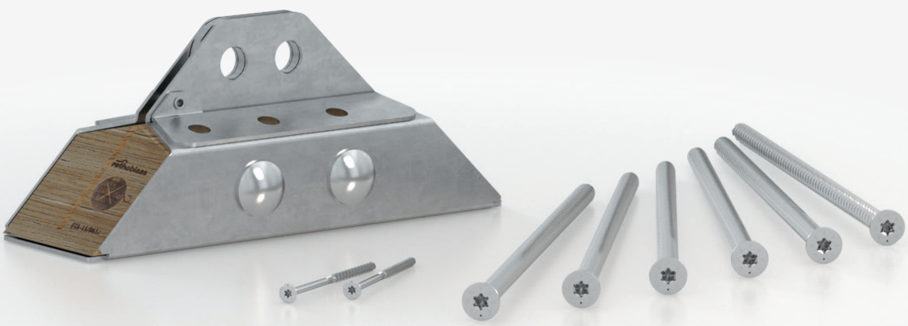
X-ONE

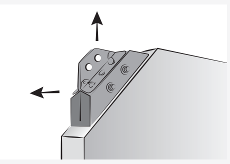
PATENTED

CE
ETA 15/0632

software
myProject

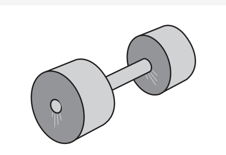
Universal connector for CLT panels





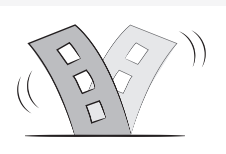
UNIQUE SOLUTION

One element for transferring the shear and traction stresses, for lifting, handling, positioning and fastening all thicknesses of CLT panels



STRONG

The insertion of 6 full thread screws with large diameter, with radial distribution and symmetric inclination enables the transfer of extremely high stresses in every direction

