overstrength ratio for each floor of the building and for each direction is determined by the following expression:

$$\Omega_{i,j} = min\left\{\frac{\sum_{k=1}^{N_{i,j}} V_{Rd,i,j,k}^{CLT,CD}}{\sum_{k=1}^{N_{i,j}} |V_{Ed,i,j,k}|};\frac{\sum_{k=1}^{N_{i,j}} V_{Rd,i,j,k}^{ang,CD}}{\sum_{k=1}^{N_{i,j}} |V_{Ed,i,j,k}|};\frac{\sum_{k=1}^{N_{i,j}} M_{Rd,i,j,k}^{hd,CD}}{\sum_{k=1}^{N_{i,j}} |M_{Ed,i,j,k}|}\right\}$$

where:

$\sum_{k=1}^{N_{i,j}} V_{Rd,i,j,k}^{CLT,CD}$ is the sum of the design resistances related to the vertical mechanical connection between CLT walls of the j-th shear wall at the i-th storey, taking into account the overstrength factor through the ratio $\gamma_{Rd}/k_{R,deg}$;

$\sum_{k=1}^{N_{i,j}} V_{Rd,i,j,k}^{ang,CD}$ is the sum of the design lateral strength related to shear connections of the j-th shear wall at the i-th storey, taking into account the overstrength factor through the ratio $\gamma_{Rd}/k_{R,deg}$;

$\sum_{k=1}^{N_{i,j}} M_{Rd,i,j,k}^{hd,CD}$ is the sum of the design rocking strength of the j-th shear wall at the i-th storey, taking into account the overstrength factor through the ratio $\gamma_{Rd}/k_{R,deg}$;

$\sum_{k=1}^{N_{i,j}} |V_{Ed,i,j,k}|$ is the sum of the absolute values of the design global shear of the j-th shear wall at the i-th storey due to the seismic action;

$\sum_{k=1}^{N_{i,j}} |M_{Ed,i,j,k}|$ is the sum of the absolute values of the design rocking moment of the jth shear wall at the i-th storey due to the seismic action;

$\boldsymbol{N_{i,j}}$ is the number of shear-walls parallel to the seismic action at the i-th storey.

Overstrength ratios (dynamic analysis)

The following table shows the various contributions that contribute to the determination of the overstrength ratio for the x direction for the various levels of the building.

Diaphragms	Ωx related to the tensile connections	Ωx related to the shear connections	Ωx related to the sheathing panels connections	Ωx related to the jointed CLT connections	Ωx minimum
1	2.04	3.01	-	-	2.04
2	2.07	5.18	-	-	2.07

Overstrength ratio for the x direction: 2.04

Similarly, the following table shows the various contributions that contribute to the determination of the overstrength ratio for the y direction for the various levels of the building.

Diaphragms	Ωy related to the tensile connections	Ωy related to the shear connections	Ωy related to the sheathing panels connections	Ωy related to the jointed CLT connections	Ωy minimum
1	2.26	2.78	-	-	2.26
2	3.55	4.76	-	-	3.55

Overstrength ratio for the y direction: 2.26

Limitation of actions to the values determined in the non-dissipative case: Yes

DCL behavior factor q_{DCL} 1.50

Design of the structural elements

CLT floors

Calculation model

The calculation model adopted for the design of CLT in bending out-of-plane is that of mechanically jointed beams with deformable connection in accordance with Appendix B of EN 1995-1-1. The shear flexibility of the transverse layers is considered using the γ-method (gamma): namely with Möhler theory for CLT panel having up to 3 layers oriented in the direction of calculation and with Shelling theory for CLT panel having more than 3 layers oriented in the direction of calculation.

The effective bending stiffness is taken as:

$$EJ_{eff} = \sum_{i=1}^{n} \left(E_i J_i + \gamma_i E_i A_i a_i^2 \right)$$

$$\gamma_i = \left[1 + \frac{\pi^2 E_i A_i}{G_R \cdot \frac{b}{d} \cdot l_{ref}^2} \right]^{-1}$$

where:

J_i is the moment of inertia of layer i in reference to its neutral axis;

A_i is the cross-sectional area of layer i;

a_i is the distance between the centre of gravity of layer i and centre of gravity of the CLT element;

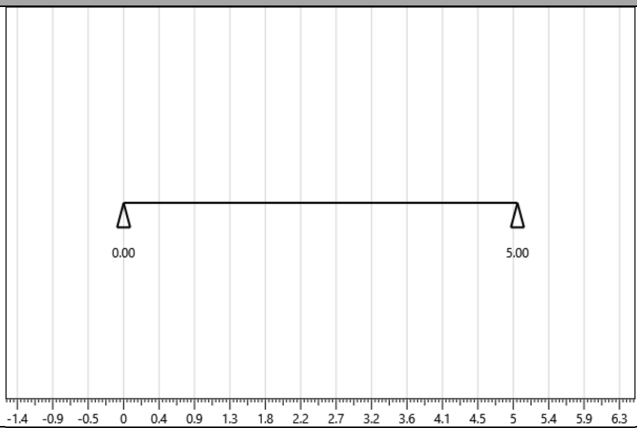
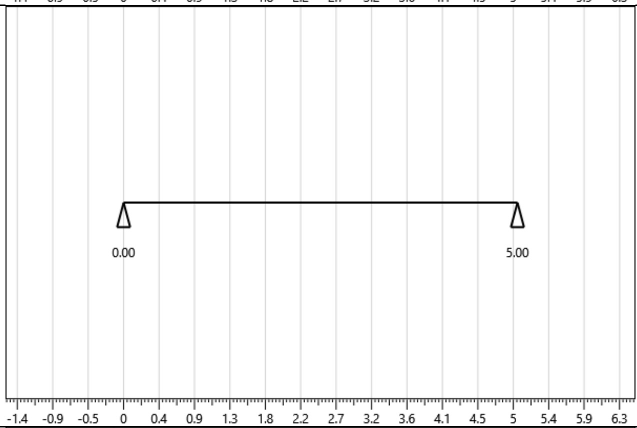
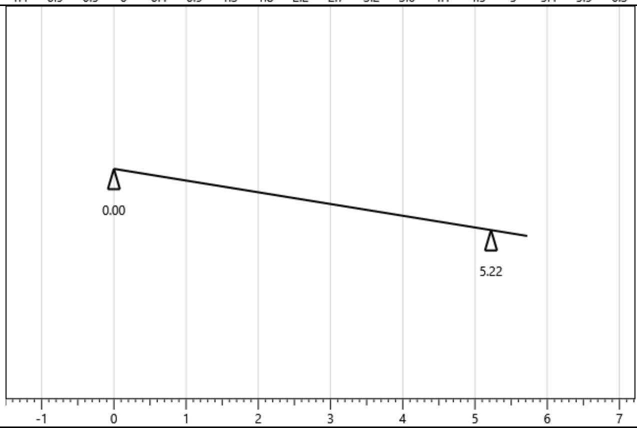
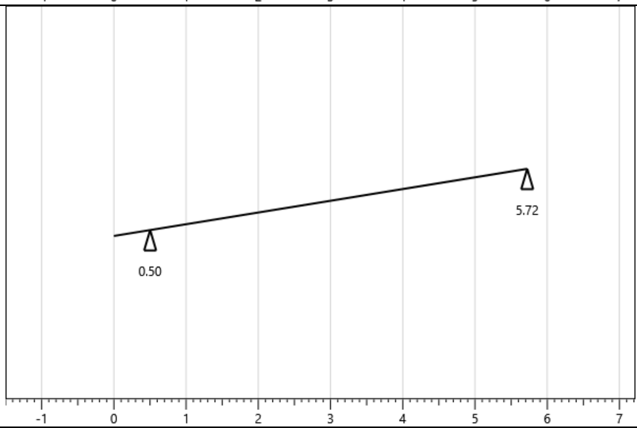
l_{ref} is the reference length of the span;

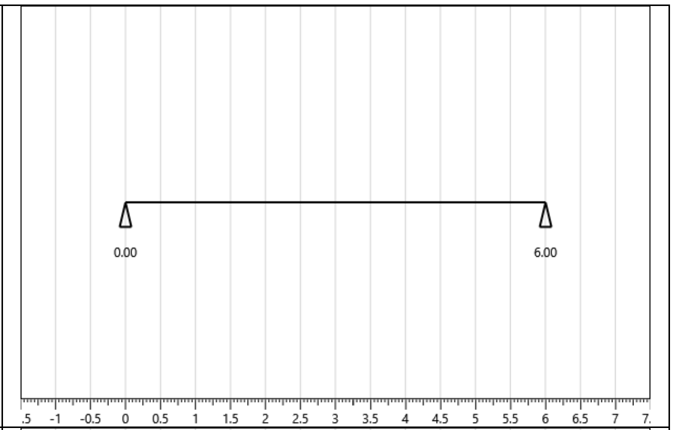
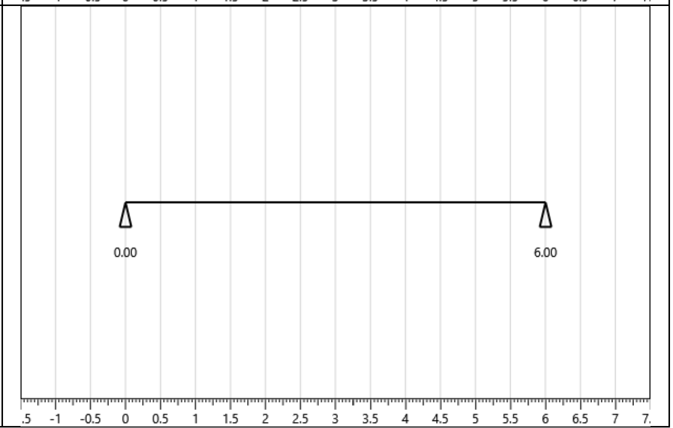
G_R is the rolling shear modulus (mean value).

The reference length of the spans (l_{ref}) is taken, depending on the static scheme, as reported in the following table.

Structural scheme	Reference length of the span
Simply supported beam	$l_{ref} = l$
Span of a continuous beam	$l_{ref} = 0.8\ l$
Internal support of a continuous beam	$l_{ref} = 0.8\ l_{min}$
Cantilever	$l_{ref} = 2\ l$

The following table shows, for each floor and relatively to the different spans, the values of the reference lengths of the spans, the effective moment of inertia of the cross-sections of the CLT floor and the structural scheme adopted.

Floor name	Calculation width of the strip of floor [m]	Reference length l_{ref} [m]	Jeff [mm^4]	Structural scheme
Solaio 12	1	5.00	4.656E8	
Solaio 13	1	5.00	4.656E8	
Solaio 20	1	4.18 1.00	2.779E8 1.215E8	
Solaio 21	1	1.00 4.18	1.218E8 2.779E8	

Solaio 22	1	6.00	4.83E8	
Solaio 23	1	6.00	4.83E8	

Bending strength

The checks are conducted according to § 6.1.6 of EN 1995-1-1. The following expression shall be satisfied:

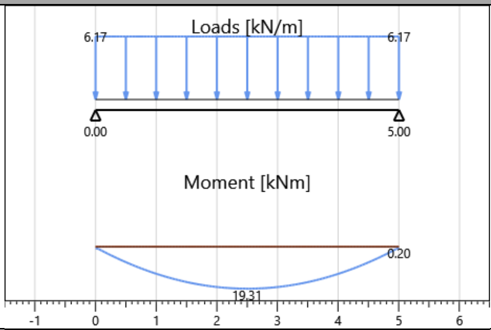
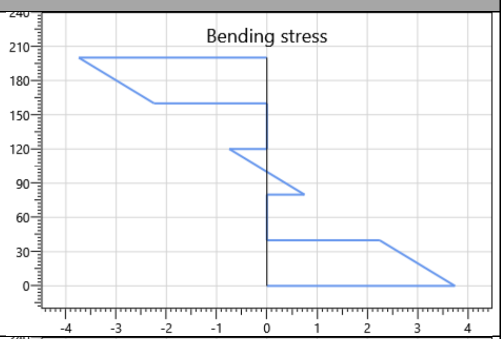
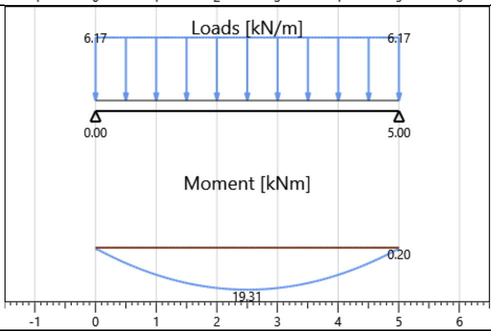
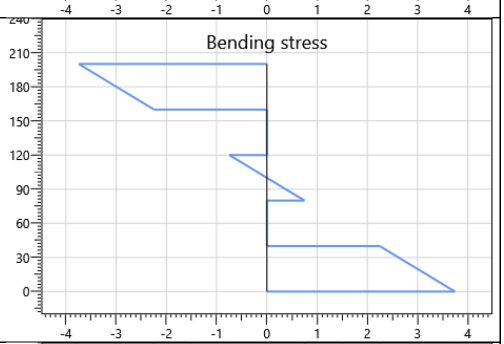
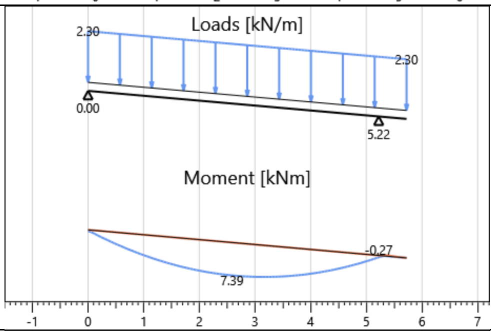
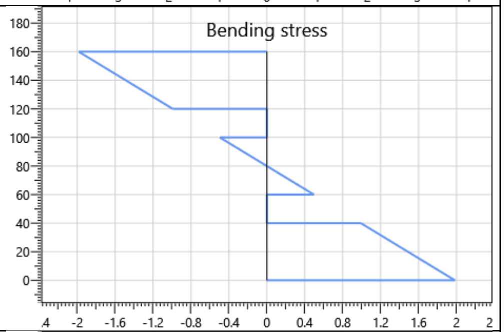
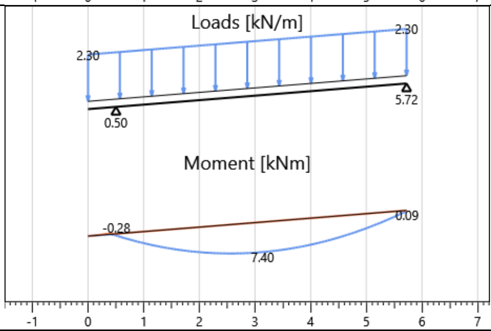
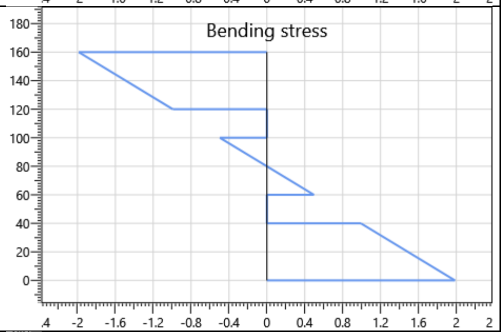
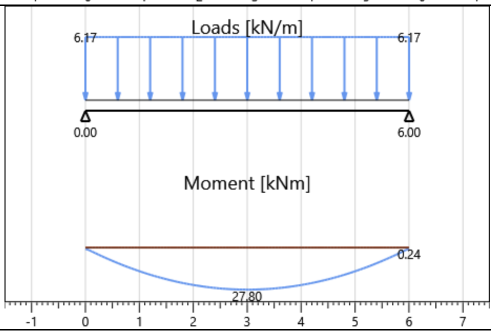
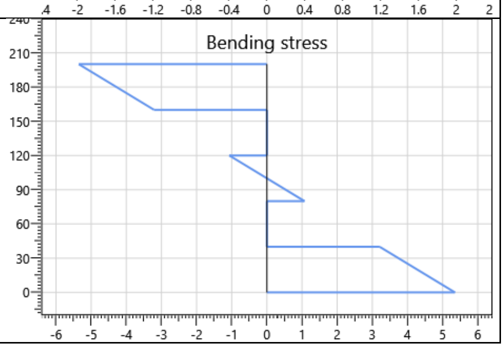
$$\frac{\sigma_{m,d}}{f_{m,d}} \leq 1$$

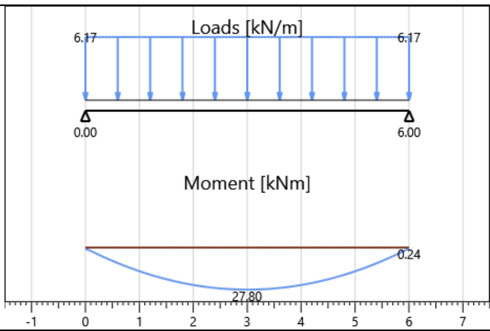
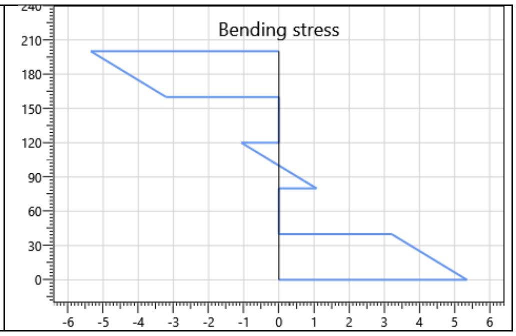
where:

$\sigma_{m,d}$ is the design bending stress;

$f_{m,d}$ isthe design bending strength.

The following table illustrates the structural schemes and the envelopes of the diagram of the bending moment for the part of each floor with the most sever checks.

Floor name	Combination	Duration	Diagram M_{3-3}	Bending stresses
Solaio 12	ULS 65	Medium-term		
Solaio 13	ULS 65	Medium-term		
Solaio 20	ULS 64	Permanent		
Solaio 21	ULS 64	Permanent		
Solaio 22	ULS 65	Medium-term		

Solaio 23	ULS 65	Medium-term		

The checks are summarized below. The values resulting from the calculations, relating to each verification, are reported in the form of a percentage.

Floor name	Section	$M_{3\text{-}3}$ [kNm]	J_{eff} [mm^4]	Comb.	Service class	k_{mod}	γ_M	$f_{m,d}$ [MPa]	$\sigma_{m,d}$ [MPa]	Check
Solaio 12	CLT floor	19.31	465593315	ULS 65	1	0.8	1.25	15.36	3.74	24%
Solaio 13	CLT floor	19.31	465593315	ULS 65	1	0.8	1.25	15.36	3.74	24%
Solaio 20	CLT roof	7.39	277929841	ULS 64	1	0.6	1.25	11.52	1.98	17%
Solaio 21	CLT roof	7.40	277922204	ULS 64	1	0.6	1.25	11.52	1.99	17%
Solaio 22	CLT floor	27.80	482977788	ULS 65	1	0.8	1.25	15.36	5.35	35%
Solaio 23	CLT floor	27.80	482977788	ULS 65	1	0.8	1.25	15.36	5.35	35%

Shear strength

Shear strength of the layers parallel to the calculation direction

The checks are conducted according to § 6.1.7 of EN 1995-1-1. The following expression shall be satisfied:

$$\frac{\tau_{v,d}}{f_{v,d}} \leq 1$$

where:

$\tau_{v,d}$ is the design shear stress;

$f_{v,d}$ is the design shear strength for the actual condition.

The maximum design shear stress in the longitudinal layers can be evaluated using the following expression:

$$\tau_{v,d} = \frac{V_d \cdot S_{max}}{J_{eff} \cdot b}$$

where:

V_d is the total shear force at the location in question;

S_{max} is the statical moment of area;

J_{eff} is the effective moment of inertia of the CLT element cross section;

b is the width of the CLT element cross section ($k_{cr} = 1$).

Rolling shear strength of the transversal layers

The checks are conducted according to § 6.1.7 of EN 1995-1-1. The following expression shall be satisfied:

$$\frac{\tau_{R,d}}{f_{v,R,d}} \leq 1$$

where:

$\tau_{R,d}$ the design rolling shear stress;

$f_{v,R,d}$ the design shear strength.

The maximum design shear stress in the transversal layers can be evaluated using the following expression:

$$\tau_{R,d} = \frac{V_d \cdot S_{R,max}}{J_{eff} \cdot b}$$

where:

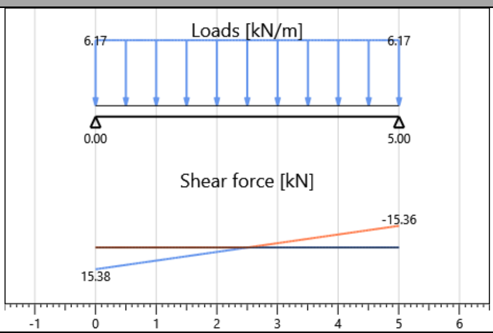
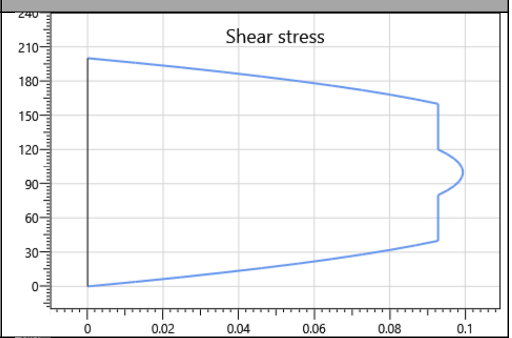
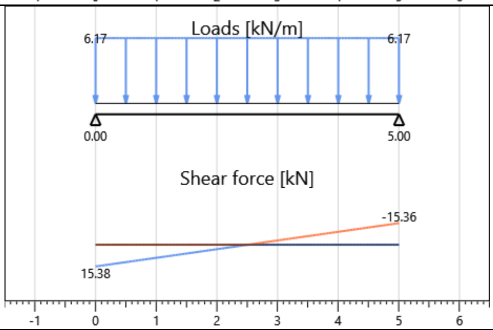
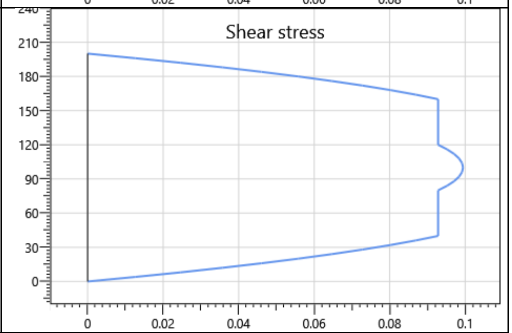
V_d is the total shear force at the location in question;

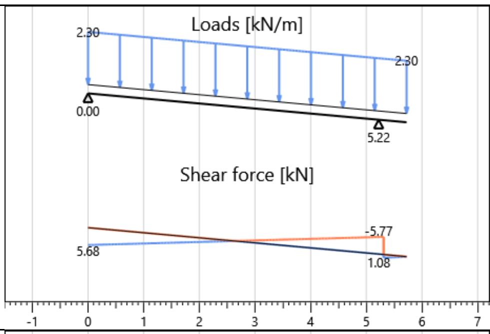
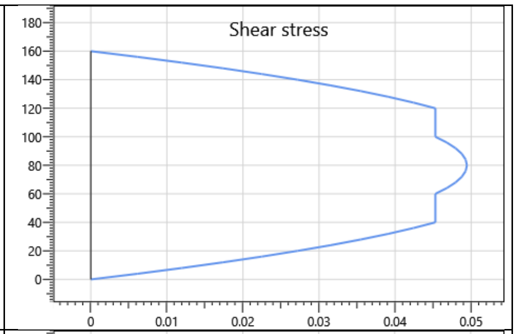
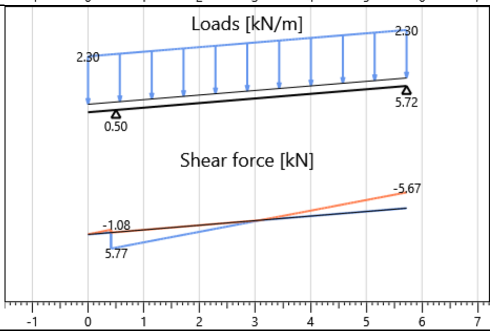
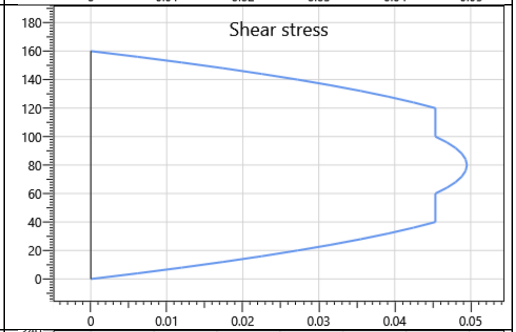
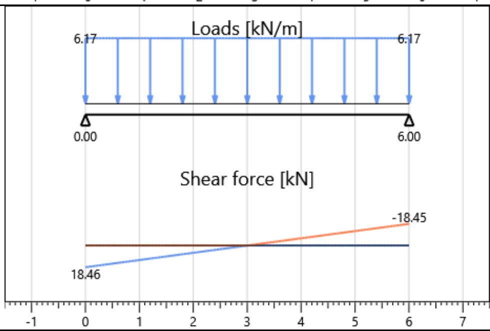
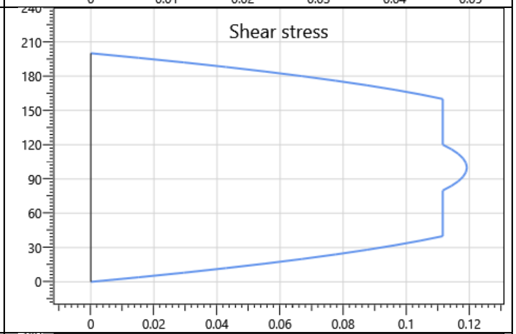
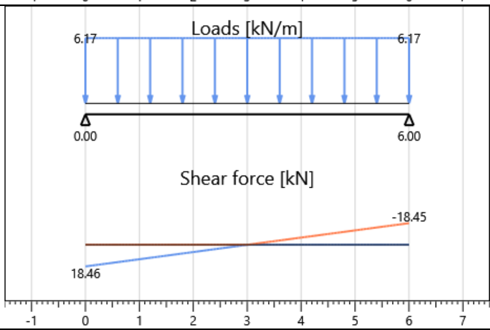
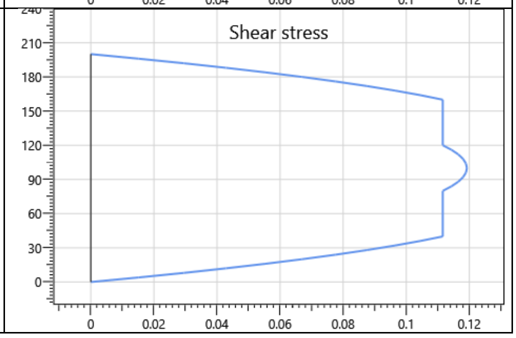
$S_{R,max}$ is the statical moment of area;

J_{eff} is the effective moment of inertia of the CLT element cross section;

b is the width of the CLT element cross section ($k_{cr} = 1$).

The following table illustrates the structural schemes and the envelopes of the diagram of the shear force for the part of each floor with the most sever checks.

Floor name	Combination	Duration	Diagram V_2	Shear stresses
Solaio 12	ULS 65	Medium-term		
Solaio 13	ULS 65	Medium-term		

Solaio 20	ULS 64	Permanent		
Solaio 21	ULS 64	Permanent		
Solaio 22	ULS 65	Medium-term		
Solaio 23	ULS 65	Medium-term		

The checks are summarized below. The values resulting from the calculations, relating to each verification, are reported in the form of a percentage.

Floor name	Cross section	V_2 [kN]	J_{eff} [mm^4]	Comb.	Service Class	k_{mod}	γ_M	$f_{v,d}$ [MPa]	$\tau_{v,d}$ [MPa]	Check	$f_{R,d}$ [MPa]	$\tau_{R,d}$ [MPa]	Check
Solaio 12	CLT floor	15.38	465593315	ULS 65	1	0.8	1.25	2.56	0.10	4%	0.51	0.09	18%
Solaio 13	CLT floor	15.38	465593315	ULS 65	1	0.8	1.25	2.56	0.10	4%	0.51	0.09	18%
Solaio 20	CLT roof	-5.77	277929841	ULS 64	1	0.6	1.25	1.92	0.05	3%	0.38	0.05	12%
Solaio 21	CLT roof	5.77	277922204	ULS 64	1	0.6	1.25	1.92	0.05	3%	0.38	0.05	12%
Solaio 22	CLT floor	18.46	482977788	ULS 65	1	0.8	1.25	2.56	0.12	5%	0.51	0.11	22%
Solaio 23	CLT floor	18.46	482977788	ULS 65	1	0.8	1.25	2.56	0.12	5%	0.51	0.11	22%

Floors deflections (SLS)

The deflection checks are carried out according to § 2.2.3 of EN 1995-1-1.

The net deflection below a straight line between the supports, $w_{net,fin}$, is taken as:

$$w_{net,fin} = w_{inst} + w_{creep} - w_c = w_{fin} - w_c$$

where:

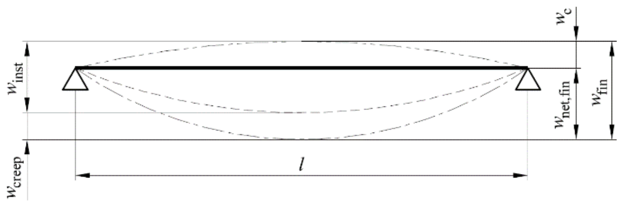
$w_{net,fin}$ is the net final deflection;

w_{inst} is the instantaneous deflection;

w_{creep} is the creep deflection;

w_c is the precamber (if applied);

w_{fin} is the final deflection.



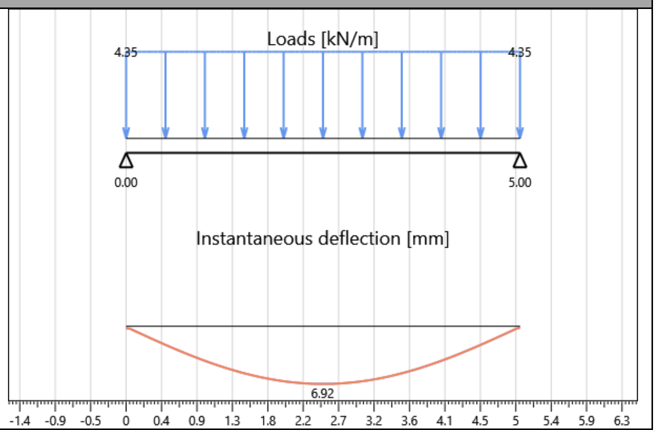
The limiting values for deflections of floors are assumed as shown in the following table.

Deformation limits name	$w_{inst, span}$	$w_{net, fin, span}$	$w_{inst, overhang}$	$w_{net, fin, overhang}$	Neglect overhang check for deformation < 0
Solaio in legno	l/300	l/250	l/150	l/125	No

Instantaneous deflection

The instantaneous deflection *w_{inst}* is calculated for the characteristic (rare) combination of actions.

The following table shows the deformation of each floor (relative to the element in which the deformation checks are the most severe).

Floor name	Deformation limits name	Combination	Instantaneous deflection
Solaio 12	Solaio in legno	SLS characteristic 3	

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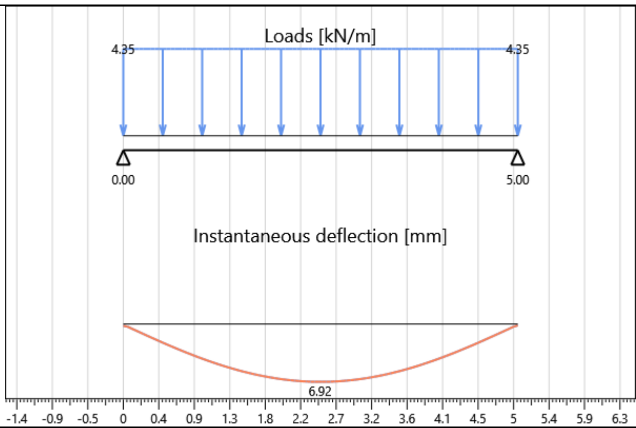
<tr><td>Solaio 13</td><td>Solaio in legno</td><td>SLS characteristic 3</td><td>
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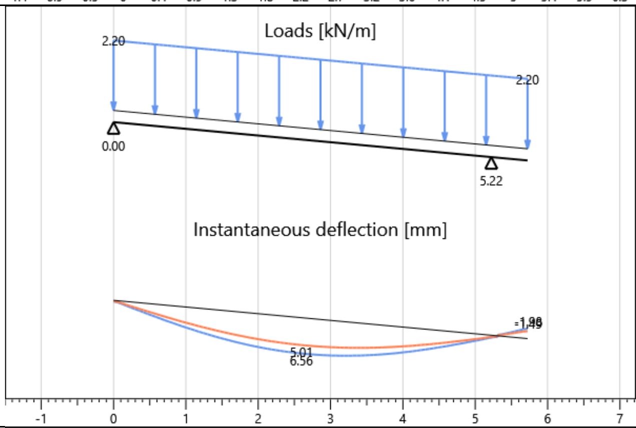
<tr><td>Solaio 20</td><td>Solaio in legno</td><td>SLS characteristic 8</td><td>
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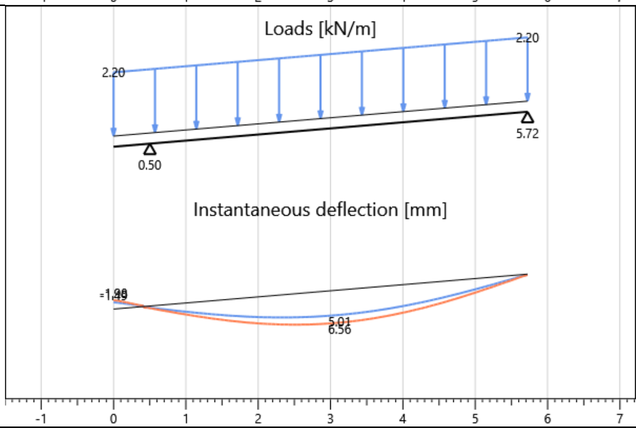
<tr><td>Solaio 21</td><td>Solaio in legno</td><td>SLS characteristic 8</td><td>
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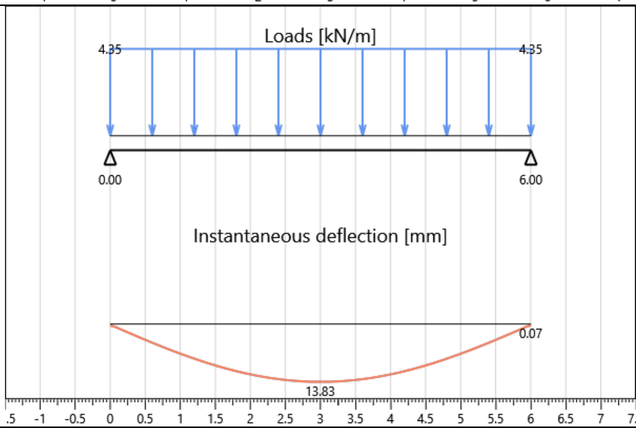
<tr><td>Solaio 22</td><td>Solaio in legno</td><td>SLS characteristic 3</td><td>
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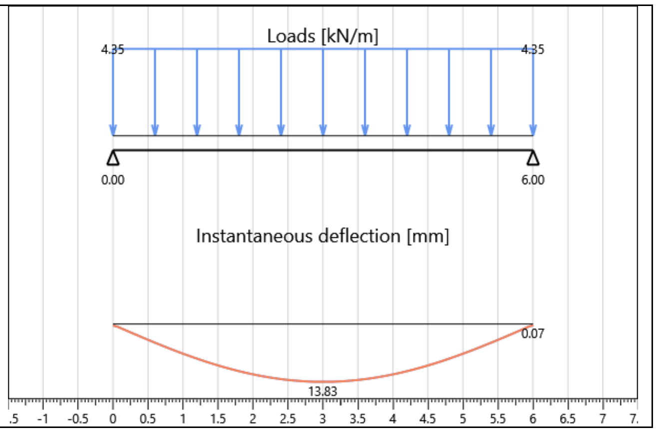
Solaio 23	Solaio in legno	SLS characteristic 3	

The table below shows the instantaneous deflection checks of the floor elements.

Floor name	Section	Combination	Most restrictive check	w_{inst} [mm]	$w_{inst\ limit}$ [mm]	Deflection limit	Check
Solaio 12	CLT floor	SLS characteristic 3	Internal span	6.92	16.68	l/300	42%
Solaio 13	CLT floor	SLS characteristic 3	Internal span	6.92	16.68	l/300	42%
Solaio 20	CLT roof	SLS characteristic 8	Cantilever beams	-1.98	3.34	l/150	59%
Solaio 21	CLT roof	SLS characteristic 8	Cantilever beams	-1.98	3.35	l/150	59%
Solaio 22	CLT floor	SLS characteristic 3	Internal span	13.83	20.01	l/300	69%
Solaio 23	CLT floor	SLS characteristic 3	Internal span	13.83	20.01	l/300	69%

Final deflection

For structures consisting of members, components and connections with the same creep behaviour and under the assumption of a linear relationship between the actions and the corresponding deformations the final deformation, w_{fin}, may be taken as:

$$w_{fin} = w_{fin,G} + w_{fin,Q1} + \sum w_{fin,Qi}$$

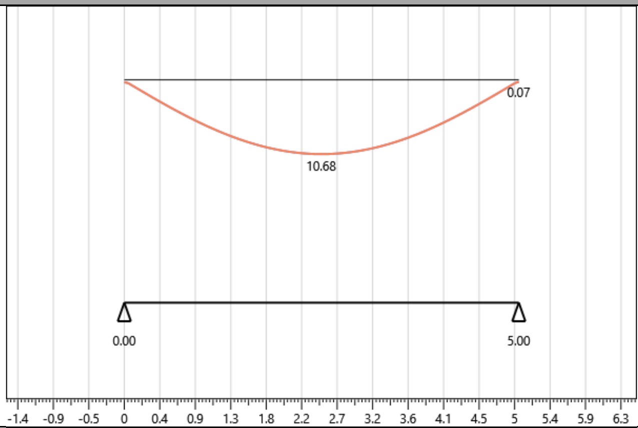
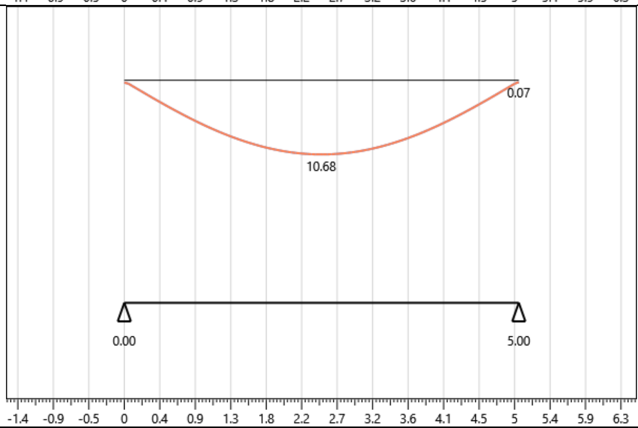
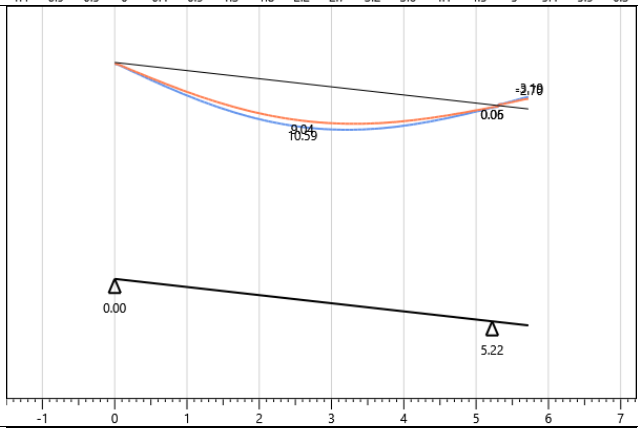
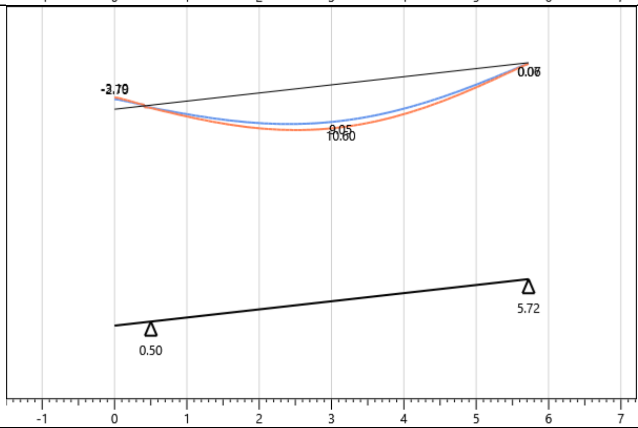
where:

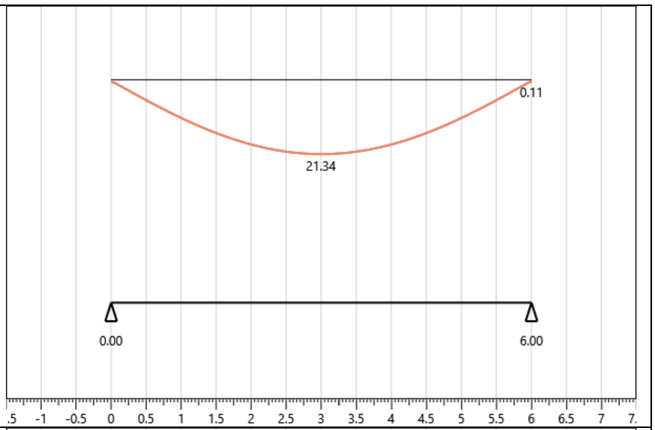
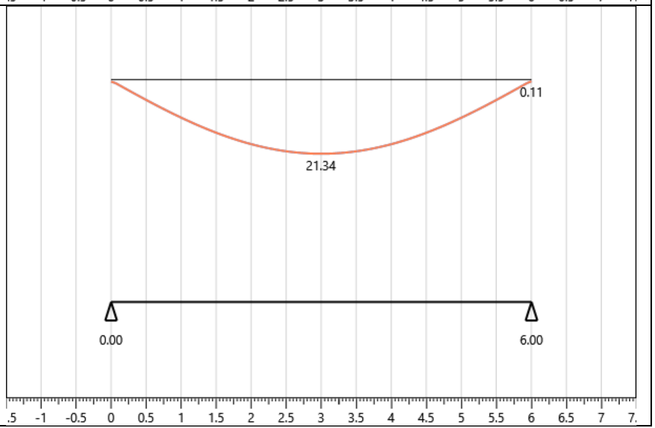
$w_{fin,G} = w_{inst,G} \cdot (1 + k_{def})$ for a permanent action, G

$w_{fin,Q,1} = w_{inst,Q,1} \cdot (1 + \Psi_{2,1} \cdot k_{def})$ for the leading variable action, Q_1

$w_{fin,Q,i} = w_{inst,Q,i} \cdot (\Psi_{0,i} + \Psi_{2,1} \cdot k_{def})$ for accompanying variable actions, Q_i (i>1)

The following table shows the deformation of each floor (relative to the element in which the deformation checks are the most severe).

Floor name	Deformation limits name	Combination	Final deflection
Solaio 12	Solaio in legno	SLS characteristic 3	
Solaio 13	Solaio in legno	SLS characteristic 3	
Solaio 20	Solaio in legno	SLS characteristic 8	
Solaio 21	Solaio in legno	SLS characteristic 8	

Solaio 22	Solaio in legno	SLS characteristic 3	
Solaio 23	Solaio in legno	SLS characteristic 3	

The table below shows the final deflection checks of the floor elements.

Floor name	Section	Combination	Service class	k_{def}	Most restrictive check	w_{fin} [mm]	$w_{fin\ limit}$ [mm]	Deflection limit	Check
Solaio 12	CLT floor	SLS characteristic 3	1	0.8	Internal span	10.68	20.01	l/250	53%
Solaio 13	CLT floor	SLS characteristic 3	1	0.8	Internal span	10.68	20.01	l/250	53%
Solaio 20	CLT roof	SLS characteristic 8	1	0.8	Cantilever beams	-3.19	4.01	l/125	79%
Solaio 21	CLT roof	SLS characteristic 8	1	0.8	Cantilever beams	-3.19	4.02	l/125	79%
Solaio 22	CLT floor	SLS characteristic 3	1	0.8	Internal span	21.34	24.01	l/250	89%
Solaio 23	CLT floor	SLS characteristic 3	1	0.8	Internal span	21.34	24.01	l/250	89%

Timber beams

Bending strength

The checks are conducted according to § 6.3.2 of EN 1995-1-1. The following expression shall be satisfied:

$$\frac{\sigma_{m,d}}{k_{crit} \cdot f_{m,d}} \leq 1$$

where:

$\sigma_{m,d}$ is the design bending stress;

$f_{m,d}$ is the design bending strength;

k_{crit} is a factor which takes into account the reduced bending strength due to lateral buckling.