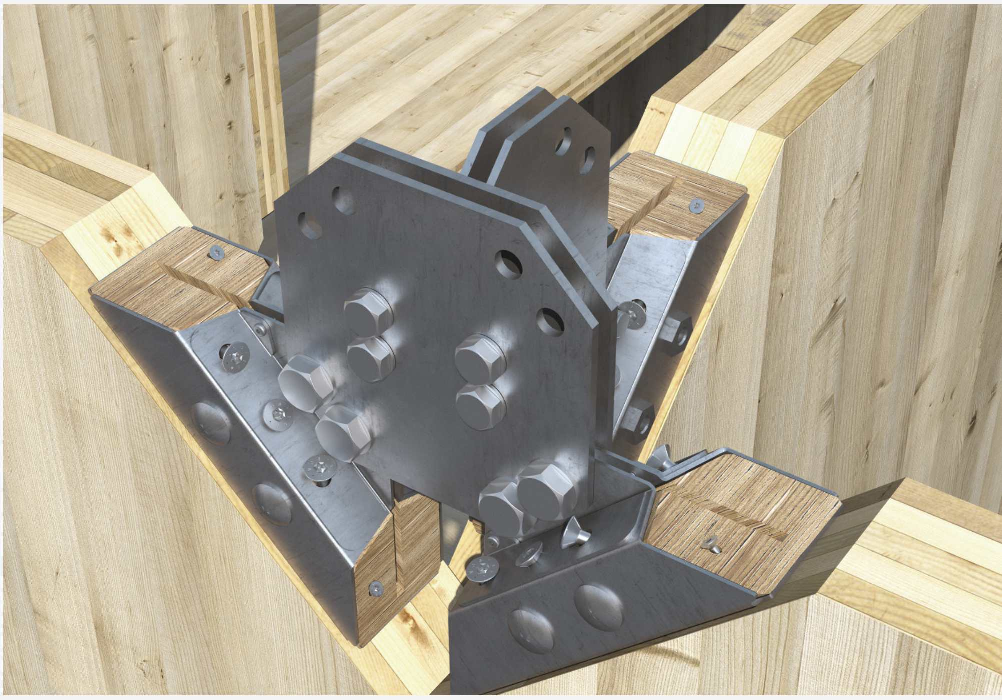


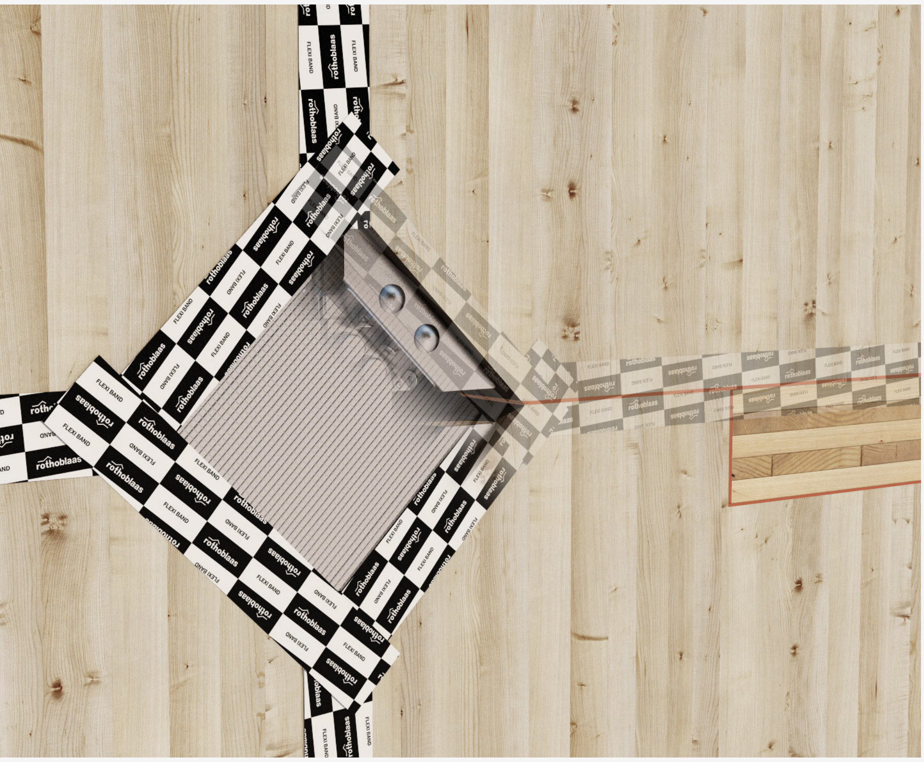
STRUCTURAL SAFETY

Connection system ideal for seismic design with tested and certified values of ductility (EC - ETA 15/0632)

DID YOU KNOW THAT...?

X-ONE is the main component of the X-RAD system, it is the first connection in the world designed and optimised to make the most out of the mechanical resources of the CLT. It can be used in the complete X-RAD system for multi-storey buildings and in all applications that require the transfer of strong stresses.





EFFECTIVE

The system involves simple tightening of a few bolts. In the foundation solution, connection with X-PLATE plates is extremely fast and effective

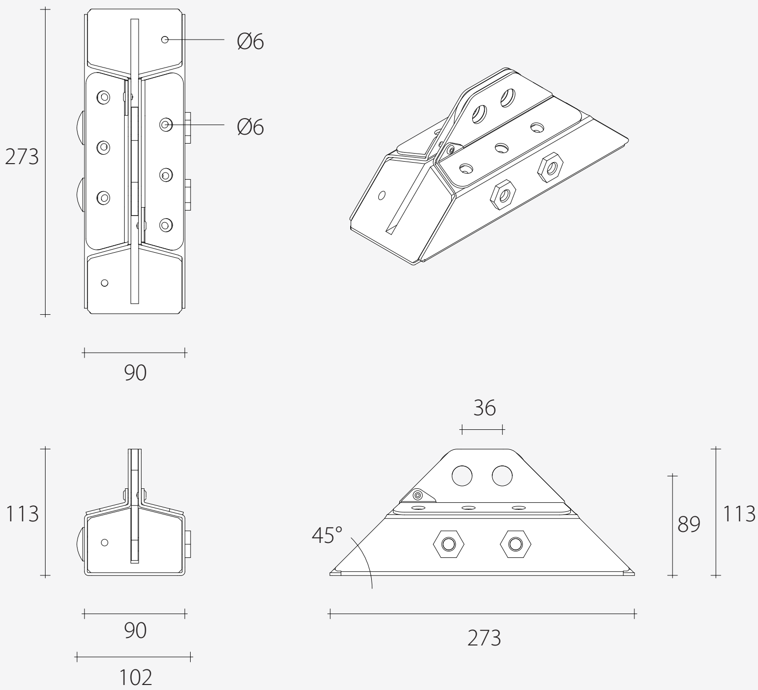
FUNCTIONAL

The mid-floor and top nodes are created simply and quickly with predefined bolted joints

AIRTIGHT

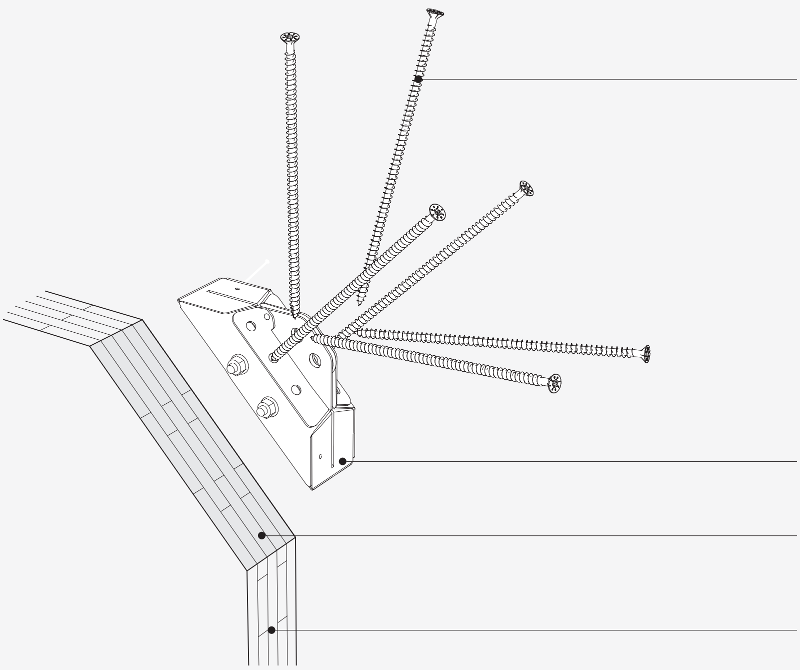
Coupling with the X-SEAL element guarantees the highest air, water and wind resistance, while also ensuring good acoustic performance

DESCRIPTION



X-ONE is a light and compact connection element, capable of ensuring excellent mechanical performance. Its geometry allows it to be used in the X-RAD system and as a single connection element for particularly demanding applications.