The factor k_{crit} is assumed equal to 1.0 for beams in which the lateral displacement of the compressed edge is prevented over the entire length and the torsional rotation is prevented at the supports. Otherwise, the factor is determined from the following expression:

$$k_{crit} = \begin{cases} 1 & for\ \lambda_{rel,m} \leq 0{,}75 \\ 1{,}56 - 0{,}75\lambda_{rel,m} & for\ 0{,}75 \leq \lambda_{rel,m} \leq 1{,}4 \\ \frac{1}{\lambda_{rel,m}^2} & for\ 1{,}4 < \lambda_{rel,m} \end{cases}$$

in which the relative slenderness for bending is taken as:

$$\lambda_{rel,m} = \sqrt{\frac{f_{m,k}}{\sigma_{m,crit}}}$$

and $\sigma_{m,crit}$, the critical bending stress calculated according to the classical theory of stability is taken as:

$$\sigma_{m,crit} = \frac{M_{y,crit}}{W_y} = \frac{\pi\sqrt{E_{0,05}\, I_z\, G_{0,05}\, I_{tor}}}{l_{ef}\, W_y}$$

where:

$E_{0,05}$ is the fifth percentile value of modulus of elasticity parallel to grain;

$G_{0,05}$ is the fifth percentile value of shear modulus parallel to grain;

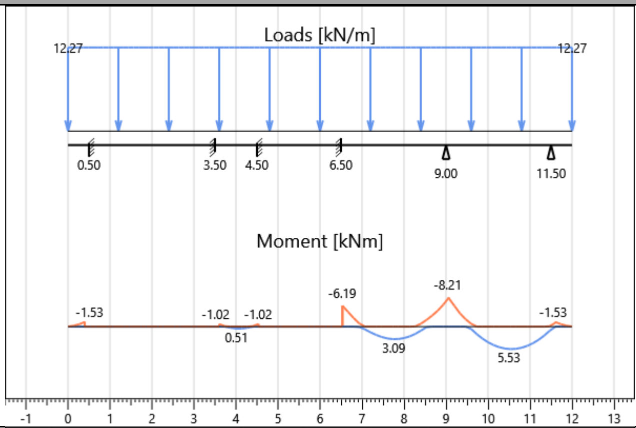
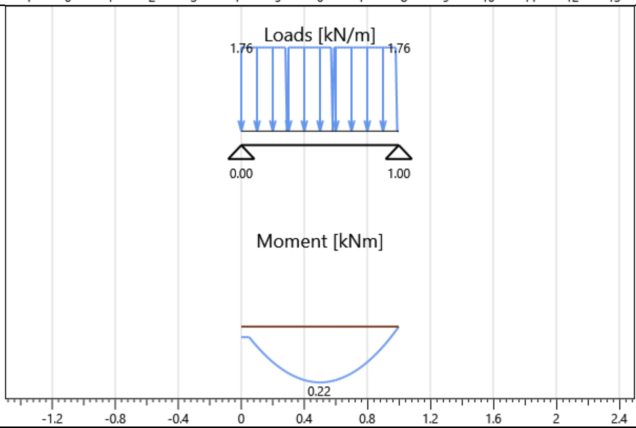
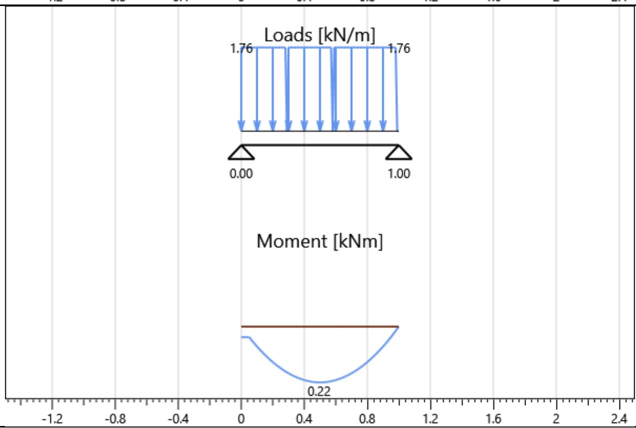
I_z is the second moment of area about the weak axis z;

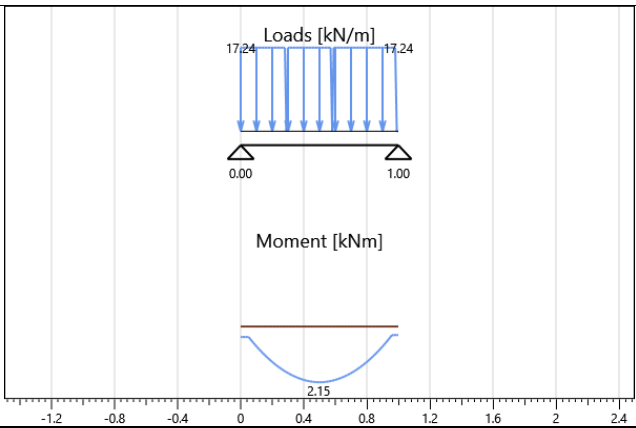
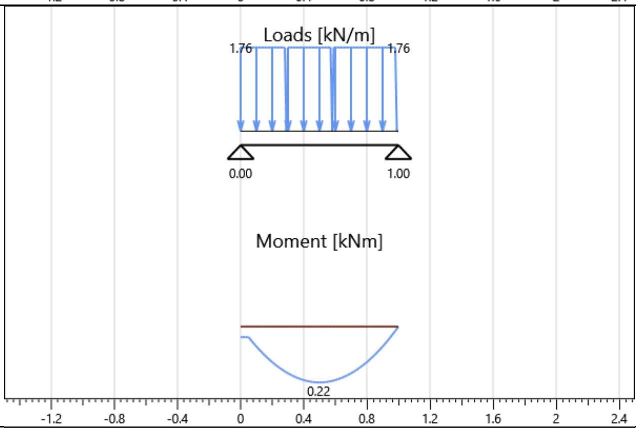
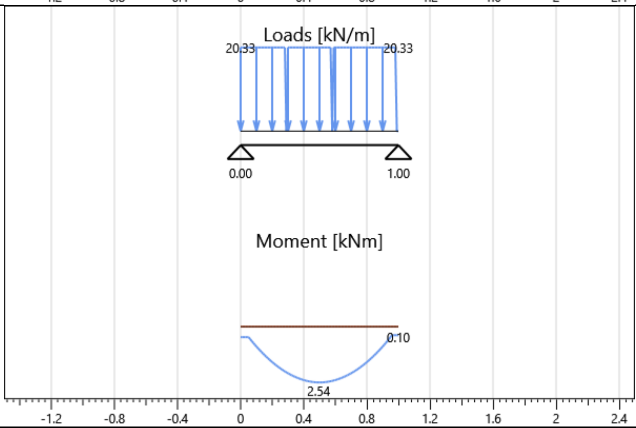
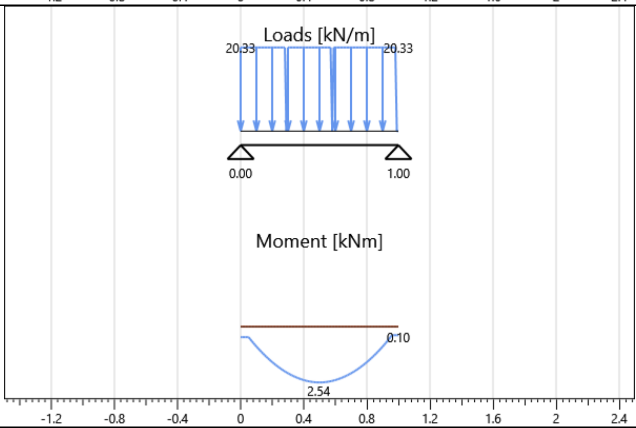
I_{tor} is the torsional moment of inertia;

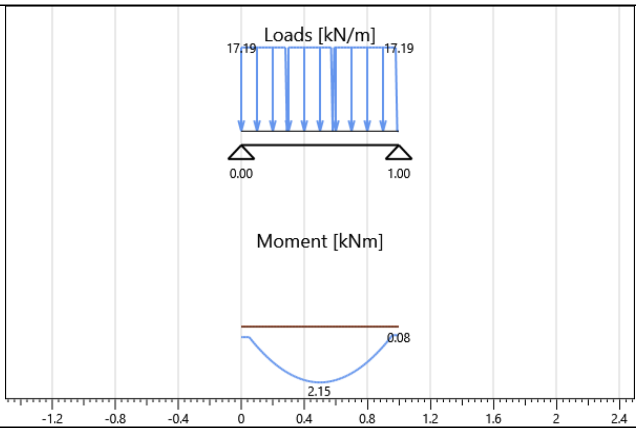
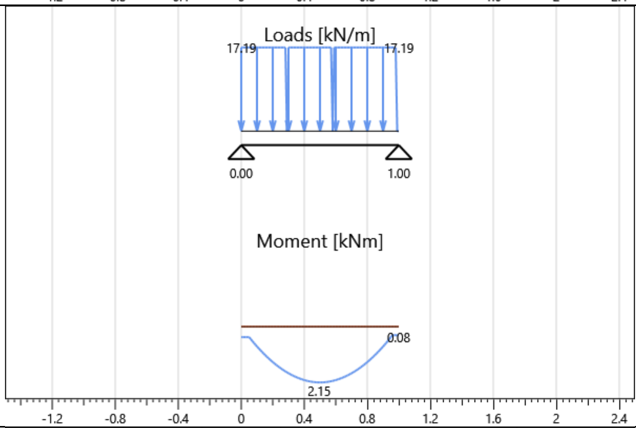
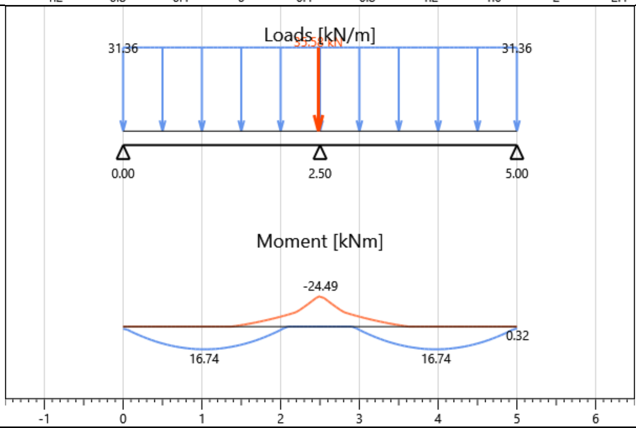
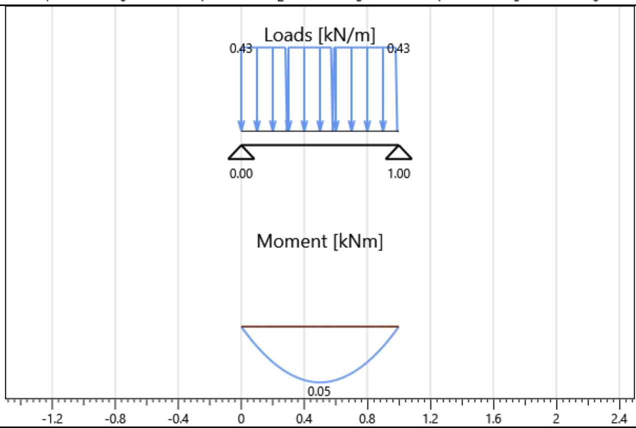
l_{ef} is the effective length of the beam, depending on the support conditions and the load configuration;

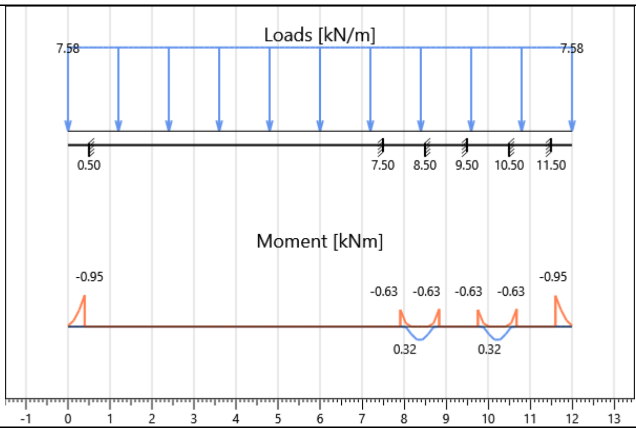
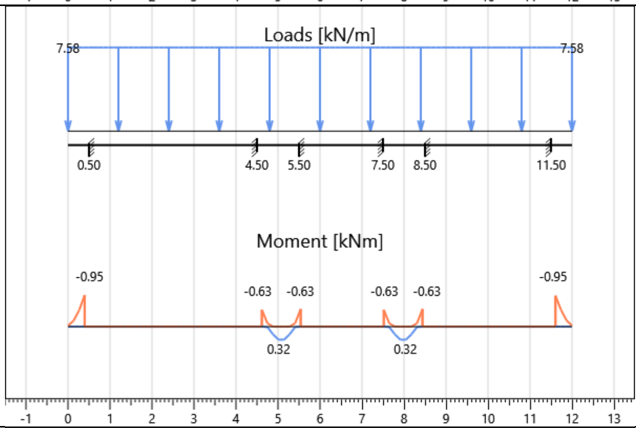
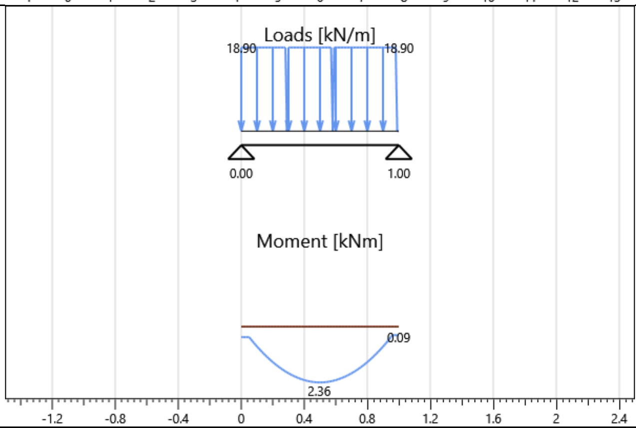
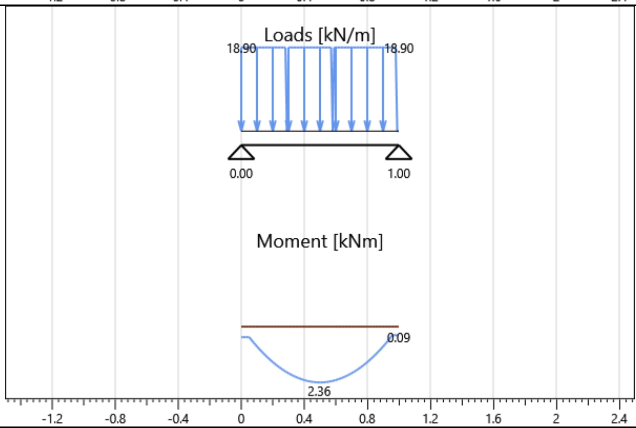
W_y is the section modulus about the strong axis y.

The following table shows, for each beam, the bending moment relating to the worst Ultimate Limit State combination.

Beam	Combination	Duration	Diagram $M_{3\text{-}3}$
Trave 35	ULS 64	Permanent	
Trave 36	ULS 64	Permanent	
Trave 37	ULS 64	Permanent	

Trave 39	ULS 65	Medium-term	
Trave 40	ULS 64	Permanent	
Trave 42	ULS 65	Medium-term	
Trave 43	ULS 65	Medium-term	

Trave 46	ULS 65	Medium-term	
Trave 47	ULS 65	Medium-term	
Trave 48	ULS 65	Medium-term	
Trave 49	ULS 64	Permanent	

Trave 50	ULS 64	Permanent	
Trave 51	ULS 64	Permanent	
Trave 52	ULS 65	Medium-term	
Trave 53	ULS 65	Medium-term	

The checks are summarized below. The values resulting from the calculations, relating to each verification, are reported in the form of a percentage.

Beam name	Section	$M_{3\text{-}3\,max}$ [kNm]	W [mm³]	Lateral restraints	$\sigma_{m,crit}$ [MPa	k_{crit}	Comb.	k_h	k_{mod}	γ_M	$f_{m,d}$ [MPa]	$\sigma_{m,d}$ [MPa]	Check
Trave 35	Ridge beam	8.21	2613333	No torsional buckling	-	1.00	ULS 64	1.00	0.6	1.25	11.52	3.14	27%
Trave 36	Architrave	0.22	1333333	No torsional buckling	-	1.00	ULS 64	1.00	0.6	1.25	11.52	0.16	1%
Trave 37	Architrave	0.22	1333333	No torsional buckling	-	1.00	ULS 64	1.00	0.6	1.25	11.52	0.16	1%
Trave 39	Architrave	2.15	1333333	No torsional buckling	-	1.00	ULS 65	1.00	0.8	1.25	15.36	1.62	11%
Trave 40	Architrave	0.22	1333333	No torsional buckling	-	1.00	ULS 64	1.00	0.6	1.25	11.52	0.16	1%
Trave 42	Architrave	2.54	1333333	No torsional buckling	-	1.00	ULS 65	1.00	0.8	1.25	15.36	1.90	12%
Trave 43	Architrave	2.54	1333333	No torsional buckling	-	1.00	ULS 65	1.00	0.8	1.25	15.36	1.90	12%
Trave 46	Architrave	2.15	1333333	No torsional buckling	-	1.00	ULS 65	1.00	0.8	1.25	15.36	1.61	10%
Trave 47	Architrave	2.15	1333333	No torsional buckling	-	1.00	ULS 65	1.00	0.8	1.25	15.36	1.61	10%
Trave 48	Internal beam	24.49	3413333	No torsional buckling	-	1.00	ULS 65	1.00	0.8	1.25	15.36	7.18	47%
Trave 49	Internal beam	0.05	3413333	No torsional buckling	-	1.00	ULS 64	1.00	0.6	1.25	11.52	0.02	0%
Trave 50	Ridge beam	0.95	2613333	No torsional buckling	-	1.00	ULS 64	1.00	0.6	1.25	11.52	0.36	3%
Trave 51	Ridge beam	0.95	2613333	No torsional buckling	-	1.00	ULS 64	1.00	0.6	1.25	11.52	0.36	3%
Trave 52	Ridge beam	2.36	2613333	No torsional buckling	-	1.00	ULS 65	1.00	0.8	1.25	15.36	0.90	6%
Trave 53	Ridge beam	2.36	2613333	No torsional buckling	-	1.00	ULS 65	1.00	0.8	1.25	15.36	0.90	6%

Shear strength

The checks are conducted according to § 6.1.7 of EN 1995-1-1. The following expression shall be satisfied:

$$\frac{\tau_d}{f_{v,d}} \leq 1$$

where:

τ_d is the design shear stress;

$f_{v,d}$ is the design shear strength for the actual condition.

For the verification of shear resistance of members in bending, the influence of cracks should betaken into account using an effective width of the member given as:

$$b_{ef} = k_{cr} \cdot b$$

where b is the width of the relevant section of the member.

The following value of k_{cr} are used

k_{cr} = 0.67 (≤1) for solid timber

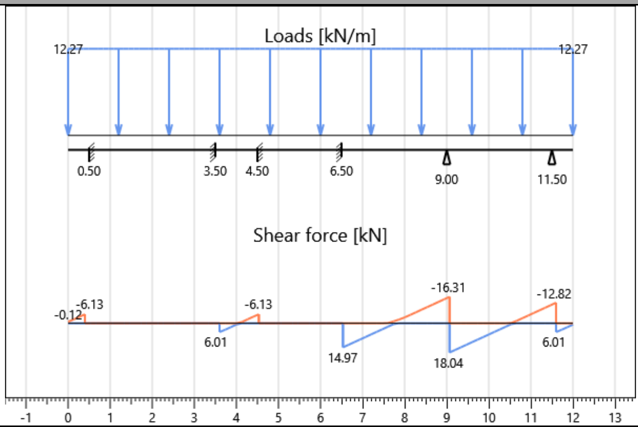
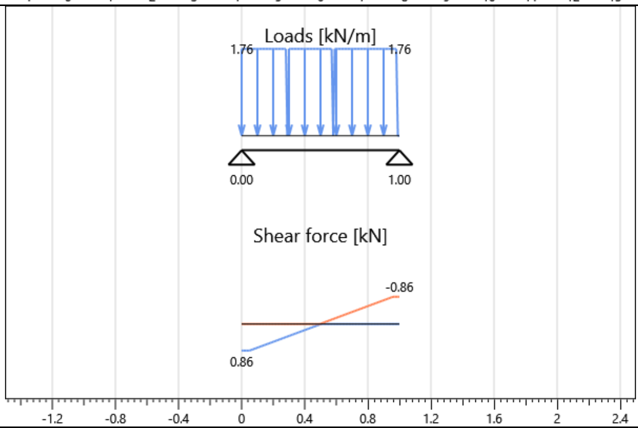
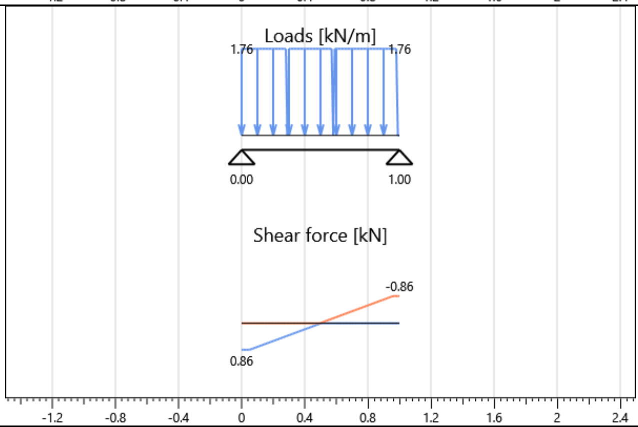
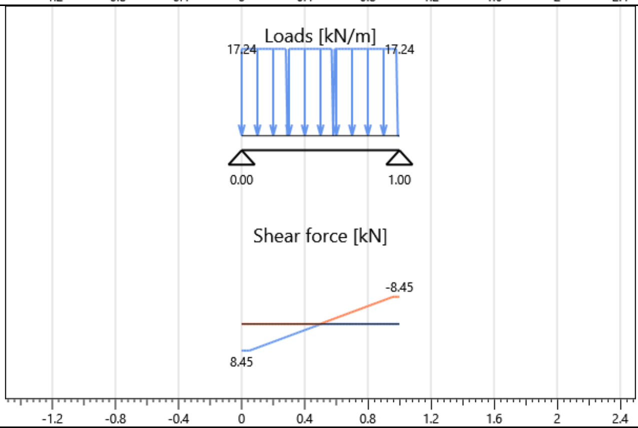
k_{cr} = 0.67 (≤1) for glued laminated timber

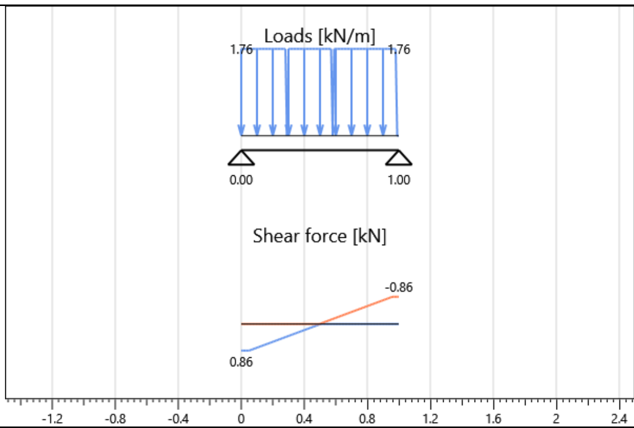
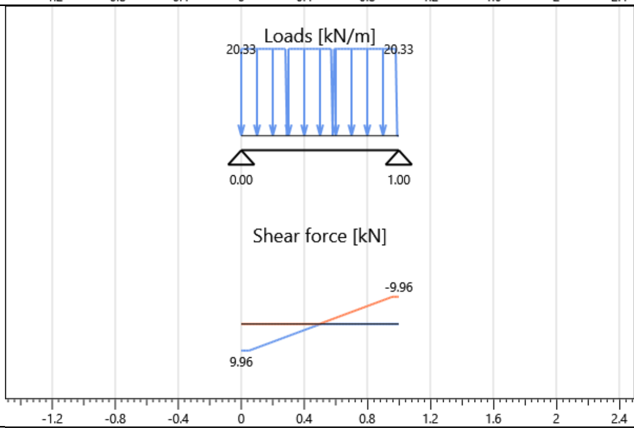
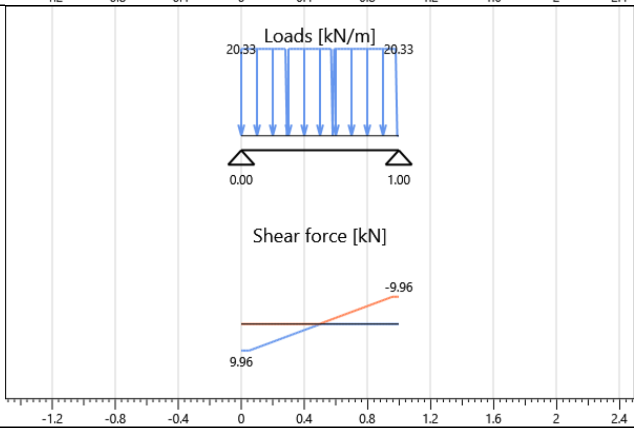
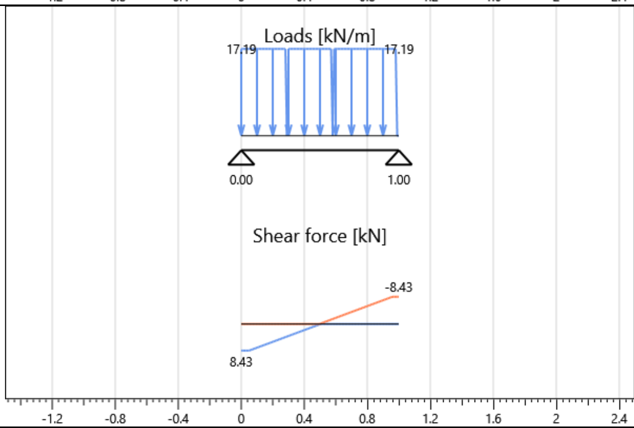
The maximum design shear stress in a rectangular cross section can be evaluated using the following expression:

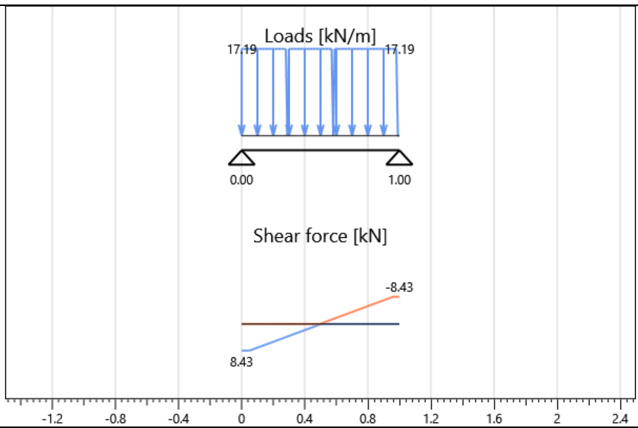
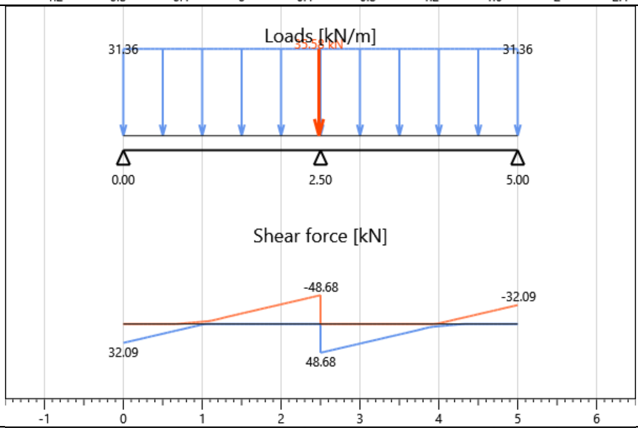
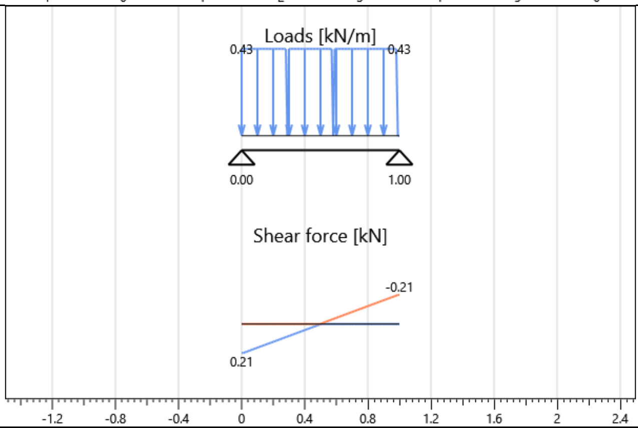
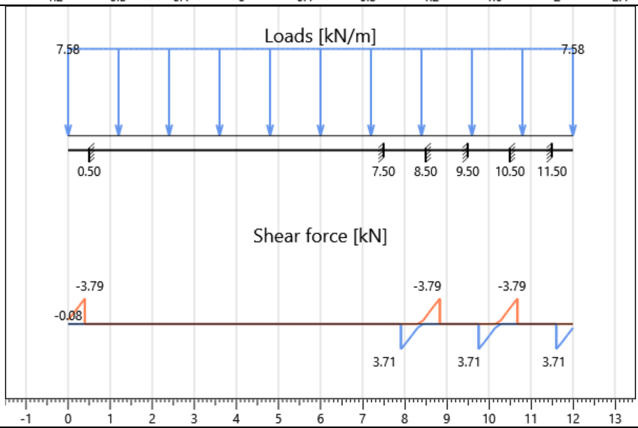
$$\tau_d = \frac{3}{2} \cdot \frac{V_d}{k_{cr} \cdot A}$$

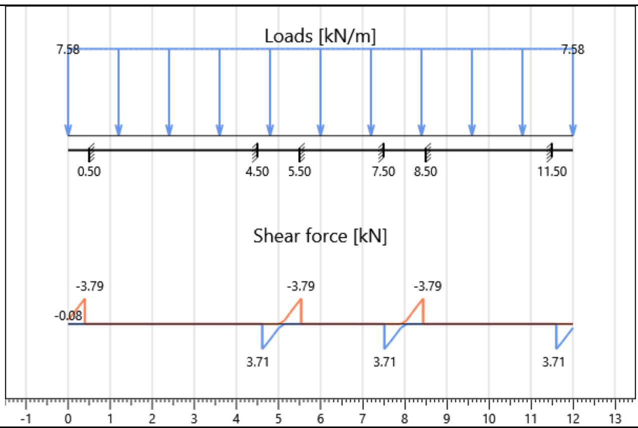
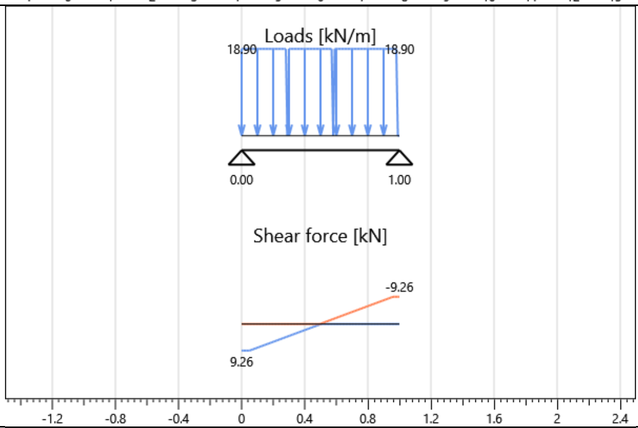
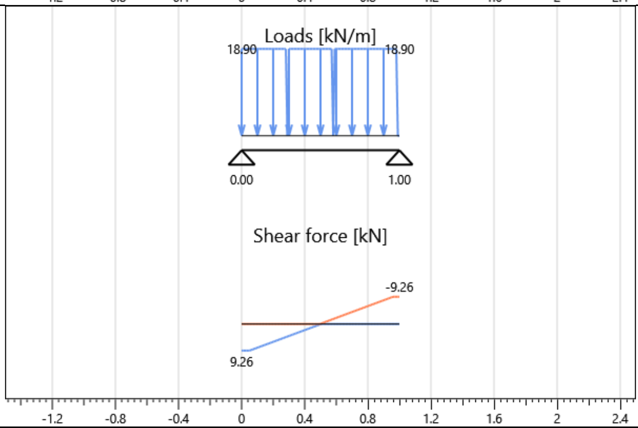
where A is the area of a joist cross section.

The following table illustrates the structural schemes and the envelopes of the shear force diagram for each beam.

Beam name	Combination	Duration	Diagram V_2
Trave 35	ULS 64	Permanent	
Trave 36	ULS 64	Permanent	
Trave 37	ULS 64	Permanent	
Trave 39	ULS 65	Medium-term	

Trave 40	ULS 64	Permanent	
Trave 42	ULS 65	Medium-term	
Trave 43	ULS 65	Medium-term	
Trave 46	ULS 65	Medium-term	

Trave 47	ULS 65	Medium-term	
Trave 48	ULS 65	Medium-term	
Trave 49	ULS 64	Permanent	
Trave 50	ULS 64	Permanent	

Trave 51	ULS 64	Permanent	
Trave 52	ULS 65	Medium-term	
Trave 53	ULS 65	Medium-term	

The checks are summarized below. The values resulting from the calculations, relating to each verification, are reported in the form of a percentage.

Beam name	Section	$V_{2\,max}$ [kN]	Area [mm^2]	k_{cr}	Comb.	Service class	k_{mod}	γ_M	$f_{v,d}$ [MPa]	$\tau_{2,d}$ [MPa]	Check
Trave 35	Ridge beam	18.04	56000	0.67	ULS 64	1	0.6	1.25	1.68	0.72	43%
Trave 36	Architrave	0.86	40000	0.67	ULS 64	1	0.6	1.25	1.68	0.05	3%
Trave 37	Architrave	0.86	40000	0.67	ULS 64	1	0.6	1.25	1.68	0.05	3%
Trave 39	Architrave	8.45	40000	0.67	ULS 65	1	0.8	1.25	2.24	0.47	21%
Trave 40	Architrave	0.86	40000	0.67	ULS 64	1	0.6	1.25	1.68	0.05	3%
Trave 42	Architrave	9.96	40000	0.67	ULS 65	1	0.8	1.25	2.24	0.56	25%
Trave 43	Architrave	9.96	40000	0.67	ULS 65	1	0.8	1.25	2.24	0.56	25%
Trave 46	Architrave	8.43	40000	0.67	ULS 65	1	0.8	1.25	2.24	0.47	21%
Trave 47	Architrave	8.43	40000	0.67	ULS 65	1	0.8	1.25	2.24	0.47	21%
Trave 48	Internal beam	48.68	64000	0.67	ULS 65	1	0.8	1.25	2.24	1.70	76%
Trave 49	Internal beam	0.21	64000	0.67	ULS 64	1	0.6	1.25	1.68	0.01	0%
Trave 50	Ridge beam	3.79	56000	0.67	ULS 64	1	0.6	1.25	1.68	0.15	9%
Trave 51	Ridge beam	3.79	56000	0.67	ULS 64	1	0.6	1.25	1.68	0.15	9%
Trave 52	Ridge beam	9.26	56000	0.67	ULS 65	1	0.8	1.25	2.24	0.37	17%
Trave 53	Ridge beam	9.26	56000	0.67	ULS 65	1	0.8	1.25	2.24	0.37	17%

Beams deflections (SLS)

The deflection checks are carried out according to § 2.2.3 of EN 1995-1-1.

The net deflection below a straight line between the supports, $w_{net,fin}$, is taken as:

$$w_{net,fin} = w_{inst} + w_{creep} - w_c = w_{fin} - w_c$$

where:

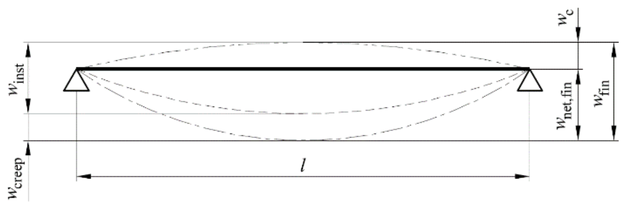
$w_{net,fin}$ is the net final deflection;

w_{inst} is the instantaneous deflection;

w_{creep} is the creep deflection;

w_c is the precamber (if applied);

w_{fin} is the final deflection.



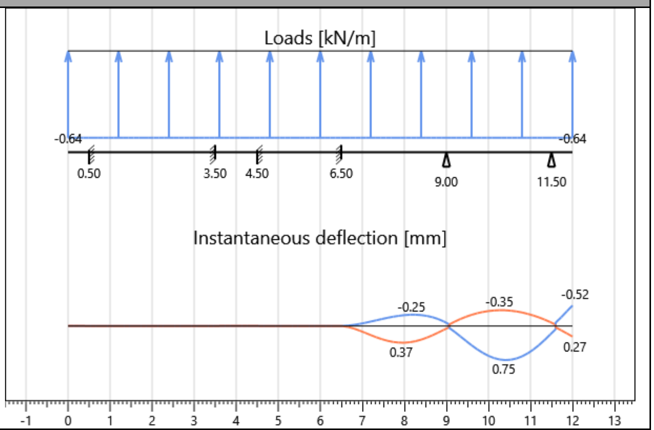
The limiting values for deflections of beams are assumed as shown in the following table.

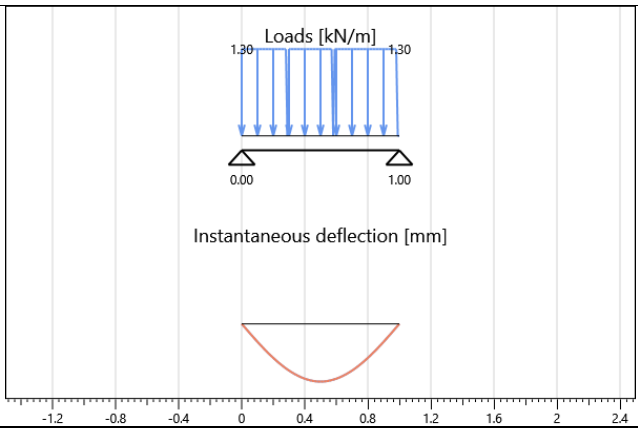
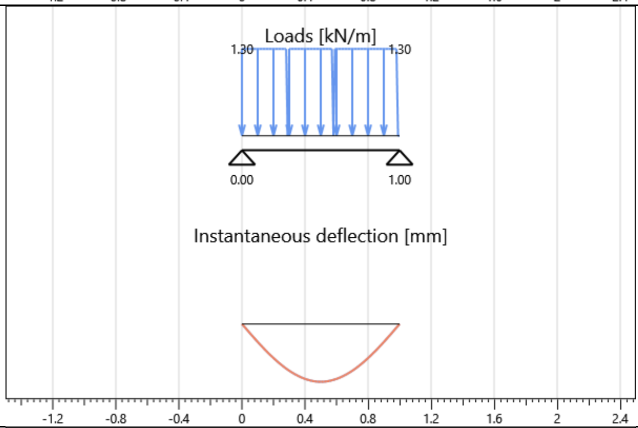
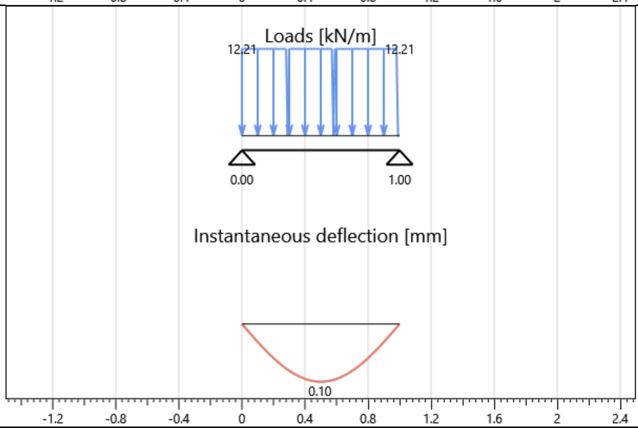
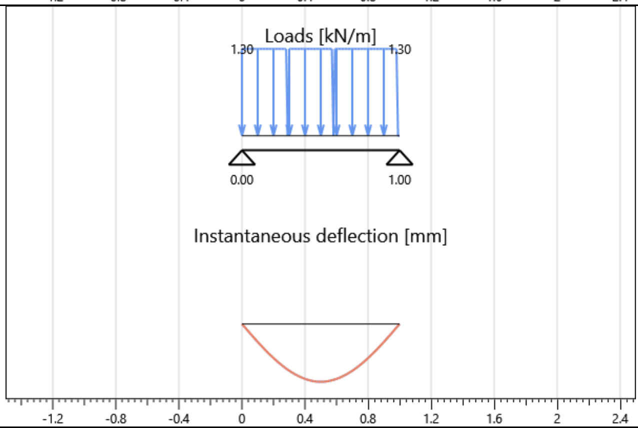
Deformation limits name	$w_{inst, span}$	$w_{net, fin, span}$	$w_{inst, overhang}$	$w_{net, fin, overhang}$	Neglect overhang check for deformation < 0
Trave in legno	l/300	l/250	l/150	l/125	No

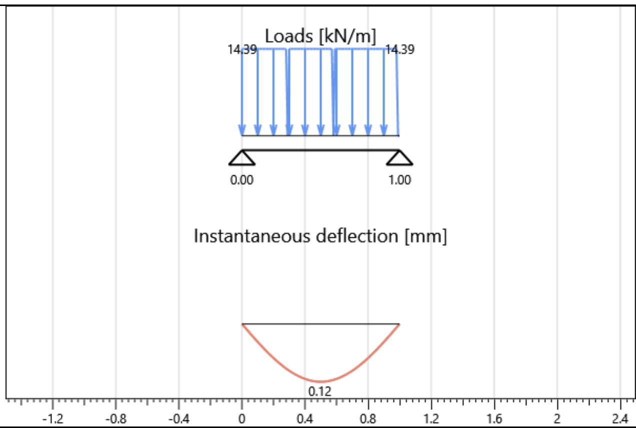
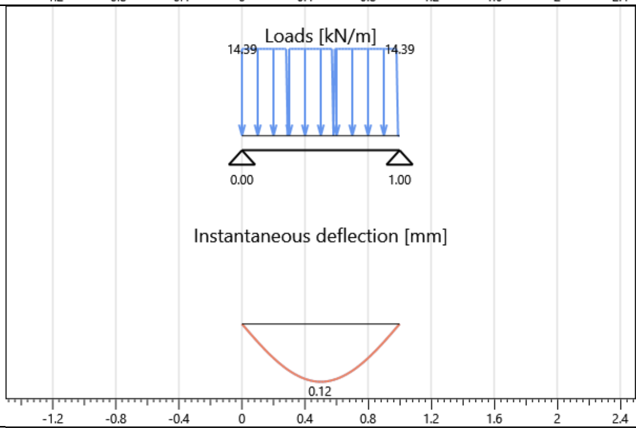
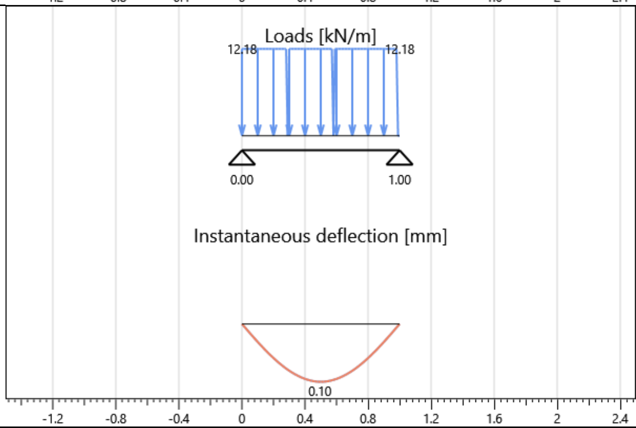
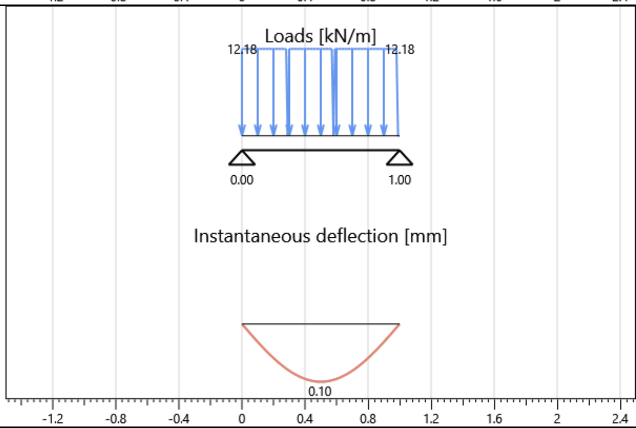
Instantaneous deflection

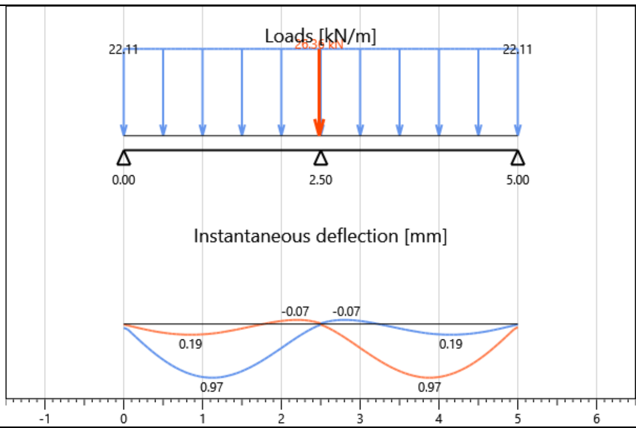
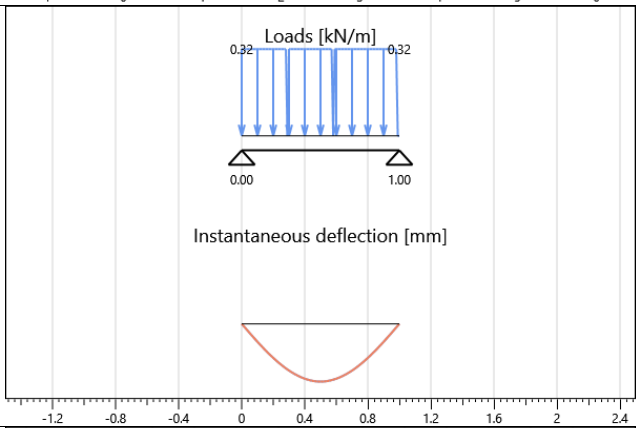
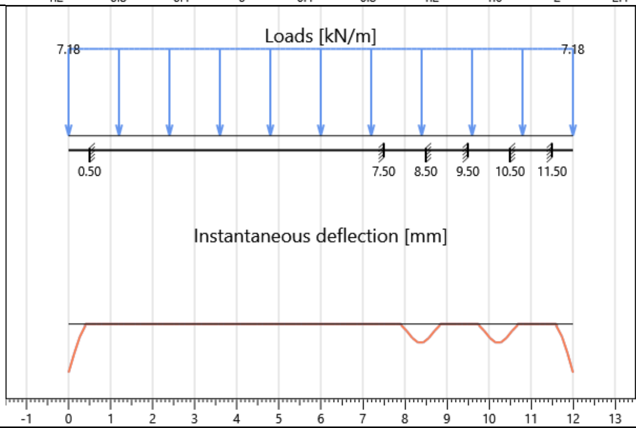
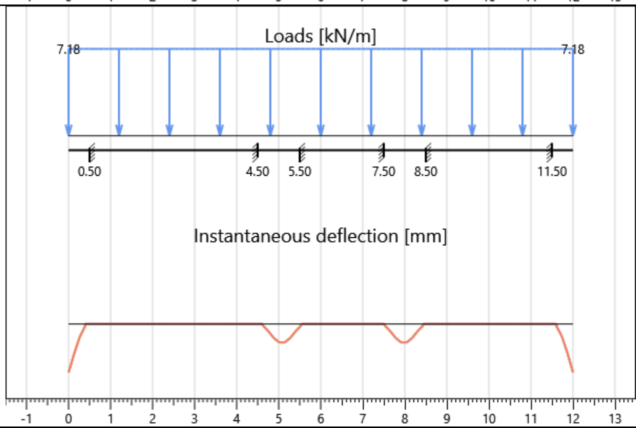
The instantaneous deflection w_{inst} is calculated for the characteristic (rare) combination of actions.