X-ONE is fastened to the CLT panel by 6 XVGS11350 connectors inserted through oriented pre-bored holes. The fixing of the screws in the CLT according to the direction dictated by the X-ONE guide holes ensures extremely resistant fastening in every stress direction.



CODES AND DIMENSIONS

X-ONE

code	B [mm]	L [mm]	H [mm]		pcs/box
XONE	90	273	113		1

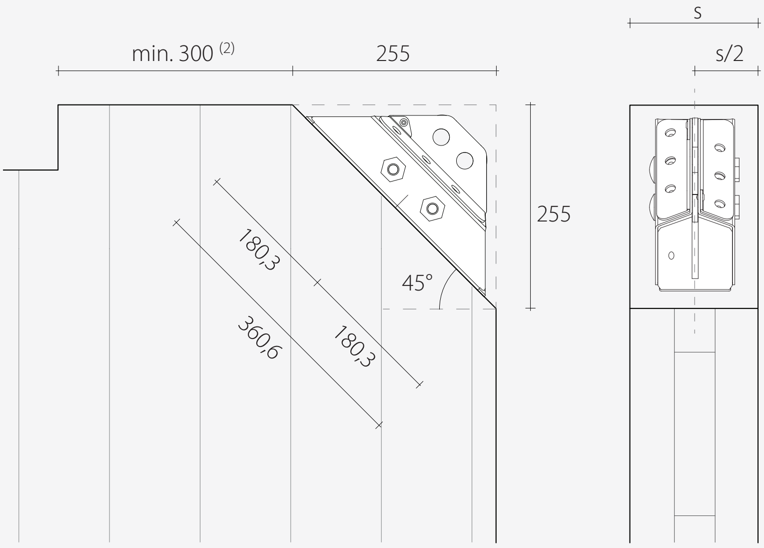
X-VGS SCREW

code	d_1 [mm]	L [mm]	b [mm]	TX	pcs/box
XVGS11350	11	350	340	50	25

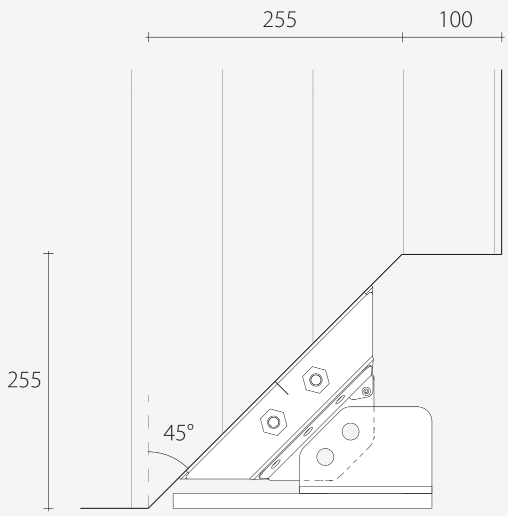
POSITIONING

Independently of the thickness of the panel and its location on the site, the cut for the fastening of X-ONE is made at the tops of the walls, at 45°, and it is 360,6 mm long.

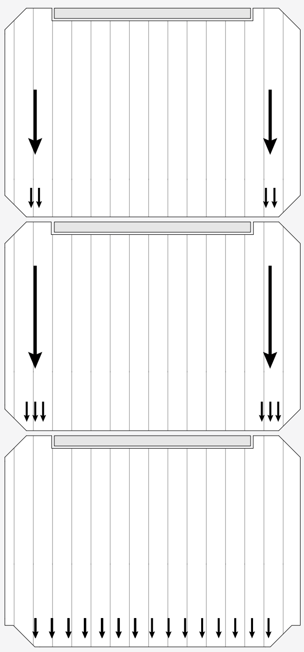
STANDARD MID-FLOOR AND TOP NODES CUT [(1)]



STANDARD BASIC NODES CUT [(1)]



X-ONE is fixed on the inclined surface in a central position, both with respect to the length of the cut and in the direction of the panel thickness **(s)**. This rules holds for all the thicknesses of the panel.



The creation of a specific housing for the floor panels avoids the interposition of the slabs between the wall panels and the resulting problems related to compression at right angles to the fibres. It thus allows direct transmission of vertical loads between the wall panels in concentrated zones at the ends of them.

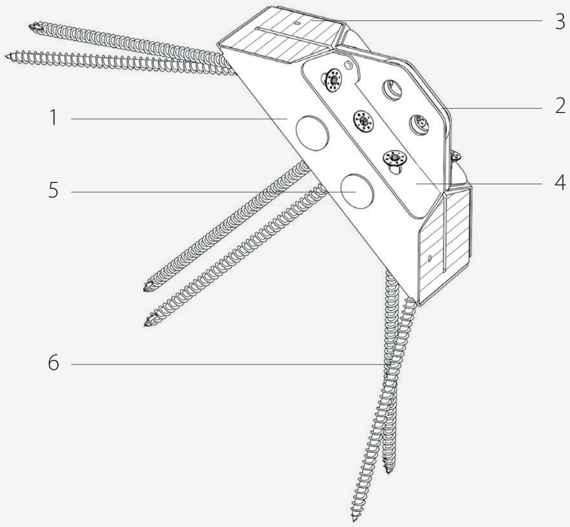
NOTES: [(1)] For non-standard cases see pages 62-63.
[(2)] We recommend not making cuts in and processing the CLT panel within a radius of 300 mm from the tops of X-ONE, in order to avoid damaging the fastening screws and cutting tools.

STRUCTURAL ENGINEERING

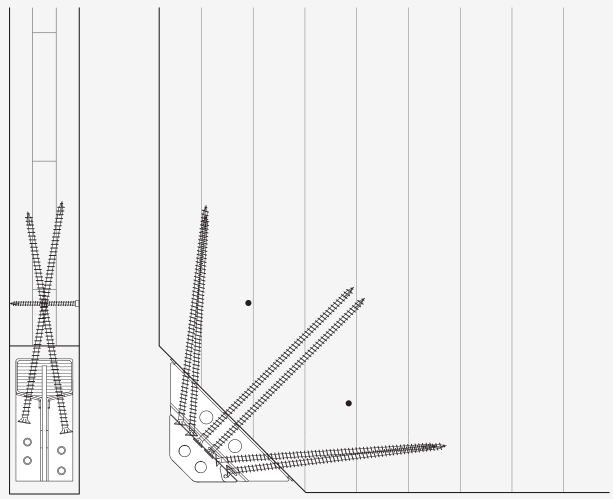
The objective of this section is to provide the designer with a resistance domain (characteristic and design) which describes the resistance of the **X-ONE** element stressed in different directions.
The pre-assembled X-ONE component, fixed to the CLT panel by means of special connectors and made up of:

1. external box in bent metal plate, thickness 2.5 mm
2. internal stiffening plate, thickness 6 mm, with fastening holes for M16 bolts
3. insert in Laminated Veneer Lumber (LVL)
4. washer-plates, thickness 2.5 mm
5. internal M12 bolts with nuts
6. VGS full thread fasteners Ø11 mm (code XVGS11350)

X-ONE AND CONNECTORS



PLACING OF CONNECTORS WITH VARIABLE INCLINATION



The failure domain of X-ONE in a stress field variable between 0° and 360° (in the CLT panel plane) is determined according to 3 approaches:

- **experimental investigations:** load tests on the connection with different stress directions
- **analysis of the finite elements (FEM):** extension of the experimental results to different stress directions
- **analytical models:** confirmation of the experimental results and of the FEM analysis and simplification of the design approach

The results obtained constitute the basis for preparation of the European Technical Assessment **ETA 15/0632** issued by the OIB (Österreichisches Institut für Bautechnik - AT).

FOR MORE INFORMATION

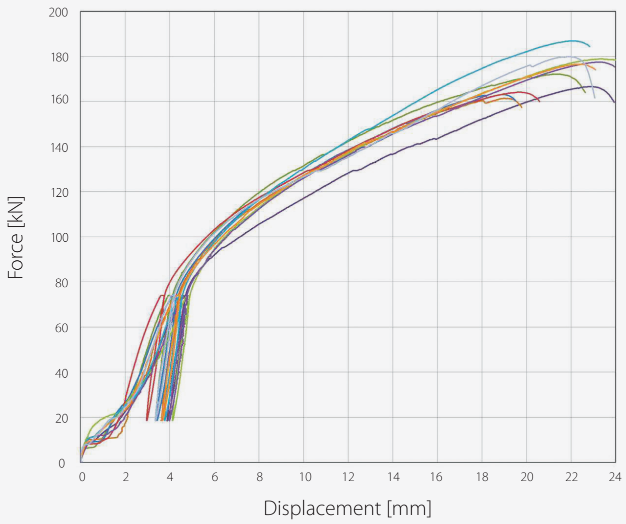
- A. Polastri, A. Angeli, ***"An innovative connection system for CLT structures: experimental - numerical analysis"***, 13th World Conference on Timber Engineering 2014, WCTE 2014, Quebec City, Canada.
- A. Polastri, A. Angeli, G. Dal Ri, ***"A new construction system for CLT structures"***, 13th World Conference on Timber Engineering 2014, WCTE 2014, Quebec City, Canada.
- A. Polastri, ***"An innovative connector system for fast and safe erection with CLT"***, 20. Internationales Holzbau-Forum 2014, Garmisch Partenkirchen, Germany.
- A. Polastri, R. Brandner, D. Casagrande, ***"Numerical analyses of high- and medium- rise CLT buildings braced with cores and additional shear walls, Structures and Architecture: Concepts, Applications and Challenges"***, Proceedings of the 3nd International Conference on Structures and Architecture, ICSA 2016.
- A. Angeli, A. Polastri, E. Callegari, M. Chiodega, ***"Mechanical characterization of an innovative connection system for CLT structures"***, 14th World Conference on Timber Engineering 2016, WCTE 2016, Vienna, Austria.
- A. Polastri, C. Loss, L. Pozza, I. Smith, ***"CLT buildings laterally braced with core and perimeter walls"***, 14th World Conference on Timber Engineering 2016, WCTE 2016, Vienna, Austria.
- A. Polastri, I. Giongo, S. Pacchioli, M. Piazza, ***"Structural analysis of CLT multi-storey buildings assembled with the innovative X-RAD connection system: case-study of a tall-building"***, 14th World Conference on Timber Engineering 2016, WCTE 2016, Vienna, Austria.