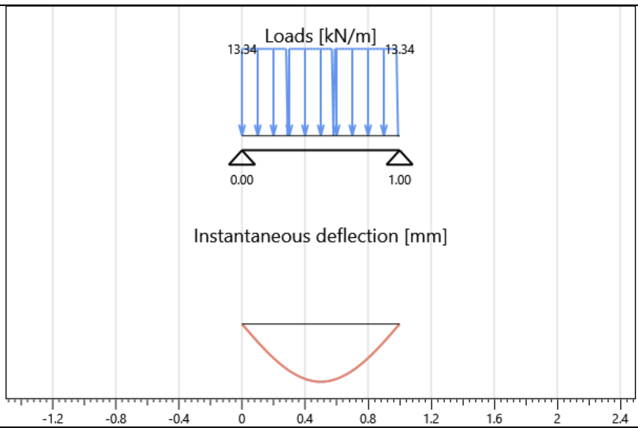
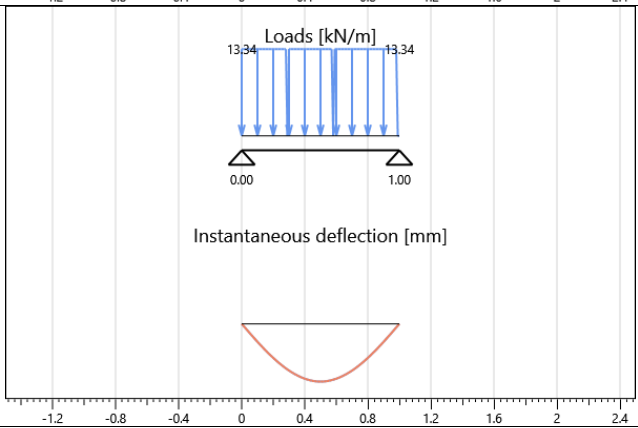
The following table shows the deformation of each beam.

Beam name	Deformation limits name	Combination	Instantaneous deflection
Trave 35	Trave in legno	SLS characteristic 20	

Trave 36	Trave in legno	SLS characteristic 3	
Trave 37	Trave in legno	SLS characteristic 3	
Trave 39	Trave in legno	SLS characteristic 3	
Trave 40	Trave in legno	SLS characteristic 3	

Trave 42	Trave in legno	SLS characteristic 3	
Trave 43	Trave in legno	SLS characteristic 3	
Trave 46	Trave in legno	SLS characteristic 3	
Trave 47	Trave in legno	SLS characteristic 3	

Trave 48	Trave in legno	SLS characteristic 3	
Trave 49	Trave in legno	SLS characteristic 3	
Trave 50	Trave in legno	SLS characteristic 8	
Trave 51	Trave in legno	SLS characteristic 8	

Trave 52	Trave in legno	SLS characteristic 3	
Trave 53	Trave in legno	SLS characteristic 3	

The table below shows the instantaneous deflection checks of the beams.

Beam name	Section	Combination	Most restrictive check	w_{inst} [mm]	$w_{inst\ limit}$ [mm]	Deflection limit	Check
Trave 35	Ridge beam	SLS characteristic 20	Cantilever beams	-0.52	3.33	l/150	16%
Trave 36	Architrave	SLS characteristic 3	Internal span	0.01	3.33	l/300	0%
Trave 37	Architrave	SLS characteristic 3	Internal span	0.01	3.33	l/300	0%
Trave 39	Architrave	SLS characteristic 3	Internal span	0.10	3.33	l/300	3%
Trave 40	Architrave	SLS characteristic 3	Internal span	0.01	3.33	l/300	0%
Trave 42	Architrave	SLS characteristic 3	Internal span	0.12	3.33	l/300	4%
Trave 43	Architrave	SLS characteristic 3	Internal span	0.12	3.33	l/300	4%
Trave 46	Architrave	SLS characteristic 3	Internal span	0.10	3.33	l/300	3%
Trave 47	Architrave	SLS characteristic 3	Internal span	0.10	3.33	l/300	3%
Trave 48	Internal beam	SLS characteristic 3	Internal span	0.97	8.33	l/300	12%
Trave 49	Internal beam	SLS characteristic 3	Internal span	0.00	3.33	l/300	0%
Trave 50	Ridge beam	SLS characteristic 8	Cantilever beams	0.01	3.33	l/150	0%
Trave 51	Ridge beam	SLS characteristic 8	Cantilever beams	0.01	3.33	l/150	0%
Trave 52	Ridge beam	SLS characteristic 3	Internal span	0.04	3.33	l/300	1%
Trave 53	Ridge beam	SLS characteristic 3	Internal span	0.04	3.33	l/300	1%

Final deflection

For structures consisting of members, components and connections with the same creep behaviour and under the assumption of a linear relationship between the actions and the corresponding deformations the final deformation, w_{fin}, may be taken as:

$$w_{fin} = w_{fin,G} + w_{fin,Q1} + \sum w_{fin,Qi}$$

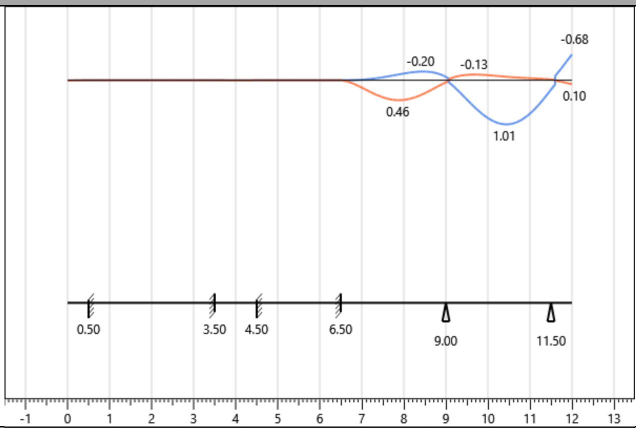
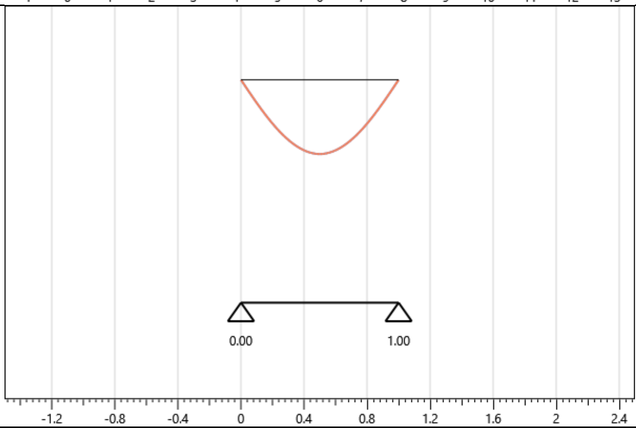
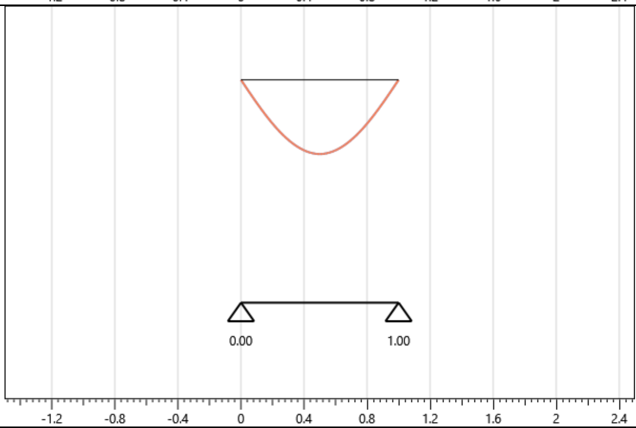
where:

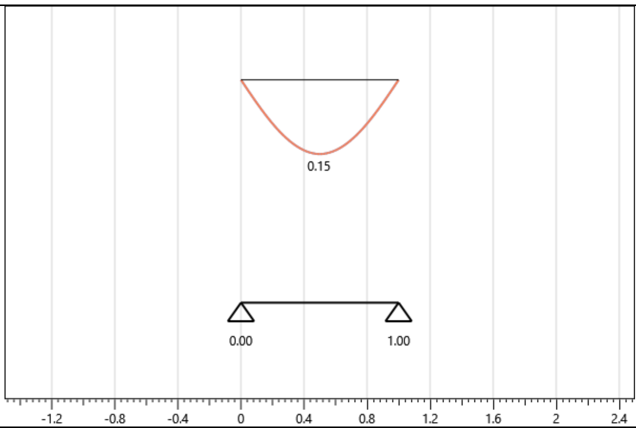
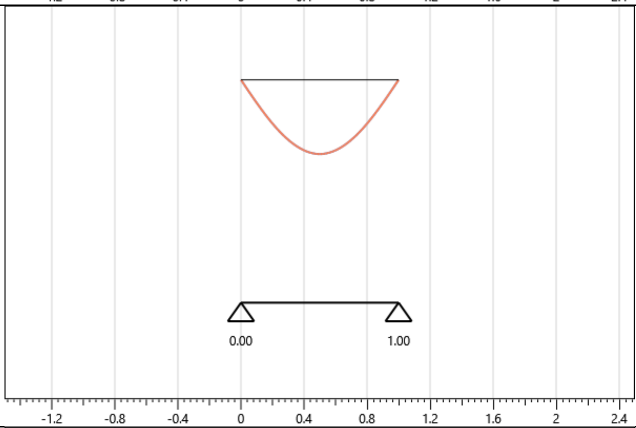
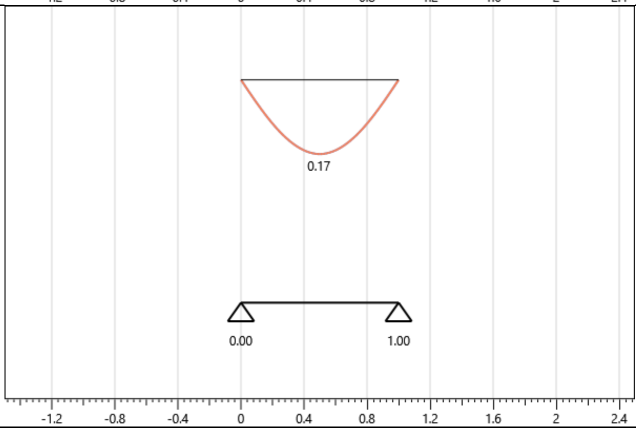
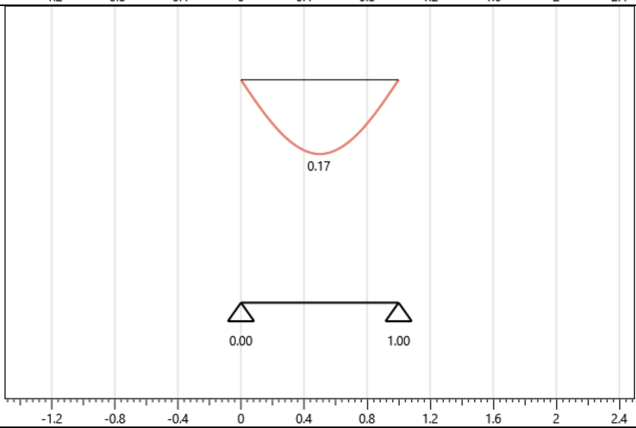
$w_{fin,G} = w_{inst,G} \cdot (1 + k_{def})$ for a permanent action, G

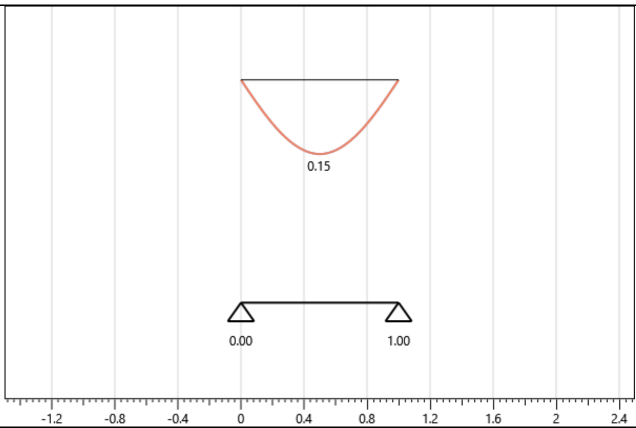
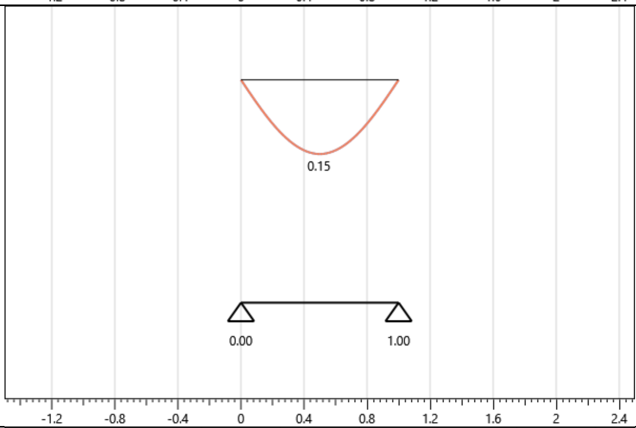
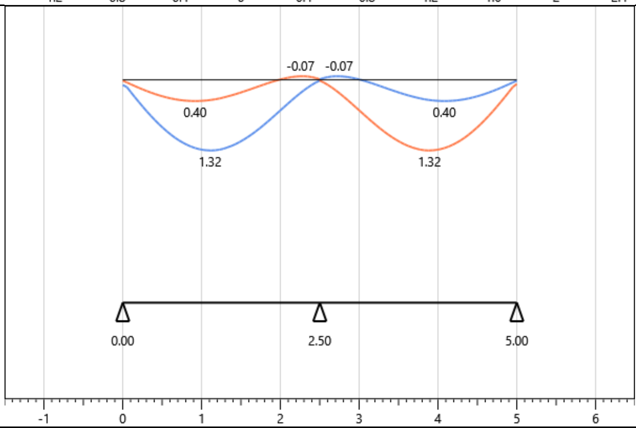
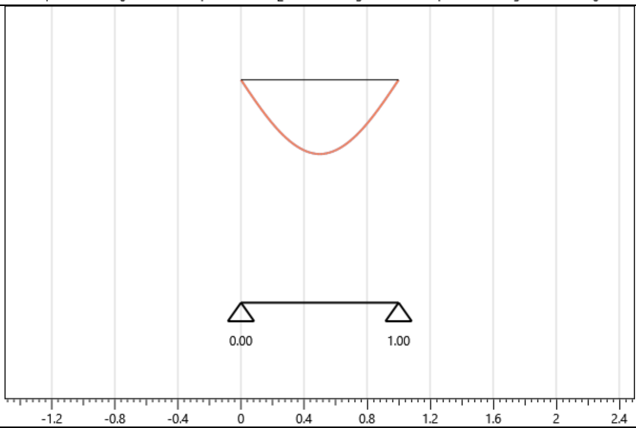
$w_{fin,Q,1} = w_{inst,Q,1} \cdot (1 + \Psi_{2,1} \cdot k_{def})$ for the leading variable action, Q_1

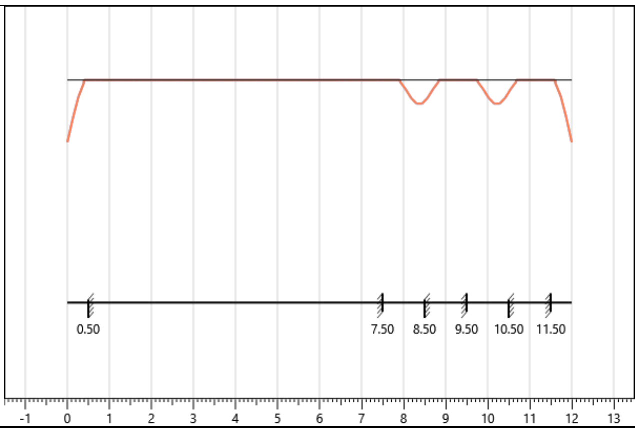
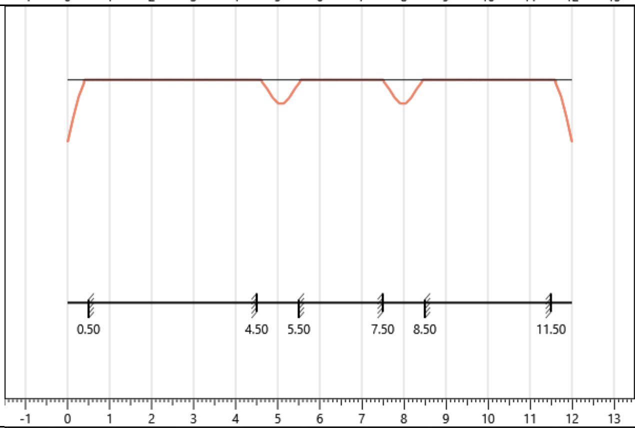
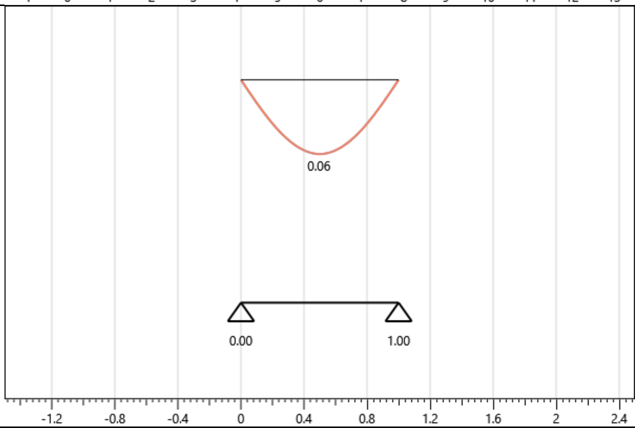
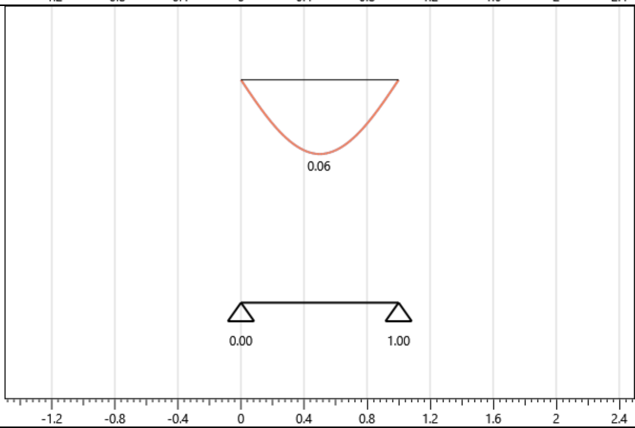
$w_{fin,Q,i} = w_{inst,Q,i} \cdot (\Psi_{0,i} + \Psi_{2,1} \cdot k_{def})$ for accompanying variable actions, Q_i (i>1)

The following table shows the deformation of each floor (relative to the element in which the deformation checks are the most severe).

Beam name	Deformation limits name	Combination	Final deflection
Trave 35	Trave in legno	SLS characteristic 20	
Trave 36	Trave in legno	SLS characteristic 3	
Trave 37	Trave in legno	SLS characteristic 3	

Trave 39	Trave in legno	SLS characteristic 3	
Trave 40	Trave in legno	SLS characteristic 3	
Trave 42	Trave in legno	SLS characteristic 3	
Trave 43	Trave in legno	SLS characteristic 3	

Trave 46	Trave in legno	SLS characteristic 3	
Trave 47	Trave in legno	SLS characteristic 3	
Trave 48	Trave in legno	SLS characteristic 3	
Trave 49	Trave in legno	SLS characteristic 3	

Trave 50	Trave in legno	SLS characteristic 8	
Trave 51	Trave in legno	SLS characteristic 8	
Trave 52	Trave in legno	SLS characteristic 3	
Trave 53	Trave in legno	SLS characteristic 3	

The table below shows the final deflection checks for every beam.

Beam name	Section	Combination	Service class	k_{def}	Most restrictive check	w_{fin} [mm]	$w_{fin\ limit}$ [mm]	Deflection limit	Check
Trave 35	Ridge beam	SLS characteristic 20	1	0.6	Cantilever beams	-0.68	4.00	l/125	17%
Trave 36	Architrave	SLS characteristic 3	1	0.6	Internal span	0.02	4.00	l/250	0%
Trave 37	Architrave	SLS characteristic 3	1	0.6	Internal span	0.02	4.00	l/250	0%
Trave 39	Architrave	SLS characteristic 3	1	0.6	Internal span	0.15	4.00	l/250	4%
Trave 40	Architrave	SLS characteristic 3	1	0.6	Internal span	0.02	4.00	l/250	0%
Trave 42	Architrave	SLS characteristic 3	1	0.6	Internal span	0.17	4.00	l/250	4%
Trave 43	Architrave	SLS characteristic 3	1	0.6	Internal span	0.17	4.00	l/250	4%
Trave 46	Architrave	SLS characteristic 3	1	0.6	Internal span	0.15	4.00	l/250	4%
Trave 47	Architrave	SLS characteristic 3	1	0.6	Internal span	0.15	4.00	l/250	4%
Trave 48	Internal beam	SLS characteristic 3	1	0.6	Internal span	1.32	10.00	l/250	13%
Trave 49	Internal beam	SLS characteristic 3	1	0.6	Internal span	0.00	4.00	l/250	0%
Trave 50	Ridge beam	SLS characteristic 8	1	0.6	Cantilever beams	0.02	4.00	l/125	0%
Trave 51	Ridge beam	SLS characteristic 8	1	0.6	Cantilever beams	0.02	4.00	l/125	0%
Trave 52	Ridge beam	SLS characteristic 3	1	0.6	Internal span	0.06	4.00	l/250	1%
Trave 53	Ridge beam	SLS characteristic 3	1	0.6	Internal span	0.06	4.00	l/250	1%

Timber columns

Stability of columns

The stability of columns subjected to compression is verified in accordance with § 6.3.2 of EN 1995-1-1.

The relative slenderness ratios should be taken as:

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

and

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

where:

$\lambda_{,y}$ and $\lambda_{rel,y}$ are slenderness ratios corresponding to bending about the y-axis (deflection in the z-direction);

$\lambda_{,z}$ and $\lambda_{rel,z}$ are slenderness ratios corresponding to bending about the z-axis (deflection in the y-direction).

Where both $\lambda_{rel,z} \leq 0,3$ and $\lambda_{rel,y} \leq 0,3$, the stresses should satisfy the expressions (6.19) and (6.20) in 6.2.4 of EN 1995-1-1.