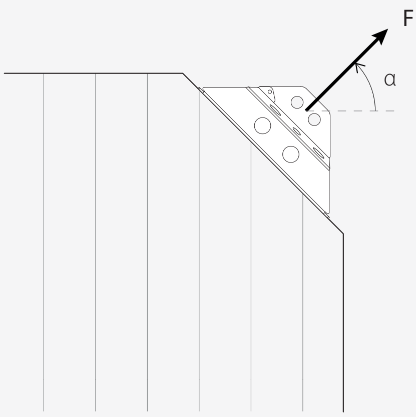
EXPERIMENTAL INVESTIGATIONS

The laboratory tests were carried out in three different research centres:

- **TU-GRAZ (Lignum Test Centre of the University of Graz - AT)**: monotonic tests to identify the resistance and rigidity parameters contained in ETA 15/0632
- **CNR-IVALSA (Trees and Timber Institute in San Michele A.A - IT)**: monotonic and cyclic tests to define ductility and behaviour from a seismic perspective
- **DICAM (Department of Civil, Environmental and Mechanical Engineering of the University of Trento - IT)**: tests on the overall wall-connection system

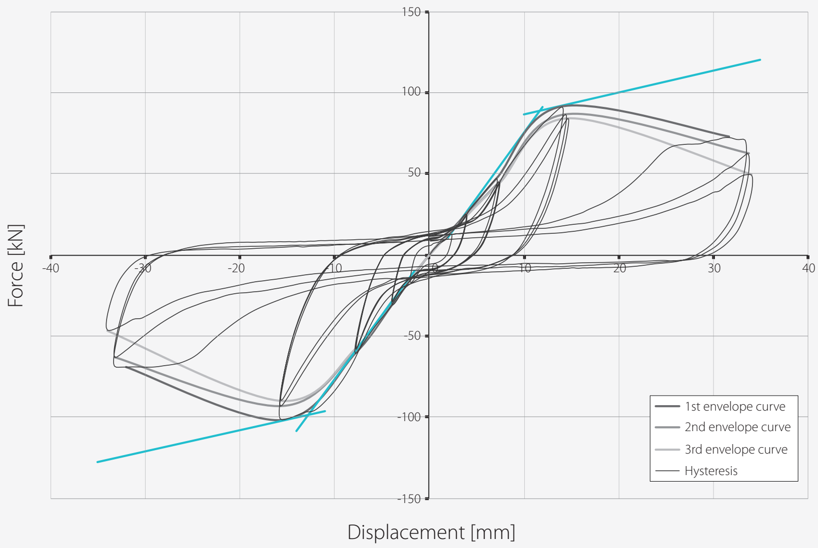
MONOTONIC TEST

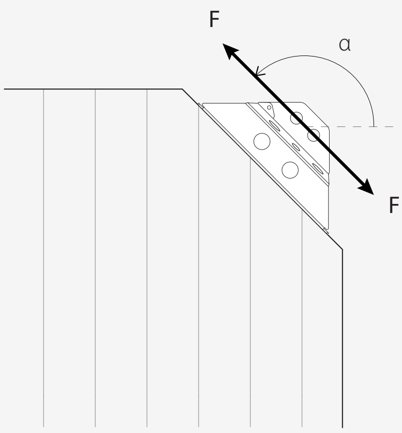




Example of output from monotonic test: force-movement for stress curves α = 45°

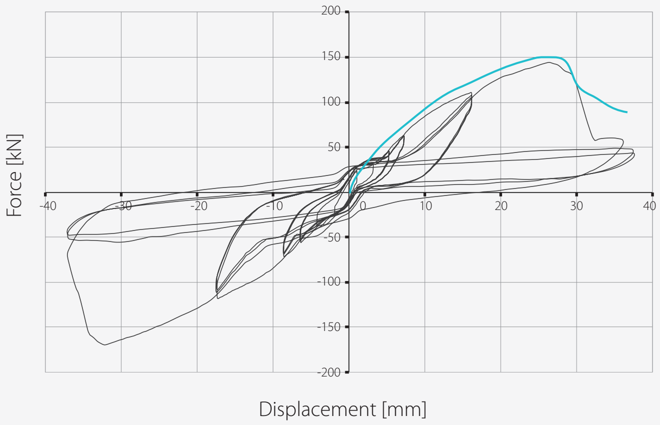
CYCLICAL TEST





Example of output from cyclical test: diagram force-movement for stress diagram α = 135° - 315°

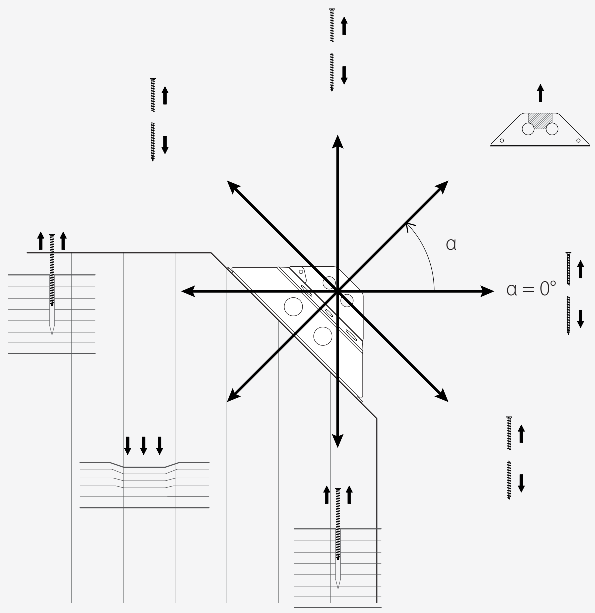
The experimental study of X-ONE made it possible to design and perform, at the University of Trento, cyclic failure tests on complete wall systems where the CLT panel was fastened to the ground using the X-RAD system. The experimental campaign ended with the testing of a complex system with multiple X-RAD connections between 4 CLT panels which made it possible to analyse the interaction among the various components (X-ONE, X-PLATE, CLT panels).



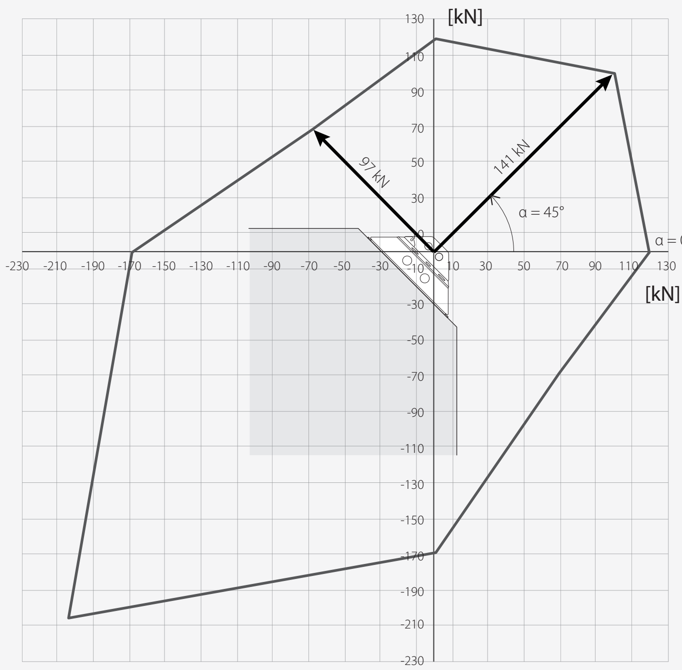
Example of output from cyclical test on wall system:
force-displacement diagram and test setup for single panel

In all the tests performed the connection was taken to breakage in order to observe the behaviour of the system as the stress direction applied changed.

At the end of the experimental phase the resistance diagram of the connection was defined through interpolation of the data collected.



Schematisation of the failure modes observed with changes in stress (0° ≤ α < 360°)

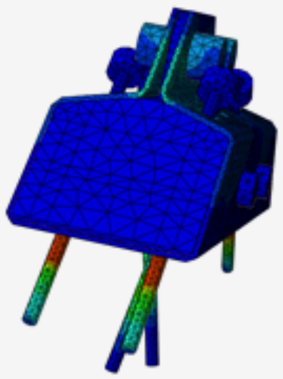


Experimental resistance domain

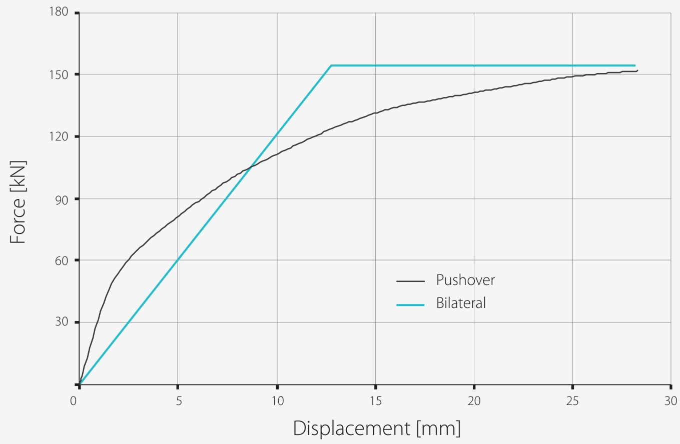
- α = 0° - 90° - 135° - 315° tension VGS connectors
- α = 45° block tearing of the plates
- α = 180° - 225° - 270° wood side failure mechanisms

FINITE ELEMENT ANALYSIS

The results collected in the experimental tests and observation of breaking characteristics led to the creation and validation of a finite-element model, capable of describing the overall behaviour of the X-ONE connection subject to movements in different directions.
Analyses of the push-over type were simulated; these were then linearised through bilaterals in order to provide the values of maximum resistance to changes in the direction of movement.