In all other cases the stresses, which will be increased due to deflection, should satisfy the following expressions:

$$\frac{\sigma_{c,0,d}}{k_{c,y} \cdot f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$\frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

where the symbols are defined as follows:

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

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

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

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

where:

β_c is a factor for members within the straightness limits defined in Section 10 of EN 1995-1-1 and assumes the following values

$$\beta_c = \begin{cases} 0{,}2\ for\ solid\ timber \\ 0{,}1\ for\ glued\ laminated\ timber\ and\ LVL \end{cases}$$

The values of the actions in the tables below are related, for each pillar, to the most severe combination of load for the Ultimate Limit State of instability.

Comb.: The most severe combination of load

Dur.: Load duration

N: Axial force

V_2: Shear force along the local axis 2

V_3: Shear force along the local axis 3

M_{2-2}: Bending moment about local axis 2

M_{3-3}: Bending moment about local axis 3

Column name	Comb.	Dur.	N [kN]	V2 [kN]	V3 [kN]	M2-2 [kNm]	M3-3 [kNm]
Pilastro 5	ULS 64	Permanent	35.58	0.00	0.00	0.00	0.00
Pilastro 12	ULS 65	Medium-term	134.44	0.00	0.00	0.00	0.00

The following table summarizes the stability checks for the columns.

Sect.: Column cross section

h: Column height

Area: Cross sectional area of the column

J_y: Area moment of inertia with respect to the y axis

J_z: Area moment of inertia with respect to the z axis

Comb.: The most severe load combination

k_{mod}: Modification factor taking into account the effect of the duration of load and moisture content

γ_M: Partial factor for a material property

$f_{c,0,d}$: Design compressive strength along the grain

$\sigma_{c,0,d}$: Design compressive stress along the grain

Column name	Sect.	h [m]	Area [mm^2]	J_y [mm^4]	J_z [mm^4]	kc,y	kc,z	Comb	Service Class	k_{mod}	γ_M	$f_{c,0,d}$	$\sigma_{c,0,d}$ [MPa]	Check
Pilastro 5	Column	4.25	40000	1.33E8	1.33E8	0.62	0.62	ULS 64	1	0.6	1.25	11.52	0.89	12%
Pilastro 12	Column	3.2	40000	1.33E8	1.33E8	0.85	0.85	ULS 65	1	0.8	1.25	15.36	3.36	26%

CLT walls

Buckling of CLT walls

The stability checks of CLT walls are conducted with reference to what reported in 6.3.2 of EN 1995-1-1.

The values of the actions in the table below are related, for each wall, to the most severe combination of load for the Ultimate Limit State of stability.

Wall name	Length [m]	Comb.	Dur.	N [kN]	M2-2 [kNm]
PX1-1	2.00	ULS 81	Instantaneous	8.74	6.27
PY1-1	1.00	ULS 81	Instantaneous	1.88	2.55
PY1-2	1.00	ULS 81	Instantaneous	1.56	2.55
PX1-4	2.00	ULS 64	Permanent	9.05	0.00
PX1-3	2.00	ULS 81	Instantaneous	8.75	6.27
PY1-6	3.00	ULS 81	Instantaneous	7.53	7.65
PX1-6	2.00	ULS 64	Permanent	9.05	0.00
PY1-8	4.00	ULS 81	Instantaneous	10.35	10.20
PX1-9	2.00	ULS 81	Instantaneous	8.74	6.27
PY1-5	3.00	ULS 64	Permanent	64.93	0.00
PY1-4	2.00	ULS 64	Permanent	50.41	0.00
PX1-7	2.00	ULS 81	Instantaneous	8.75	6.27
Parete 29	1.00	ULS 81	Instantaneous	1.49	0.34
Parete 30	1.00	ULS 81	Instantaneous	1.49	0.34
Parete 34	1.00	ULS 81	Instantaneous	1.49	0.34
Parete 35	1.00	ULS 81	Instantaneous	1.49	0.34
PX1-8	4.00	ULS 81	Instantaneous	22.88	21.05
PY1-3	7.00	ULS 81	Instantaneous	18.82	17.86
PY1-7	2.00	ULS 81	Instantaneous	4.39	5.10
Parete 72	1.00	ULS 81	Instantaneous	1.49	0.34
PX1-2	4.00	ULS 81	Instantaneous	19.90	21.05
PX0-1	2.00	ULS 81	Instantaneous	19.12	6.91
Parete 78	1.00	ULS 81	Instantaneous	1.49	0.34
PX0-2	4.00	ULS 84	Instantaneous	65.83	13.82
PX0-3	2.00	ULS 81	Instantaneous	19.13	6.91
Parete 81	1.00	ULS 81	Instantaneous	1.49	0.34
PY0-6	3.00	ULS 84	Instantaneous	68.95	10.36
PY0-7	2.00	ULS 84	Instantaneous	35.49	6.91
PY0-8	4.00	ULS 81	Instantaneous	30.23	13.82
Parete 88	1.00	ULS 81	Instantaneous	1.49	0.34
Parete 89	1.00	ULS 81	Instantaneous	1.49	0.34
PX1-5	4.00	ULS 64	Permanent	30.58	0.00
PX0-9	2.00	ULS 84	Instantaneous	58.78	6.91
PX0-8	4.00	ULS 84	Instantaneous	122.96	13.82
PX0-7	2.00	ULS 84	Instantaneous	58.79	6.91
Parete 95	1.00	ULS 81	Instantaneous	1.49	0.34
Parete 96	1.00	ULS 81	Instantaneous	1.49	0.34
PY0-5	3.00	ULS 64	Permanent	79.40	0.00
PY0-4	2.00	ULS 64	Permanent	67.77	0.00
PX0-6	2.00	ULS 65	Medium-term	65.06	0.00
PX0-5	4.00	ULS 65	Medium-term	157.29	0.00
PX0-4	2.00	ULS 65	Medium-term	65.06	0.00
PY0-3	7.00	ULS 84	Instantaneous	72.74	24.18
PY0-2	1.00	ULS 84	Instantaneous	34.45	3.45
PY0-1	1.00	ULS 84	Instantaneous	27.29	3.45
Parete 109	1.00	ULS 81	Instantaneous	1.49	0.34
Parete 110	1.00	ULS 81	Instantaneous	1.49	0.34

The stability checks of the CLT panels are performed considering a wall portion of unitary length.

Where both $\lambda_{rel,z}$ ≤0,3 and $\lambda_{rel,y}$ ≤0,3, the stresses should satisfy the expressions (6.19) and (6.20) in 6.2.4 of EN 1995-1-1.

In all other cases the stresses, which will be increased due to deflection, should satisfy the following expressions:

$$\frac{\sigma_{c,0,d}}{k_c \cdot f_{c,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \leq 1$$

Mechanical model for the internal stress pattern in CLT elements

The calculation model adopted for the design of CLT in bending out-of-plane is that of mechanically jointed beams with deformable connection. The calculation of CLT elements is calculated as a mechanically jointed structure in accordance with Appendix B of EN 1995-1-1. The shear flexibility of the transverse layers is considered using the γ-method (gamma): namely with Möhler theory for CLT panel having up to 3 layers oriented in the direction of calculation and with Shelling theory for CLT panel having more than 3 layers oriented in the direction of calculation.

The effective bending stiffness is taken as:

$$EJ_{eff} = \sum_{i=1}^{n} \left(E_i J_i + \gamma_i E_i A_i a_i^2 \right)$$

$$\gamma_i = \left[1 + \frac{\pi^2 E_i A_i}{G_R \cdot \frac{b}{d} \cdot h^2} \right]^{-1}$$

where:

J_i is the moment of inertia of layer i in reference to its neutral axis;

A_i is the cross-sectional area of layer I;

a_i is the distance between the centre of gravity of layer i and centre of gravity of the CLT element;

h It is the height of the wall;

G_R is the rolling shear modulus (mean value).

The results of the stability checks are reported below expressed as percentages.

A_{net}: Cross sectional area of the wall portion considered in the verification (linear meter)

J_{eff}: Cross sectional effective moment of inertia of the wall portion

Comb.: The most severe combination of load

k_{mod}: Modification factor taking into account the effect of the duration of load and moisture content

γ_M: Partial factor for a material property

$f_{c,0,k}$: Design compressive strength along the grain

$f_{m,k}$: Design bending strength

$\sigma_{c,0,d}$: Design compressive stress along the grain

Wall name	Section	h [m]	A_{net} [mm²/m]	J_{eff} [mm⁴/m]	k_c	Comb.	Service Class	k_{mod}	γ_M	$f_{c,0,k}$ [MPa]	$f_{m,k}$ [MPa]	$\sigma_{c,0,d}$ [MPa]	$\sigma_{m,d}$ [MPa]	Check
PX1-1	CLT wall	3.2	60000	60534188	0.32	ULS 81	1	1.1	1.25	21	24	0.08	2.41	13%
PY1-1	CLT wall	2.75	60000	59407016	0.42	ULS 81	1	1.1	1.25	21	24	0.03	1.97	10%
PY1-2	CLT wall	2.75	60000	59407016	0.42	ULS 81	1	1.1	1.25	21	24	0.03	1.97	10%
PX1-4	CLT wall	3.2	60000	60534188	0.32	ULS 64	1	0.6	1.25	21	24	0.08	0.00	2%
PX1-3	CLT wall	3.2	60000	60534188	0.32	ULS 81	1	1.1	1.25	21	24	0.08	2.41	13%
PY1-6	CLT wall	2.75	60000	59407016	0.42	ULS 81	1	1.1	1.25	21	24	0.05	1.97	10%
PX1-6	CLT wall	3.2	60000	60534188	0.32	ULS 64	1	0.6	1.25	21	24	0.08	0.00	2%
PY1-8	CLT wall	2.75	60000	59407016	0.42	ULS 81	1	1.1	1.25	21	24	0.05	1.97	10%
PX1-9	CLT wall	3.2	60000	60534188	0.32	ULS 81	1	1.1	1.25	21	24	0.08	2.41	13%
PY1-5	CLT wall	4.25	60000	63063782	0.19	ULS 64	1	0.6	1.25	21	24	0.41	0.00	21%
PY1-4	CLT wall	4.25	60000	63063782	0.19	ULS 64	1	0.6	1.25	21	24	0.42	0.00	22%
PX1-7	CLT wall	3.2	60000	60534188	0.32	ULS 81	1	1.1	1.25	21	24	0.08	2.41	13%
Parete 29	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
Parete 30	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
Parete 34	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
Parete 35	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
PX1-8	CLT wall	4.25	60000	62625160	0.19	ULS 81	1	1.1	1.25	21	24	0.10	4.02	22%
PY1-3	CLT wall	2.75	60000	59407016	0.42	ULS 81	1	1.1	1.25	21	24	0.05	1.97	10%
PY1-7	CLT wall	2.75	60000	59407016	0.42	ULS 81	1	1.1	1.25	21	24	0.04	1.97	10%
Parete 72	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
PX1-2	CLT wall	3.8	60000	62625160	0.24	ULS 81	1	1.1	1.25	21	24	0.09	4.02	21%
PX0-1	CLT wall	3.2	60000	60996130	0.32	ULS 81	1	1.1	1.25	21	24	0.17	2.65	15%
Parete 78	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
PX0-2	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.46	2.65	20%
PX0-3	CLT wall	3.2	60000	60996130	0.32	ULS 81	1	1.1	1.25	21	24	0.17	2.65	15%
Parete 81	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
PY0-6	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.46	2.65	20%
PY0-7	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.46	2.65	20%
PY0-8	CLT wall	3.2	60000	60996130	0.32	ULS 81	1	1.1	1.25	21	24	0.13	2.65	15%
Parete 88	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
Parete 89	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
PX1-5	CLT wall	4.25	60000	62625160	0.19	ULS 64	1	0.6	1.25	21	24	0.17	0.00	9%
PX0-9	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.56	2.65	22%
PX0-8	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.58	2.65	22%
PX0-7	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.57	2.65	22%
Parete 95	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
Parete 96	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
PY0-5	CLT wall	3.2	60000	60996130	0.32	ULS 64	1	0.6	1.25	21	24	0.49	0.00	15%
PY0-4	CLT wall	3.2	60000	60996130	0.32	ULS 64	1	0.6	1.25	21	24	0.63	0.00	19%
PX0-6	CLT wall	3.2	60000	60996130	0.32	ULS 65	1	0.8	1.25	21	24	0.62	0.00	14%
PX0-5	CLT wall	3.2	60000	60996130	0.32	ULS 65	1	0.8	1.25	21	24	0.74	0.00	17%
PX0-4	CLT wall	3.2	60000	60996130	0.32	ULS 65	1	0.8	1.25	21	24	0.62	0.00	14%
PY0-3	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.45	2.65	20%
PY0-2	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.57	2.65	22%
PY0-1	CLT wall	3.2	60000	60996130	0.32	ULS 84	1	1.1	1.25	21	24	0.45	2.65	20%
Parete 109	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%
Parete 110	CLT wall	1.0	60000	36251612	0.93	ULS 81	1	1.1	1.25	21	24	0.02	0.29	2%

Compression perpendicular to the grain

In the area of wall support there are high local stresses perpendicular to the grain. The following expression shall be satisfied:

$$\sigma_{c,90,d} \leq k_{c,90,d} \cdot f_{c,90,d}$$

with

$$\sigma_{c,90,d} = \frac{F_{c,90,d}}{A_{full}}$$

where:

$\sigma_{c,90,d}$ is the design compressive stress in the contact area perpendicular to the grain;

$F_{c,90,d}$ is the design load of compression perpendicular to the grain;

A_{full} is the contact area on which the compression load (perpendicular to the grain) acts;

$f_{c,90,d}$ is the design compressive strength perpendicular to the grain;

$k_{c,90,d}$ is a factor taking into account the load configuration, possibility of splitting and degree of compressive deformation.

The values of the actions in the table below are related, for each wall, to the most severe combination of load for the Ultimate Limit State.

Wall name	Length [m]	Comb.	Dur.	N [kN]
PX1-1	2.00	ULS 64	Permanent	10.95
PY1-1	1.00	ULS 64	Permanent	17.35
PY1-2	1.00	ULS 64	Permanent	19.24
PX1-4	2.00	ULS 64	Permanent	9.05
PX1-3	2.00	ULS 64	Permanent	10.96
PY1-6	3.00	ULS 64	Permanent	40.67
PX1-6	2.00	ULS 64	Permanent	9.05
PY1-8	4.00	ULS 64	Permanent	52.33
PX1-9	2.00	ULS 64	Permanent	10.95
PY1-5	3.00	ULS 64	Permanent	64.93
PY1-4	2.00	ULS 64	Permanent	50.41
PX1-7	2.00	ULS 64	Permanent	10.96
Parete 29	1.00	ULS 64	Permanent	1.49
Parete 30	1.00	ULS 64	Permanent	1.49
Parete 34	1.00	ULS 64	Permanent	1.49
Parete 35	1.00	ULS 64	Permanent	1.49
PX1-8	4.00	ULS 64	Permanent	26.53
PY1-3	7.00	ULS 64	Permanent	87.32
PY1-7	2.00	ULS 64	Permanent	30.90
Parete 72	1.00	ULS 64	Permanent	1.49
PX1-2	4.00	ULS 64	Permanent	42.26
PX0-1	2.00	ULS 64	Permanent	21.33
Parete 78	1.00	ULS 64	Permanent	1.49
PX0-2	4.00	ULS 64	Permanent	78.34
PX0-3	2.00	ULS 64	Permanent	21.34
Parete 81	1.00	ULS 64	Permanent	1.49
PY0-6	3.00	ULS 70	Medium-term	110.91
PY0-7	2.00	ULS 70	Medium-term	69.06
PY0-8	4.00	ULS 64	Permanent	72.21
Parete 88	1.00	ULS 64	Permanent	1.49
Parete 89	1.00	ULS 64	Permanent	1.49
PX1-5	4.00	ULS 64	Permanent	30.58
PX0-9	2.00	ULS 65	Medium-term	67.75
PX0-8	4.00	ULS 65	Medium-term	140.15
PX0-7	2.00	ULS 65	Medium-term	67.77
Parete 95	1.00	ULS 64	Permanent	1.49
Parete 96	1.00	ULS 64	Permanent	1.49
PY0-5	3.00	ULS 64	Permanent	79.40
PY0-4	2.00	ULS 64	Permanent	67.77
PX0-6	2.00	ULS 65	Medium-term	65.06
PX0-5	4.00	ULS 65	Medium-term	157.29
PX0-4	2.00	ULS 65	Medium-term	65.06
PY0-3	7.00	ULS 70	Medium-term	159.48
PY0-2	1.00	ULS 70	Medium-term	56.83
PY0-1	1.00	ULS 70	Medium-term	46.88

Parete 109	1.00	ULS 64	Permanent	1.49
Parete 110	1.00	ULS 64	Permanent	1.49

The compression checks of the CLT panels are performed considering a wall portion of unitary length.

Section: CLT element section

A_{full}: Contact area on which the compression load (perpendicular to the grain) acts

Comb.: The most severe combination of load

k_{mod}: Modification factor taking into account the effect of the duration of load and moisture content

γ_M: Partial factor for a material property

$f_{c,90,k}$: Design compressive strength perpendicular to the grain

$\sigma_{c,90,d}$: Design compressive stress in the contact area perpendicular to the grain

Wall name	Section	A_{full} [mm²/m]	$k_{c,90}$	Comb.	Service class	k_{mod}	γ_M	$f_{c,90,k}$ [MPa]	$\sigma_{c,90,d}$ [MPa]	Check
PX1-1	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.06	3%
PY1-1	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.17	10%
PY1-2	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.19	11%
PX1-4	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.05	3%
PX1-3	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.06	3%
PY1-6	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.15	8%
PX1-6	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.05	3%
PY1-8	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.15	9%
PX1-9	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.06	3%
PY1-5	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.24	14%
PY1-4	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.25	14%
PX1-7	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.06	3%
Parete 29	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
Parete 30	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
Parete 34	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
Parete 35	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
PX1-8	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.08	4%
PY1-3	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.15	9%
PY1-7	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.15	9%
Parete 72	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
PX1-2	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.18	10%
PX0-1	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.11	6%
Parete 78	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
PX0-2	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.34	19%
PX0-3	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.11	6%
Parete 81	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
PY0-6	CLT wall	100000	1.5	ULS 70	1	0.8	1.25	2.5	0.44	18%
PY0-7	CLT wall	100000	1.5	ULS 70	1	0.8	1.25	2.5	0.44	18%
PY0-8	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.21	12%
Parete 88	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
Parete 89	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
PX1-5	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.10	6%
PX0-9	CLT wall	100000	1.5	ULS 65	1	0.8	1.25	2.5	0.38	16%
PX0-8	CLT wall	100000	1.5	ULS 65	1	0.8	1.25	2.5	0.39	16%
PX0-7	CLT wall	100000	1.5	ULS 65	1	0.8	1.25	2.5	0.38	16%
Parete 95	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
Parete 96	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
PY0-5	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.29	16%
PY0-4	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.38	21%
PX0-6	CLT wall	100000	1.5	ULS 65	1	0.8	1.25	2.5	0.37	15%
PX0-5	CLT wall	100000	1.5	ULS 65	1	0.8	1.25	2.5	0.44	19%
PX0-4	CLT wall	100000	1.5	ULS 65	1	0.8	1.25	2.5	0.37	15%
PY0-3	CLT wall	100000	1.5	ULS 70	1	0.8	1.25	2.5	0.44	18%
PY0-2	CLT wall	100000	1.5	ULS 70	1	0.8	1.25	2.5	0.56	23%
PY0-1	CLT wall	100000	1.5	ULS 70	1	0.8	1.25	2.5	0.47	19%
Parete 109	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%
Parete 110	CLT wall	100000	1.5	ULS 64	1	0.6	1.25	2.5	0.01	1%

Shear (load in-plane)

The internal stress pattern in a CLT element subjected to shear forces can lead to failure of the material in two different mechanisms: shear bearing (mechanism I) in the boards and torsion-like (mechanism II) in the gluing interfaces.

The values of the actions in the table below are related, for each wall, to the most severe combination of load for the shear Ultimate Limit State.

In the case of seismic combinations, the overstrength ratio Ω, the shear forces $V2^{CD}$ evaluated in accordance with the rules of capacity design and the shear forces $V2^{ND}$ determined in the case of non-dissipative structural behavior are also reported.

Wall name	Length [m]	Comb.	Dur.	V2 [kN]	Ω	$V2^{CD}$ [kN]	Limitation to the non-dissipative value	$V2^{ND}$ [kN]
PX1-1	2.00	Dynamic SLV 1 ex+ ey-	Instantaneous	8.11	2.04	16.54	Yes	16.23
PY1-1	1.00	Dynamic SLV 8 ex- ey+	Instantaneous	1.81	2.26	4.09	Yes	3.62
PY1-2	1.00	Dynamic SLV 8 ex- ey+	Instantaneous	1.81	2.26	4.09	Yes	3.62
PX1-4	2.00	Dynamic SLV 1 ex+ ey-	Instantaneous	7.36	2.04	15.01	Yes	14.72
PX1-3	2.00	Dynamic SLV 1 ex+ ey-	Instantaneous	8.11	2.04	16.54	Yes	16.23
PY1-6	3.00	Dynamic SLV 5 ex+ ey+	Instantaneous	14.68	2.26	33.19	Yes	29.36
PX1-6	2.00	Dynamic SLV 1 ex+ ey-	Instantaneous	7.36	2.04	15.01	Yes	14.72
PY1-8	4.00	Dynamic SLV 5 ex+ ey+	Instantaneous	25.78	2.26	58.27	Yes	51.56
PX1-9	2.00	Dynamic SLV 1 ex+ ey+	Instantaneous	8.66	2.04	17.66	Yes	17.32
PY1-5	3.00	Dynamic SLV 5 ex+ ey+	Instantaneous	5.65	2.26	12.78	Yes	11.31
PY1-4	2.00	Dynamic SLV 5 ex+ ey+	Instantaneous	2.80	2.26	6.34	Yes	5.61
PX1-7	2.00	Dynamic SLV 1 ex+ ey+	Instantaneous	8.66	2.04	17.66	Yes	17.32
PX1-8	4.00	Dynamic SLV 1 ex+ ey+	Instantaneous	19.27	2.04	39.29	Yes	38.54
PY1-3	7.00	Dynamic SLV 8 ex- ey+	Instantaneous	45.34	2.26	102.48	Yes	90.67
PY1-7	2.00	Dynamic SLV 5 ex+ ey+	Instantaneous	7.95	2.26	17.97	Yes	15.90
PX1-2	4.00	Dynamic SLV 1 ex+ ey-	Instantaneous	18.05	2.04	36.80	Yes	36.10
PX0-1	2.00	Dynamic SLV 1 ex+ ey-	Instantaneous	10.62	2.04	21.65	Yes	21.24
PX0-2	4.00	Dynamic SLV 1 ex+ ey-	Instantaneous	33.69	2.04	68.68	Yes	67.37
PX0-3	2.00	Dynamic SLV 1 ex+ ey-	Instantaneous	10.62	2.04	21.65	Yes	21.24
PY0-6	3.00	Dynamic SLV 5 ex+ ey+	Instantaneous	22.74	2.26	51.40	Yes	45.48
PY0-7	2.00	Dynamic SLV 5 ex+ ey+	Instantaneous	11.43	2.26	25.83	Yes	22.85
PY0-8	4.00	Dynamic SLV 5 ex+ ey+	Instantaneous	36.24	2.26	81.93	Yes	72.49
PX1-5	4.00	Dynamic SLV 1 ex+ ey-	Instantaneous	16.38	2.04	33.39	Yes	32.76
PX0-9	2.00	Dynamic SLV 1 ex+ ey+	Instantaneous	11.52	2.04	23.49	Yes	23.05
PX0-8	4.00	Dynamic SLV 1 ex+ ey+	Instantaneous	36.55	2.04	74.52	Yes	73.10
PX0-7	2.00	Dynamic SLV 1 ex+ ey+	Instantaneous	11.52	2.04	23.49	Yes	23.05
PY0-5	3.00	Dynamic SLV 8 ex- ey+	Instantaneous	17.61	2.26	39.80	Yes	35.21
PY0-4	2.00	Dynamic SLV 8 ex- ey+	Instantaneous	8.85	2.26	20.00	Yes	17.69
PX0-6	2.00	Dynamic SLV 1 ex+ ey-	Instantaneous	9.39	2.04	19.15	Yes	18.78
PX0-5	4.00	Dynamic SLV 1 ex+ ey-	Instantaneous	29.79	2.04	60.74	Yes	59.58
PX0-4	2.00	Dynamic SLV 1 ex+ ey-	Instantaneous	9.39	2.04	19.15	Yes	18.78
PY0-3	7.00	Dynamic SLV 8 ex- ey+	Instantaneous	68.44	2.26	154.71	Yes	136.88
PY0-2	1.00	Dynamic SLV 8 ex- ey+	Instantaneous	2.65	2.26	6.00	Yes	5.31
PY0-1	1.00	Dynamic SLV 8 ex- ey+	Instantaneous	2.65	2.26	6.00	Yes	5.31

The verifications are carried out against the shear forces V2. If the most severe load combination is of the seismic type, the checks are carried out against the $V2^{CD}$ shear forces, possibly limited to $V2^{ND}$ values.