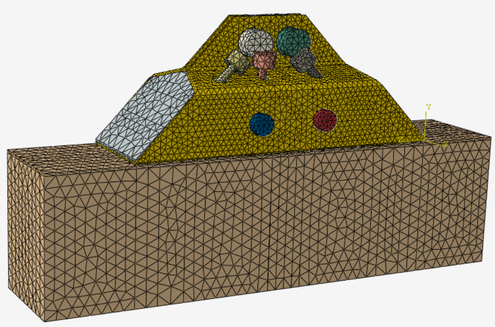


FEM of the X-ONE element and of the connectors

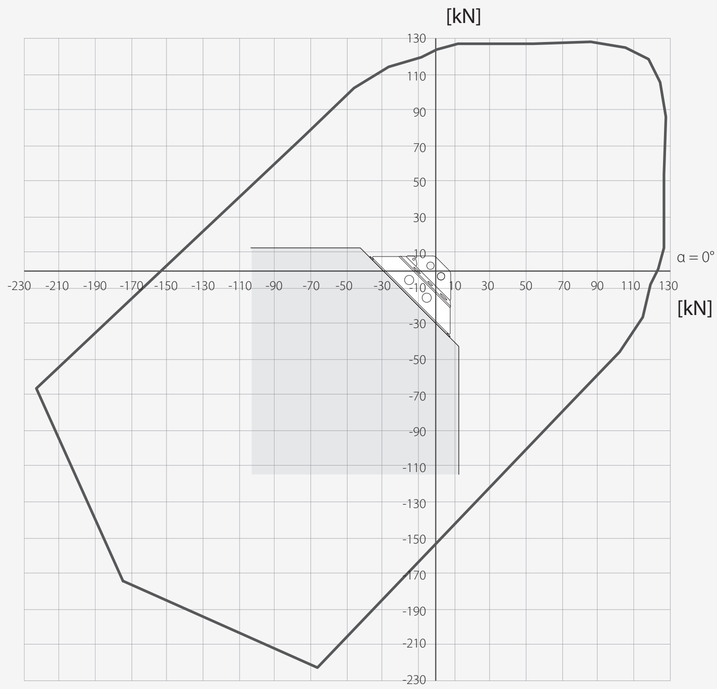


Example of capacity curve with linearisation

The points representing maximum resistances found by the FEM analyses enable the definition of a further resistance domain for the connection.



FEM modelling of the X-ONE connector and CLT panel

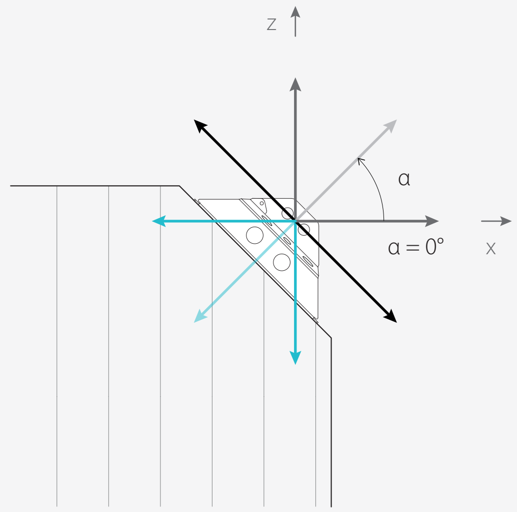


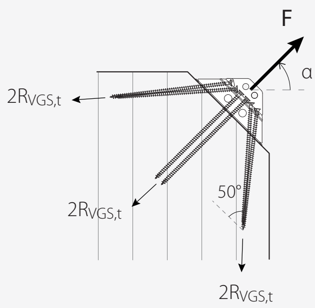
Resistance domain obtained from the FEM simulations

ANALYTICAL MODELS

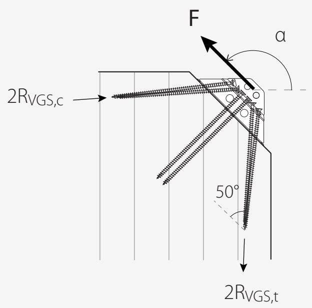
The experimental campaign and the finite-element model show how the X-ONE + CLT panel system has different ways of failure on changes in the stress direction. For the purposes of defining calculation models, 8 main stress directions were identified within a x-z reference system, in which the behavioural symmetries of the connection can be noted.