Mechanism I - shear

The internal shear stress can be evaluated as

$$\tau_z = \frac{v_2}{\sum t_{i,ext}}$$

$$\tau_y = \frac{v_2}{\sum t_{i,int}}$$

where:

v_2 is the shear per linear metre acting on the CLT element;

$t_{i,ext}$ is the thickness of the i-th layer having orientation parallel to the external layers;

$t_{i,int}$ is the thickness of the i-th layer having orientation parallel to the internal layers;

τ_z is the shear stress acting on the layers having orientation parallel to the external layers;

τ_y is the shear stress acting on the layers having orientation parallel to the internal layers.

The stress to be used in the checks is the maximum between the two:

$$\tau_d = max(\tau_z;\ \tau_y)$$

The following expression shall be satisfied

$$\tau_d \leq f_{v,d}$$

where:

$f_{v,d}$ the shear strength calculated as

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

Mechanism II – torsion

The internal torsional stress can be expressed as

$$\tau_{T,d} = \frac{M_T}{W}$$

where:

M_T the internal torsional moment;

W the polar moment of resistance.

The polar moment of resistance is defined by the following expression

$$W = \frac{{a_{ref}}^3}{3}$$

where a_{ref} is the average width of the boards assumed equal to 150 mm.

The internal torsional moment M_T can be evaluated according to the model proposed in different European Technical Assessments (ETA) where the following expression is used

$$M_T = \frac{v_2 \cdot {a_{ref}}^2}{n_{strati-1}}$$

The following expression shall be satisfied

$$\tau_{T,d} \leq f_{T,d}$$

where:

$f_{T,d}$ the design value of the torsional strength of glued interfaces.

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

Below is the table with the shear checks for each CLT wall. The two different mechanisms (shear and torsion) are verified.

Comb.: The most severe combination of load

k_{mod}: Modification factor taking into account the effect of the duration of load and moisture content

γ_M: Partial factor for a material property

$f_{v,k}$: CLT characteristic shear strength (Mechanism I)

τ_d: Design shear stress in the layers

M_T: Torsional moment on every glued interfaces

W: Polar moment of resistance

$f_{T,k}$: Characteristic value of the torsional shear strength of the glued interfaces

$\tau_{T,d}$: Design shear stress (due to torsion) in the external layers

Wall name	Section	Comb.	Service class	k_{mod}	γ_M	$f_{v,k}$ [MPa]	τ_d [MPa]	Check - shear	M_T [Nmm]	W [mm^3]	$f_{T,k}$ [MPa]	$\tau_{T,d}$ [MPa]	Check torsion
PX1-1	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.2	6%	45637	1125000	2.5	0.04	2%
PY1-1	CLT wall	Dynamic SLV 8 ex- ey+	1	1.1	1.25	4	0.09	3%	20359	1125000	2.5	0.02	1%
PY1-2	CLT wall	Dynamic SLV 8 ex- ey+	1	1.1	1.25	4	0.09	3%	20359	1125000	2.5	0.02	1%
PX1-4	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.18	5%	41406	1125000	2.5	0.04	2%
PX1-3	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.2	6%	45637	1125000	2.5	0.04	2%
PY1-6	CLT wall	Dynamic SLV 5 ex+ ey+	1	1.1	1.25	4	0.24	7%	55056	1125000	2.5	0.05	2%
PX1-6	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.18	5%	41406	1125000	2.5	0.04	2%
PY1-8	CLT wall	Dynamic SLV 5 ex+ ey+	1	1.1	1.25	4	0.32	9%	72503	1125000	2.5	0.06	3%
PX1-9	CLT wall	Dynamic SLV 1 ex+ ey+	1	1.1	1.25	4	0.22	6%	48716	1125000	2.5	0.04	2%
PY1-5	CLT wall	Dynamic SLV 5 ex+ ey+	1	1.1	1.25	4	0.09	3%	21200	1125000	2.5	0.02	1%
PY1-4	CLT wall	Dynamic SLV 5 ex+ ey+	1	1.1	1.25	4	0.07	2%	15766	1125000	2.5	0.01	1%
PX1-7	CLT wall	Dynamic SLV 1 ex+ ey+	1	1.1	1.25	4	0.22	6%	48716	1125000	2.5	0.04	2%
PX1-8	CLT wall	Dynamic SLV 1 ex+ ey+	1	1.1	1.25	4	0.24	7%	54197	1125000	2.5	0.05	2%
PY1-3	CLT wall	Dynamic SLV 8 ex- ey+	1	1.1	1.25	4	0.32	9%	72860	1125000	2.5	0.06	3%
PY1-7	CLT wall	Dynamic SLV 5 ex+ ey+	1	1.1	1.25	4	0.2	6%	44705	1125000	2.5	0.04	2%
PX1-2	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.23	6%	50771	1125000	2.5	0.05	2%
PX0-1	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.27	8%	59736	1125000	2.5	0.05	2%
PX0-2	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.42	12%	94743	1125000	2.5	0.08	4%
PX0-3	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.27	8%	59736	1125000	2.5	0.05	2%
PY0-6	CLT wall	Dynamic SLV 5 ex+ ey+	1	1.1	1.25	4	0.38	11%	85276	1125000	2.5	0.08	3%
PY0-7	CLT wall	Dynamic SLV 5 ex+ ey+	1	1.1	1.25	4	0.29	8%	64270	1125000	2.5	0.06	3%
PY0-8	CLT wall	Dynamic SLV 5 ex+ ey+	1	1.1	1.25	4	0.45	13%	101933	1125000	2.5	0.09	4%
PX1-5	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.2	6%	46064	1125000	2.5	0.04	2%
PX0-9	CLT wall	Dynamic SLV 1 ex+ ey+	1	1.1	1.25	4	0.29	8%	64817	1125000	2.5	0.06	3%
PX0-8	CLT wall	Dynamic SLV 1 ex+ ey+	1	1.1	1.25	4	0.46	13%	102800	1125000	2.5	0.09	4%
PX0-7	CLT wall	Dynamic SLV 1 ex+ ey+	1	1.1	1.25	4	0.29	8%	64817	1125000	2.5	0.06	3%
PY0-5	CLT wall	Dynamic SLV 8 ex- ey+	1	1.1	1.25	4	0.29	8%	66020	1125000	2.5	0.06	3%
PY0-4	CLT wall	Dynamic SLV 8 ex- ey+	1	1.1	1.25	4	0.22	6%	49757	1125000	2.5	0.04	2%
PX0-6	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.23	7%	52829	1125000	2.5	0.05	2%
PX0-5	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.37	11%	83788	1125000	2.5	0.07	3%
PX0-4	CLT wall	Dynamic SLV 1 ex+ ey-	1	1.1	1.25	4	0.23	7%	52829	1125000	2.5	0.05	2%
PY0-3	CLT wall	Dynamic SLV 8 ex- ey+	1	1.1	1.25	4	0.49	14%	109990	1125000	2.5	0.1	4%
PY0-2	CLT wall	Dynamic SLV 8 ex- ey+	1	1.1	1.25	4	0.13	4%	29864	1125000	2.5	0.03	1%
PY0-1	CLT wall	Dynamic SLV 8 ex- ey+	1	1.1	1.25	4	0.13	4%	29864	1125000	2.5	0.03	1%

Connections

Hold down – Connection at the base of the structure

The design resistance R_d of the hold-downs is determined as the minimum value among the resistances relating to the following failure modes:

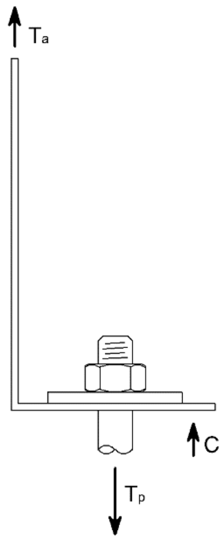
- nailing failure;
- hold-downs steel failure;
- failure of the concrete anchors.

Tensile force

The tensile force acting on the hold down (T_a) is evaluated as described in paragraph "Model Description".

The tensile force acting on the concrete anchors is calculated taking into account the additional moment due to the non-alignment between the external force acting on the vertical flange of the hold down and the anchors themselves using a coefficient, indicated as k_t.

$$T_p = T_a \cdot k_t$$



Wall name	Length [m]	Connection name	N° of anchors at each wall end	Comb.	Dur.	N [kN]	$M_{3\text{-}3}$ [kNm]	Ta [kN]	kt	Tp [kN]
PX0-1	2.00	Ground traction connection - hold down	1	Dynamic SLV 1 ex+ ey-	Instantaneous	15.80	57.60	20.90	1	20.90
PX0-2	4.00	Ground traction connection - hold down	1	Dynamic SLV 1 ex+ ey-	Instantaneous	60.85	175.72	13.51	1	13.51
PX0-3	2.00	Ground traction connection - hold down	1	Dynamic SLV 1 ex+ ey-	Instantaneous	15.81	57.60	20.90	1	20.90
PY0-6	3.00	Ground traction connection - hold down	1	Dynamic SLV 5 ex+ ey+	Instantaneous	67.23	111.73	3.63	1	3.63
PY0-7	2.00	Ground traction connection - hold down	1	Dynamic SLV 5 ex+ ey+	Instantaneous	42.33	57.67	7.67	1	7.67
PY0-8	4.00	Ground traction connection - hold down	1	Dynamic SLV 5 ex+ ey+	Instantaneous	53.49	184.47	19.37	1	19.37
PX0-9	2.00	Ground traction connection - hold down	1	Dynamic SLV 1 ex+ ey+	Instantaneous	37.99	62.05	12.03	1	12.03
PX0-8	4.00	Ground traction connection - hold down	1	Dynamic SLV 1 ex+ ey+	Instantaneous	79.41	189.37	7.64	1	7.64
PX0-7	2.00	Ground traction connection - hold down	1	Dynamic SLV 1 ex+ ey+	Instantaneous	38.00	62.05	12.03	1	12.03
PY0-5	3.00	Ground traction connection - hold down	1	Horizontal ULS 1	Instantaneous	58.82	0.13	0.00	1	0.00
PY0-4	2.00	Ground traction connection - hold down	1	Horizontal ULS 1	Instantaneous	50.20	0.07	0.00	1	0.00

PX0-6	2.00	Ground traction connection - hold down	1	Dynamic SLV 1 ex+ ey-	Instantaneous	36.02	51.46	7.72	1	7.72
PX0-5	4.00	Ground traction connection - hold down	1	Horizontal ULS 1	Instantaneous	77.94	105.66	0.00	1	0.00
PX0-4	2.00	Ground traction connection - hold down	1	Dynamic SLV 1 ex+ ey-	Instantaneous	36.02	51.46	7.72	1	7.72
PY0-3	7.00	Ground traction connection - hold down	1	Horizontal ULS 1	Instantaneous	98.79	4.23	0.00	1	0.00
PY0-2	1.00	Ground traction connection - hold down	1	Horizontal ULS 1	Instantaneous	30.83	0.17	0.00	1	0.00
PY0-1	1.00	Ground traction connection - hold down	1	Horizontal ULS 1	Instantaneous	25.84	0.17	0.00	1	0.00

Nailing resistance

The design value of the load-bearing capacity of the nailing is given by the following expression

$$R_{c,d} = \frac{k_{mod} \cdot R_{c,k,dens}}{\gamma_M}$$

where:

$R_{c,k,dens}$ is the characteristic value of the nailing resistance. This value is reduced by the k_{dens} factor when the density of the material used is less than 350 kg/m^3. k_{dens} can be evaluated using the formula $R_{c,k,dens} = R_{c,k} \cdot \left(\frac{\rho_k}{350}\right)^2$;

k_{mod} is the modification factor taking into account the effect of the duration of load and moisture content;

γ_M is the is the partial factor for the connections.

Steel resistance

The tensile design strength of the hold-down can be evaluated according to the formula

$$R_{s,d} = \frac{R_{s,k}}{\gamma_{M2}}$$

where:

$R_{s,k}$ is the characteristic value of the resistance of the hold-down;

γ_{M2} is the partial factor for resistance of cross-sections in tension to fracture.

Concrete anchors resistance

The tension resistance of the concrete anchors can be evaluated according to the formula

$$R_{p,d} = \frac{R_{p,k}}{\gamma}$$

where:

$R_{p,k}$ is the characteristic value of the resistance of the concrete anchors;

γ is the safety factor.

The checks are summarized in the following table which shows the characteristic values of the resistances associated with collapse of the various components.

Name: Name of the connection in which the hold-down is used

Comb.: The most severe combination of load

$T_{a,d}$: Design value of the tensile force acting on the hold down

$T_{p,d}$: Design value of the tensile force acting on the concrete anchors

k_{mod}: Modification factor taking into account the effect of the duration of load and moisture content

$k_{R,deg}$: Resistance degradation coefficient due to cyclic actions

γ_M: Partial safety factor

$R_{a,d}$: Design value of the hold down resistance, assumed to be the lower of the values of the design resistance of all the failure mechanisms associated with it

$R_{p,d}$: Design value of the concrete anchors resistance

$$T_{a,d} \leq R_{a,d} = min(R_{c,d}; R_{s,d})$$

$$T_{p,d} \leq R_{p,d}$$

Wall name	Connection name	Comb.	Service class	$T_{a,d}$ [kN]	$R_{c,k,dens}$ [kN]	$R_{s,k}$ [kN]	k_{mod}	$k_{R,deg}$	γ_M	γ_{M2}	$R_{a,d}$ [kN]	$T_{p,d}$ [kN]	$R_{p,k}$ [kN]	γ	$R_{p,d}$ [kN]	Failure mode	Check
PX0-1	Ground traction connection - hold down	Dynamic SLV 1 ex+ ey-	1	20.90	38.60	63.4	1.1	1	1.3	1.25	32.66	20.90	72.45	1.5	48.30	Tensile: nailing	64%
PX0-2	Ground traction connection - hold down	Dynamic SLV 1 ex+ ey-	1	13.51	38.60	63.4	1.1	1	1.3	1.25	32.66	13.51	72.45	1.5	48.30	Tensile: nailing	41%
PX0-3	Ground traction connection - hold down	Dynamic SLV 1 ex+ ey-	1	20.90	38.60	63.4	1.1	1	1.3	1.25	32.66	20.90	72.45	1.5	48.30	Tensile: nailing	64%
PY0-6	Ground traction connection - hold down	Dynamic SLV 5 ex+ ey+	1	3.63	38.60	63.4	1.1	1	1.3	1.25	32.66	3.63	72.45	1.5	48.30	Tensile: nailing	11%
PY0-7	Ground traction connection - hold down	Dynamic SLV 5 ex+ ey+	1	7.67	38.60	63.4	1.1	1	1.3	1.25	32.66	7.67	72.45	1.5	48.30	Tensile: nailing	23%
PY0-8	Ground traction connection - hold down	Dynamic SLV 5 ex+ ey+	1	19.37	38.60	63.4	1.1	1	1.3	1.25	32.66	19.37	72.45	1.5	48.30	Tensile: nailing	59%
PX0-9	Ground traction connection - hold down	Dynamic SLV 1 ex+ ey+	1	12.03	38.60	63.4	1.1	1	1.3	1.25	32.66	12.03	72.45	1.5	48.30	Tensile: nailing	37%
PX0-8	Ground traction connection - hold down	Dynamic SLV 1 ex+ ey+	1	7.64	38.60	63.4	1.1	1	1.3	1.25	32.66	7.64	72.45	1.5	48.30	Tensile: nailing	23%
PX0-7	Ground traction	Dynamic SLV 1 ex+ ey+	1	12.03	38.60	63.4	1.1	1	1.3	1.25	32.66	12.03	72.45	1.5	48.30	Tensile: nailing	37%

	connection - hold down																
PY0-5	Ground traction connection - hold down	Horizontal ULS 1	1	0.00	38.60	63.4	1.1	1	1.3	1.25	-	0.00	72.45	1.5	-	-	0%
PY0-4	Ground traction connection - hold down	Horizontal ULS 1	1	0.00	38.60	63.4	1.1	1	1.3	1.25	-	0.00	72.45	1.5	-	-	0%
PX0-6	Ground traction connection - hold down	Dynamic SLV 1 ex+ ey-	1	7.72	38.60	63.4	1.1	1	1.3	1.25	32.66	7.72	72.45	1.5	48.30	Tensile: nailing	24%
PX0-5	Ground traction connection - hold down	Horizontal ULS 1	1	0.00	38.60	63.4	1.1	1	1.3	1.25	-	0.00	72.45	1.5	-	-	0%
PX0-4	Ground traction connection - hold down	Dynamic SLV 1 ex+ ey-	1	7.72	38.60	63.4	1.1	1	1.3	1.25	32.66	7.72	72.45	1.5	48.30	Tensile: nailing	24%
PY0-3	Ground traction connection - hold down	Horizontal ULS 1	1	0.00	38.60	63.4	1.1	1	1.3	1.25	-	0.00	72.45	1.5	-	-	0%
PY0-2	Ground traction connection - hold down	Horizontal ULS 1	1	0.00	38.60	63.4	1.1	1	1.3	1.25	-	0.00	72.45	1.5	-	-	0%
PY0-1	Ground traction connection - hold down	Horizontal ULS 1	1	0.00	38.60	63.4	1.1	1	1.3	1.25	-	0.00	72.45	1.5	-	-	0%

Capacity design: local level

In order to ensure compliance with the rules of capacity design at the local level (connection), it must be verified that the resistances associated with the brittle failure modes are over-resistant compared to the resistance associated with the ductile failure mode.

$$R_{brittle,d} \geq \frac{\gamma_{Rd}}{k_{R,deg}} \cdot R_{ductile,d}$$

The checks on the over-resistance of the brittle failure modes are summarized in percentage form in the following table.

Wall name	Connection name	$R_{c,d}$ [kN]	$R_{s,d}$ [kN]	$R_{p,d}$ [kN]	Ductile failure	$k_{R,deg}$	γ_{Rd}	Local capacity design verification: nailing	Local capacity design verification: steel connection element	Local capacity design verification: anchors
PX0-1	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PX0-2	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PX0-3	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PY0-6	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PY0-7	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PY0-8	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PX0-9	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PX0-8	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PX0-7	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PY0-5	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PY0-4	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PX0-6	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%

PX0-5	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PX0-4	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PY0-3	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PY0-2	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%
PY0-1	Ground traction connection - hold down	32.66	50.72	48.30	Nailing	1	1.3	-	84%	88%

Timber to timber tensile plate – Upper levels connection

The design resistance R_d of a punched strap is determined as the minimum value among the resistances relating to the following failure modes:

- nailing failure;
- punched strap steel failure.

Tensile force

The tensile force acting on the punched metal plate (T_a) is evaluated as described in paragraph "Model Description".

Wall name	Length [m]	Connection name	N° of connections at each wall end	Comb.	Dur.	N [kN]	M_{3-3} [kNm]	Ta [kN]
PX1-1	2.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey-	Instantaneous	8.11	24.74	8.32
PY1-1	1.00	Upper levels traction connection - tensile plate	1	Horizontal ULS 1	Instantaneous	12.85	0.05	0.00
PY1-2	1.00	Upper levels traction connection - tensile plate	1	Horizontal ULS 1	Instantaneous	14.25	0.05	0.00
PX1-4	2.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey-	Instantaneous	6.71	22.45	7.87
PX1-3	2.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey-	Instantaneous	8.12	24.74	8.31
PY1-6	3.00	Upper levels traction connection - tensile plate	1	Horizontal ULS 1	Instantaneous	30.12	0.37	0.00
PX1-6	2.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey-	Instantaneous	6.71	22.45	7.87
PY1-8	4.00	Upper levels traction connection - tensile plate	1	Horizontal ULS 1	Instantaneous	38.76	0.65	0.00
PX1-9	2.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey+	Instantaneous	8.11	26.41	9.15
PY1-5	3.00	Upper levels traction connection - tensile plate	1	Horizontal ULS 1	Instantaneous	48.10	0.03	0.00
PY1-4	2.00	Upper levels traction connection - tensile plate	1	Horizontal ULS 1	Instantaneous	37.34	0.02	0.00
PX1-7	2.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey+	Instantaneous	8.12	26.41	9.15
PX1-8	4.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey+	Instantaneous	19.65	76.12	9.20
PY1-3	7.00	Upper levels traction connection - tensile plate	1	Horizontal ULS 1	Instantaneous	64.68	1.16	0.00
PY1-7	2.00	Upper levels traction connection - tensile plate	1	Horizontal ULS 1	Instantaneous	22.89	0.20	0.00
PX1-2	4.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey-	Instantaneous	31.30	71.30	2.18
PX1-5	4.00	Upper levels traction connection - tensile plate	1	Dynamic SLV 1 ex+ ey-	Instantaneous	22.65	64.69	4.85

Steel resistance

The tensile resistance of the punched element is evaluated on the basis of the indications of 6.2.3 EN 1993-1-1. For sections with holes the design tension resistance $N_{t,Rd}$ should be taken as the smaller of the design plastic resistance of the gross cross-section and the design ultimate resistance of the net cross-section at holes for fasteners.

The design plastic resistance of the gross cross-section is calculated as

$$R_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}}$$

where:

A is the area of the gross cross-section;

f_y is the nominal values of the yield strength of steel;

γ_{M0} is the partial factor for resistance of cross-sections.

The net cross section resistance can be evaluated using the following expression:

$$R_{u,Rd} = \frac{0.9 \cdot A_{net} \cdot f_u}{\gamma_{M2}}$$

where:

A_{net} is the cross sectional net area;

f_u is the ultimate strength of the yield strength of steel;

γ_{M2} is the partial factor for resistance of cross-sections in tension to fracture.

Nailing resistance

The characteristic resistance of the connection was calculated as the product between the effective number of fasteners inserted and bearing capacity of the single fastener

$$R_{c,k} = n_{ef} \cdot R_{k,conn}$$

where the bearing capacity of the single fastener $R_{conn,k}$ is evaluated using Johansen theory and the effective number of fasteners is evaluated in accordance with 8.3.1.1 (8) and 8.5.1.1 (4) – EN 1995-1-1.

Wall name	Connection name	Number of rows	Number of fasteners in a row	Fasteners spacing in one row [mm]	Effective number of fasteners	$R_{conn,k}$ [kN]	$R_{c,k}$ [kN]
PX1-1	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PY1-1	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PY1-2	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PX1-4	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PX1-3	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PY1-6	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PX1-6	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PY1-8	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PX1-9	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PY1-5	Upper levels traction	3	4	40	9.75	1.99	19.38

	connection - tensile plate						
PY1-4	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PX1-7	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PX1-8	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PY1-3	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PY1-7	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PX1-2	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38
PX1-5	Upper levels traction connection - tensile plate	3	4	40	9.75	1.99	19.38

The design value of the load-bearing capacity is given by

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

where:

$R_{c,k}$ is the characteristic resistance of the fastener;

k_{mod} is the modification factor taking into account the effect of the duration of load and moisture content;

γ_M is the partial factor for connections.

The checks are summarized in the following table which shows the characteristic values of resistance associated with the different failure modes of the components.

Name: Name of the connection in which the punched strap is used

Comb.: The most severe combination of load

$T_{a,d}$: Design force acting on the connection

k_{mod}: Modification factor taking into account the effect of the duration of load and moisture content

$k_{R,deg}$: Resistance degradation coefficient due to cyclic actions

γ_M: Partial safety factor

R_d: Design value of the resistance, assumed to be the lower of the values of the design resistance of all the failure mechanisms considered

$$T_{a,d} \leq min(R_{pl,Rd};\ R_{u,d};\ R_{c,d})$$

Wall name	Connection name	Comb.	Service Class	$T_{a,d}$ [kN]	$R_{c,k}$ [kN]	$R_{pl,k}$ [kN]	$R_{u,k}$ [kN]	k_{mod}	$k_{R,deg}$	γ_M	γ_{M0}	γ_{M2}	R_d [kN]	Failure mode	Check
PX1-1	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey-	1	8.32	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	51%
PY1-1	Upper levels traction connection - tensile plate	Horizontal ULS 1	1	0.00	19.38	42	34.02	1.1	1	1.3	1	1.25	-	-	0%
PY1-2	Upper levels traction connection - tensile plate	Horizontal ULS 1	1	0.00	19.38	42	34.02	1.1	1	1.3	1	1.25	-	-	0%
PX1-4	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey-	1	7.87	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	48%
PX1-3	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey-	1	8.31	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	51%
PY1-6	Upper levels traction connection - tensile plate	Horizontal ULS 1	1	0.00	19.38	42	34.02	1.1	1	1.3	1	1.25	-	-	0%
PX1-6	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey-	1	7.87	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	48%
PY1-8	Upper levels traction connection - tensile plate	Horizontal ULS 1	1	0.00	19.38	42	34.02	1.1	1	1.3	1	1.25	-	-	0%
PX1-9	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey+	1	9.15	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	56%
PY1-5	Upper levels traction connection - tensile plate	Horizontal ULS 1	1	0.00	19.38	42	34.02	1.1	1	1.3	1	1.25	-	-	0%
PY1-4	Upper levels traction connection - tensile plate	Horizontal ULS 1	1	0.00	19.38	42	34.02	1.1	1	1.3	1	1.25	-	-	0%
PX1-7	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey+	1	9.15	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	56%
PX1-8	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey+	1	9.20	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	56%
PY1-3	Upper levels traction connection - tensile plate	Horizontal ULS 1	1	0.00	19.38	42	34.02	1.1	1	1.3	1	1.25	-	-	0%
PY1-7	Upper levels traction connection - tensile plate	Horizontal ULS 1	1	0.00	19.38	42	34.02	1.1	1	1.3	1	1.25	-	-	0%
PX1-2	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey-	1	2.18	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	13%
PX1-5	Upper levels traction connection - tensile plate	Dynamic SLV 1 ex+ ey-	1	4.85	19.38	42	34.02	1.1	1	1.3	1	1.25	16.40	Tensile: nailing	30%

Capacity design: local level

In order to ensure compliance with the rules of capacity design at the local level (connection), it must be verified that the resistances associated with the brittle failure modes are over-resistant compared to the resistance associated with the ductile failure mode.

$$R_{brittle,d} \geq \frac{\gamma_{Rd}}{k_{R,deg}} \cdot R_{ductile,d}$$

The checks on the over-resistance of the brittle failure modes are summarized in percentage form in the following table.

Wall name	Connection name	$R_{c,d}$ [kN]	$R_{pl,d}$ [kN]	$R_{u,d}$ [kN]	Ductile failure	$k_{R,deg}$	γ_{Rd}	Local capacity design verification: steel gross section	Local capacity design verification: steel net section
PX1-1	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PY1-1	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PY1-2	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%

PX1-4	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PX1-3	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PY1-6	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PX1-6	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PY1-8	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PX1-9	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PY1-5	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PY1-4	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PX1-7	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PX1-8	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PY1-3	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PY1-7	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PX1-2	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%
PX1-5	Upper levels traction connection - tensile plate	16.40	42.00	27.22	Nailing	1	1.3	51%	78%

Timber to concrete angle bracket – Connection at the base of the structure

The design resistance R_d of an angle bracket is determined as the minimum value among the resistances relating to the following failure modes:

- shear failure of the angle and/or of the group of fasteners of the connection;
- shear failure of the anchors connecting the concrete.

Shear force

The shear force acting on the single angle bracket is calculated by dividing the total shear force V_2 by the number of angle brackets present in the wall (taking into account the possible presence of angle brackets on both sides of the structural element).

$$V_a = \frac{V_2}{n_{anc}}$$

where:

V_2 is the design shear force on the considered wall;

n_{anc} is the number of shear connections present in the wall.

The shear force acting on the concrete anchors of each angle bracket is equal to V_a.

Wall name	Length [m]	Connection name	N of connections	Comb.	Dur.	V_2 [kN]	Va [kN]
PX0-1	2.00	Ground shear connection - bracket	2	Dynamic SLV 1 ex+ ey-	Instantaneous	10.62	5.31
PX0-2	4.00	Ground shear connection - bracket	4	Dynamic SLV 1 ex+ ey-	Instantaneous	33.69	8.42
PX0-3	2.00	Ground shear connection - bracket	2	Dynamic SLV 1 ex+ ey-	Instantaneous	10.62	5.31
PY0-6	3.00	Ground shear connection - bracket	3	Dynamic SLV 5 ex+ ey+	Instantaneous	22.74	7.58
PY0-7	2.00	Ground shear connection - bracket	2	Dynamic SLV 5 ex+ ey+	Instantaneous	11.43	5.71
PY0-8	4.00	Ground shear connection - bracket	4	Dynamic SLV 5 ex+ ey+	Instantaneous	36.24	9.06
PX0-9	2.00	Ground shear connection - bracket	2	Dynamic SLV 1 ex+ ey+	Instantaneous	11.52	5.76
PX0-8	4.00	Ground shear connection - bracket	4	Dynamic SLV 1 ex+ ey+	Instantaneous	36.55	9.14
PX0-7	2.00	Ground shear connection - bracket	2	Dynamic SLV 1 ex+ ey+	Instantaneous	11.52	5.76
PY0-5	3.00	Ground shear connection - bracket	3	Dynamic SLV 8 ex- ey+	Instantaneous	17.61	5.87
PY0-4	2.00	Ground shear connection - bracket	2	Dynamic SLV 8 ex- ey+	Instantaneous	8.85	4.42
PX0-6	2.00	Ground shear connection - bracket	2	Dynamic SLV 1 ex+ ey-	Instantaneous	9.39	4.70
PX0-5	4.00	Ground shear connection - bracket	4	Dynamic SLV 1 ex+ ey-	Instantaneous	29.79	7.45
PX0-4	2.00	Ground shear connection - bracket	2	Dynamic SLV 1 ex+ ey-	Instantaneous	9.39	4.70
PY0-3	7.00	Ground shear connection - bracket	7	Dynamic SLV 8 ex- ey+	Instantaneous	68.44	9.78
PY0-2	1.00	Ground shear connection - bracket	1	Dynamic SLV 8 ex- ey+	Instantaneous	2.65	2.65
PY0-1	1.00	Ground shear connection - bracket	1	Dynamic SLV 8 ex- ey+	Instantaneous	2.65	2.65

Angle bracket resistance

The design value of the shear bearing capacity of the angle bracket can be estimated from the characteristic value by means of the following expression

$$R_{a,d} = \frac{k_{mod} \cdot R_{a,k,dens}}{\gamma_M}$$

where:

$R_{a,k,dens}$ is the characteristic value of the nailing resistance. This value is reduced by the k_{dens} factor when the density of the material used is less than 350 kg/m^3. k_{dens} can be evaluated using the formula $R_{a,k,dens} = R_{a,k} \cdot \left(\frac{\rho_k}{350}\right)^2$.

Concrete anchors resistance

The shear resistance of the concrete anchors is evaluated by the following formula

$$R_{p,d} = \frac{R_{p,k}}{\gamma}$$

where:

$R_{p,k}$ is the characteristic value of the shear resistance of the concrete anchors;

γ is the safety factor.

The checks are summarized in the following table which illustrates the characteristic values of the resistances associated to the different components and their design values.

Name: Name of the connection in which the angle bracket is used

Comb.: The most severe combination of load

$V_{a,d}$: Shear force acting on the angle bracket and on the concrete anchors

k_{mod}: Modification factor taking into account the effect of the duration of load and moisture content

$k_{R,deg}$: Resistance degradation coefficient due to cyclic actions

γ_M: Partial safety factor

$R_{a,d}$: Design value of the angle bracket resistance

$R_{p,d}$: Design value of the concrete anchors resistance

$$V_{a,d} \leq R_{a,d}$$

$$V_{a,d} \leq R_{p,d}$$

Wall name	Connection name	Comb.	Service class	$V_{a,d}$ [kN]	$R_{a,k,dens}$ [kN]	k_{mod}	$k_{R,deg}$	γ_M	$R_{a,d}$ [kN]	$R_{p,k}$ [kN]	γ	$R_{p,d}$ [kN]	Failure mode	Check
PX0-1	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	5.31	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	36%
PX0-2	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	8.42	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	57%
PX0-3	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	5.31	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	36%
PY0-6	Ground shear connection - bracket	Dynamic SLV 5 ex+ ey+	1	7.58	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	51%
PY0-7	Ground shear connection - bracket	Dynamic SLV 5 ex+ ey+	1	5.71	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	39%
PY0-8	Ground shear connection - bracket	Dynamic SLV 5 ex+ ey+	1	9.06	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	62%
PX0-9	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey+	1	5.76	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	39%
PX0-8	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey+	1	9.14	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	62%
PX0-7	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey+	1	5.76	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	39%
PY0-5	Ground shear connection - bracket	Dynamic SLV 8 ex- ey+	1	5.87	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	40%
PY0-4	Ground shear connection - bracket	Dynamic SLV 8 ex- ey+	1	4.42	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	30%
PX0-6	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	4.70	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	32%
PX0-5	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	7.45	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	51%
PX0-4	Ground shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	4.70	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	32%
PY0-3	Ground shear connection - bracket	Dynamic SLV 8 ex- ey+	1	9.78	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	66%
PY0-2	Ground shear connection - bracket	Dynamic SLV 8 ex- ey+	1	2.65	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	18%
PY0-1	Ground shear connection - bracket	Dynamic SLV 8 ex- ey+	1	2.65	17.40	1.1	1	1.3	14.72	44	1.25	35.2	Shear: connection element	18%

Capacity design: local level

In order to ensure compliance with the rules of capacity design at the local level (connection), it must be verified that the resistances associated with the brittle failure modes are over-resistant compared to the resistance associated with the ductile failure mode.

$$R_{brittle,d} \geq \frac{\gamma_{Rd}}{k_{R,deg}} \cdot R_{ductile,d}$$

The checks on the over-resistance of the brittle failure modes are summarized in percentage form in the following table.

Wall name	Connection name	$R_{a,d}$ [kN]	$R_{p,d}$ [kN]	Ductile failure	$k_{R,deg}$	γ_{Rd}	Local capacity design verification: anchors
PX0-1	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PX0-2	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PX0-3	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PY0-6	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PY0-7	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PY0-8	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PX0-9	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%

PX0-8	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PX0-7	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PY0-5	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PY0-4	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PX0-6	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PX0-5	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PX0-4	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PY0-3	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PY0-2	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%
PY0-1	Ground shear connection - bracket	14.72	35.2	Nailing	1	1.3	54%

Timber to timber angle bracket

The design resistance R_d of an angle bracket is determined as the resistance of the following failure mode:

- shear failure of the angle and/or of the group of fasteners of the connection.

Shear force

The shear force acting on the single angle bracket is calculated by dividing the total shear force V_2 by the number of angle brackets present in the wall (taking into account the possible presence of angle brackets on both sides of the structural element).

$$V_a = \frac{V_2}{n_{anc}}$$

where:

V_2 is the design shear force on the considered wall;

n_{anc} is the number of shear connections present in the wall.

Wall name	Length [m]	Connection name	N of connections	Comb.	Dur.	V2 [kN]	Va [kN]
PX1-1	2.00	Upper levels shear connection - bracket	1	Dynamic SLV 1 ex+ ey-	Instantaneous	8.11	8.11
PY1-1	1.00	Upper levels shear connection - bracket	1	Dynamic SLV 8 ex- ey+	Instantaneous	1.81	1.81
PY1-2	1.00	Upper levels shear connection - bracket	1	Dynamic SLV 8 ex- ey+	Instantaneous	1.81	1.81
PX1-4	2.00	Upper levels shear connection - bracket	1	Dynamic SLV 1 ex+ ey-	Instantaneous	7.36	7.36
PX1-3	2.00	Upper levels shear connection - bracket	1	Dynamic SLV 1 ex+ ey-	Instantaneous	8.11	8.11
PY1-6	3.00	Upper levels shear connection - bracket	1	Dynamic SLV 5 ex+ ey+	Instantaneous	14.68	14.68
PX1-6	2.00	Upper levels shear connection - bracket	1	Dynamic SLV 1 ex+ ey-	Instantaneous	7.36	7.36
PY1-8	4.00	Upper levels shear connection - bracket	2	Dynamic SLV 5 ex+ ey+	Instantaneous	25.78	12.89
PX1-9	2.00	Upper levels shear connection - bracket	1	Dynamic SLV 1 ex+ ey+	Instantaneous	8.66	8.66
PY1-5	3.00	Upper levels shear connection - bracket	1	Dynamic SLV 5 ex+ ey+	Instantaneous	5.65	5.65
PY1-4	2.00	Upper levels shear connection - bracket	1	Dynamic SLV 5 ex+ ey+	Instantaneous	2.80	2.80
PX1-7	2.00	Upper levels shear connection - bracket	1	Dynamic SLV 1 ex+ ey+	Instantaneous	8.66	8.66
PX1-8	4.00	Upper levels shear connection - bracket	2	Dynamic SLV 1 ex+ ey+	Instantaneous	19.27	9.63
PY1-3	7.00	Upper levels shear connection - bracket	3	Dynamic SLV 8 ex- ey+	Instantaneous	45.34	15.11
PY1-7	2.00	Upper levels shear connection - bracket	1	Dynamic SLV 5 ex+ ey+	Instantaneous	7.95	7.95

PX1-2	4.00	Upper levels shear connection - bracket	2	Dynamic SLV 1 ex+ ey-	Instantaneous	18.05	9.03
PX1-5	4.00	Upper levels shear connection - bracket	2	Dynamic SLV 1 ex+ ey-	Instantaneous	16.38	8.19

Angle bracket resistance

The design value of the shear strength of the anchor is evaluated as

$$R_{a,d} = \frac{k_{mod} \cdot R_{a,k,dens}}{\gamma_M}$$

where:

$R_{a,k,dens}$ is the characteristic value of the nailing resistance. This value is reduced by the k_{dens} factor when the density of the material used is less than 350 kg/m^3. k_{dens} can be evaluated using the formula $R_{a,k,dens} = R_{a,k} \cdot \left(\frac{\rho_k}{350}\right)^2$;

k_{mod} is the modification factor taking into account the effect of the duration of load and moisture content;

γ_M is the partial factor for connections.

The checks are summarized in the following table which illustrates the characteristic values of the resistance associated to the angle brackets and their design values. The following expression shall be satisfied:

$$V_{a,d} \leq R_{a,d}$$

Name: Name of the connection in which the angle bracket is used

Comb.: The most severe combination of load

$V_{a,d}$: Design value of the force acting on the single angular

k_{mod}: Modification factor taking into account the effect of the duration of load and moisture content

$k_{R,deg}$: Resistance degradation coefficient due to cyclic actions

γ_M: Partial safety factor

Wall name	Connection name	Comb.	Service Class	$V_{a,d}$ [kN]	$R_{a,k,dens}$ [kN]	k_{mod}	$k_{R,deg}$	γ_M	$R_{a,d}$ [kN]	Check
PX1-1	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	8.11	37.90	1.1	1	1.3	32.07	25%
PY1-1	Upper levels shear connection - bracket	Dynamic SLV 8 ex- ey+	1	1.81	37.90	1.1	1	1.3	32.07	6%
PY1-2	Upper levels shear connection - bracket	Dynamic SLV 8 ex- ey+	1	1.81	37.90	1.1	1	1.3	32.07	6%
PX1-4	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	7.36	37.90	1.1	1	1.3	32.07	23%
PX1-3	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	8.11	37.90	1.1	1	1.3	32.07	25%
PY1-6	Upper levels shear connection - bracket	Dynamic SLV 5 ex+ ey+	1	14.68	37.90	1.1	1	1.3	32.07	46%
PX1-6	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	7.36	37.90	1.1	1	1.3	32.07	23%

PY1-8	Upper levels shear connection - bracket	Dynamic SLV 5 ex+ ey+	1	12.89	37.90	1.1	1	1.3	32.07	40%
PX1-9	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey+	1	8.66	37.90	1.1	1	1.3	32.07	27%
PY1-5	Upper levels shear connection - bracket	Dynamic SLV 5 ex+ ey+	1	5.65	37.90	1.1	1	1.3	32.07	18%
PY1-4	Upper levels shear connection - bracket	Dynamic SLV 5 ex+ ey+	1	2.80	37.90	1.1	1	1.3	32.07	9%
PX1-7	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey+	1	8.66	37.90	1.1	1	1.3	32.07	27%
PX1-8	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey+	1	9.63	37.90	1.1	1	1.3	32.07	30%
PY1-3	Upper levels shear connection - bracket	Dynamic SLV 8 ex- ey+	1	15.11	37.90	1.1	1	1.3	32.07	47%
PY1-7	Upper levels shear connection - bracket	Dynamic SLV 5 ex+ ey+	1	7.95	37.90	1.1	1	1.3	32.07	25%
PX1-2	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	9.03	37.90	1.1	1	1.3	32.07	28%
PX1-5	Upper levels shear connection - bracket	Dynamic SLV 1 ex+ ey-	1	8.19	37.90	1.1	1	1.3	32.07	26%

Damage Limitation - DLS

The “damage limitation requirement” is considered to have been satisfied, if, under a seismic action having a larger probability of occurrence than the design seismic action corresponding to the “no-collapse requirement” the interstorey drifts are limited in accordance with the following equation:

$$d_r < d_{\mathrm{r,lim}} = 0.005\ \mathrm{h}$$

where:

d_r is the interstorey drift obtained applying the reduction factor ν = 0.5 to the design ground acceleration a_g on type A ground;

h is the storey height.

The table below shows the seismic checks for the Damage Limit State.

Wall name: Wall ID

h: Storey height

Comb.: The most severe combination of load

d_r: Evaluated interstorey drift

$d_{r,lim}$: Interstorey drift limit

The table provides the Damage Limit State checks in the case of Dynamic Linear Analysis.

Wall	h [m]	Comb.	d_r [mm]	d_{lim} [mm]	Verifica
PX1-1	3.05	Dynamic SLD 4 ex+ ey-	3.40	15.25	22%
PY1-1	2.75	Dynamic SLD 8 ex- ey+	2.17	13.75	16%
PY1-2	2.75	Dynamic SLD 8 ex- ey+	2.17	13.75	16%
PX1-4	3.05	Dynamic SLD 4 ex+ ey-	3.08	15.25	20%
PX1-3	3.05	Dynamic SLD 4 ex+ ey-	3.40	15.25	22%
PY1-6	2.75	Dynamic SLD 5 ex+ ey+	2.80	13.75	20%
PX1-6	3.05	Dynamic SLD 4 ex+ ey-	3.08	15.25	20%
PY1-8	2.75	Dynamic SLD 5 ex+ ey+	2.80	13.75	20%
PX1-9	3.05	Dynamic SLD 4 ex+ ey+	3.62	15.25	24%
PY1-5	4.25	Dynamic SLD 5 ex+ ey+	2.09	21.25	10%
PY1-4	4.25	Dynamic SLD 5 ex+ ey+	2.09	21.25	10%
PX1-7	3.05	Dynamic SLD 4 ex+ ey+	3.62	15.25	24%
PX1-8	3.95	Dynamic SLD 4 ex+ ey+	3.62	19.75	18%
PY1-3	2.75	Dynamic SLD 8 ex- ey+	2.17	13.75	16%
PY1-7	2.75	Dynamic SLD 5 ex+ ey+	2.80	13.75	20%
PX1-2	3.95	Dynamic SLD 4 ex+ ey-	3.40	19.75	17%
PX0-1	3.20	Dynamic SLD 4 ex+ ey-	2.22	16.00	14%
PX0-2	3.20	Dynamic SLD 4 ex+ ey-	2.22	16.00	14%
PX0-3	3.20	Dynamic SLD 4 ex+ ey-	2.22	16.00	14%
PY0-6	3.20	Dynamic SLD 5 ex+ ey+	2.39	16.00	15%
PY0-7	3.20	Dynamic SLD 5 ex+ ey+	2.39	16.00	15%
PY0-8	3.20	Dynamic SLD 5 ex+ ey+	2.39	16.00	15%
PX1-5	3.95	Dynamic SLD 4 ex+ ey-	3.08	19.75	16%
PX0-9	3.20	Dynamic SLD 4 ex+ ey+	2.41	16.00	15%
PX0-8	3.20	Dynamic SLD 4 ex+ ey+	2.41	16.00	15%
PX0-7	3.20	Dynamic SLD 4 ex+ ey+	2.41	16.00	15%
PY0-5	3.20	Dynamic SLD 8 ex- ey+	1.85	16.00	12%
PY0-4	3.20	Dynamic SLD 8 ex- ey+	1.85	16.00	12%
PX0-6	3.20	Dynamic SLD 4 ex+ ey-	1.96	16.00	12%
PX0-5	3.20	Dynamic SLD 4 ex+ ey-	1.96	16.00	12%
PX0-4	3.20	Dynamic SLD 4 ex+ ey-	1.96	16.00	12%
PY0-3	3.20	Dynamic SLD 8 ex- ey+	1.93	16.00	12%
PY0-2	3.20	Dynamic SLD 8 ex- ey+	1.93	16.00	12%
PY0-1	3.20	Dynamic SLD 8 ex- ey+	1.93	16.00	12%