Starting from observation of the experimental collapse characteristics, the balance configurations of the connection were identified for each stress direction in accordance with the static theorem of the limit analysis.
By way of example the resistant mechanisms for two configurations are shown:



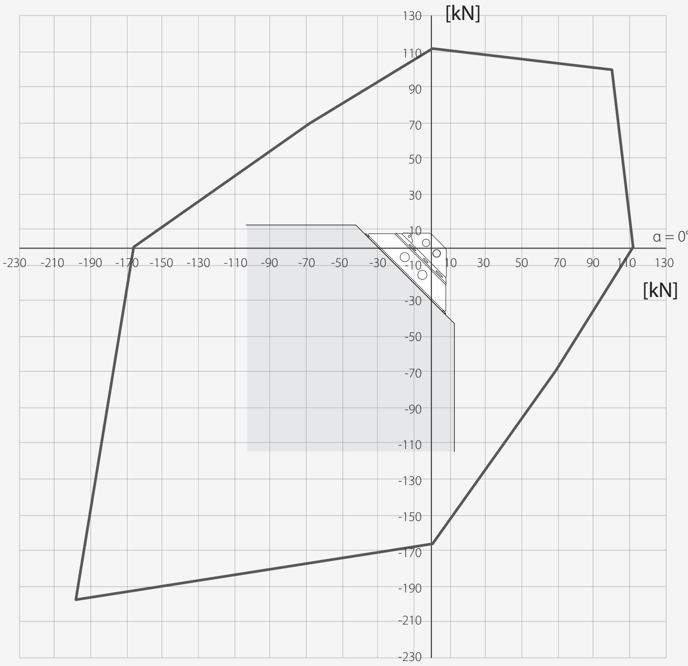


Configuration for
α = 45°



Configuration for
α = 135° - 315°

On the basis of the analytical model, it is possible to generate a further resistance domain very close to those identified experimentally and through the FEM model. This confirms the stability of the behaviour of the connection and the validity of the analysis methods adopted.



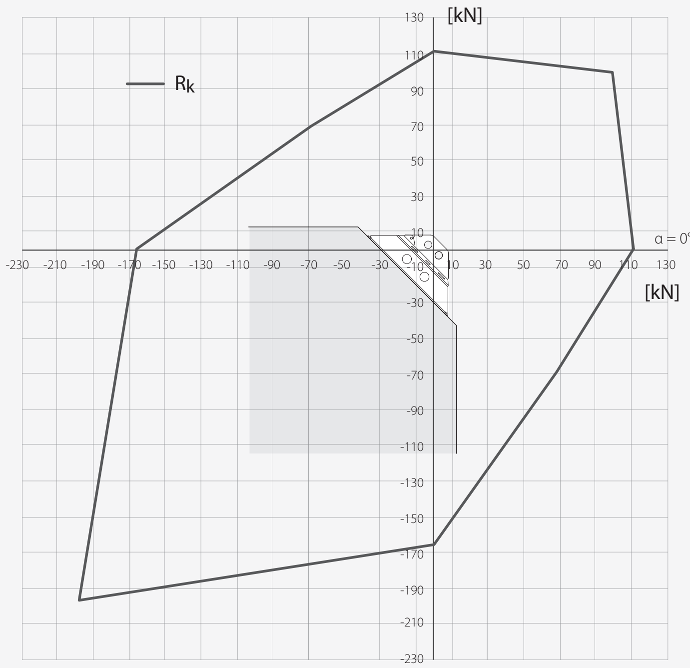
Resistance domain from analytical calculation

DESIGN RESISTANCES

For the purposes of the design verifications, the resistances provided by ETA (experimental) are used, supplemented by the analytical resistances, thus identifying the **characteristic resistance domain of X-ONE**.

Through a system design in accordance with the concepts of resistance hierarchy, with the over-sizing of a number of elements constituting X-ONE, thus facilitating certain failure modes:

- tension of the VGS connectors
- block tearing in correspondence with the M16 holes on the box + internal plate system
- wood failure (extraction of VGS connectors or wood compression)



Characteristic resistance domain

A summary table of the **characteristic resistances** is presented, in the various stress configurations together with a reference to the related safety coefficient according to the breaking characteristics (steel or wood).

α	total resistance	components of resistance		failure mode		partial safety factor (1)
	R_k [kN]	V_k [kN]	N_k [kN]			γ_M
0°	111.6	111.6	0.0	tension screw VGS	steel	$\gamma_{M2} = 1.25$
45°	141.0	99.7	99.7	block tearing on M16 holes	steel	$\gamma_{M2} = 1.25$
90°	111.6	0.0	111.6	tension screw VGS	steel	$\gamma_{M2} = 1.25$
135°	97.0	- 68.6	68.6	tension screw VGS	steel	$\gamma_{M2} = 1.25$
180°	165.9	- 165.9	0.0	VGS thread withdrawal	timber	$\gamma_{M,timber} = 1.3$
225°	279.6	- 197.7	- 197.7	compression of the wood	timber	$\gamma_{M,timber} = 1.3$
270°	165.9	0.0	- 165.9	VGS thread withdrawal	timber	$\gamma_{M,timber} = 1.3$
315°	97.0	68.6	- 68.6	tension screw VGS	steel	$\gamma_{M2} = 1.25$
360°	111.6	111.6	0.0	tension screw VGS	steel	$\gamma_{M2} = 1.25$

NOTES: In order to obtain the maximum performances of X-ONE connector and to avoid the splitting of the wood panel, it is recommended to insert 2 full thread connectors VGZ perpendicular to the CLT panel (picture right - page 24).

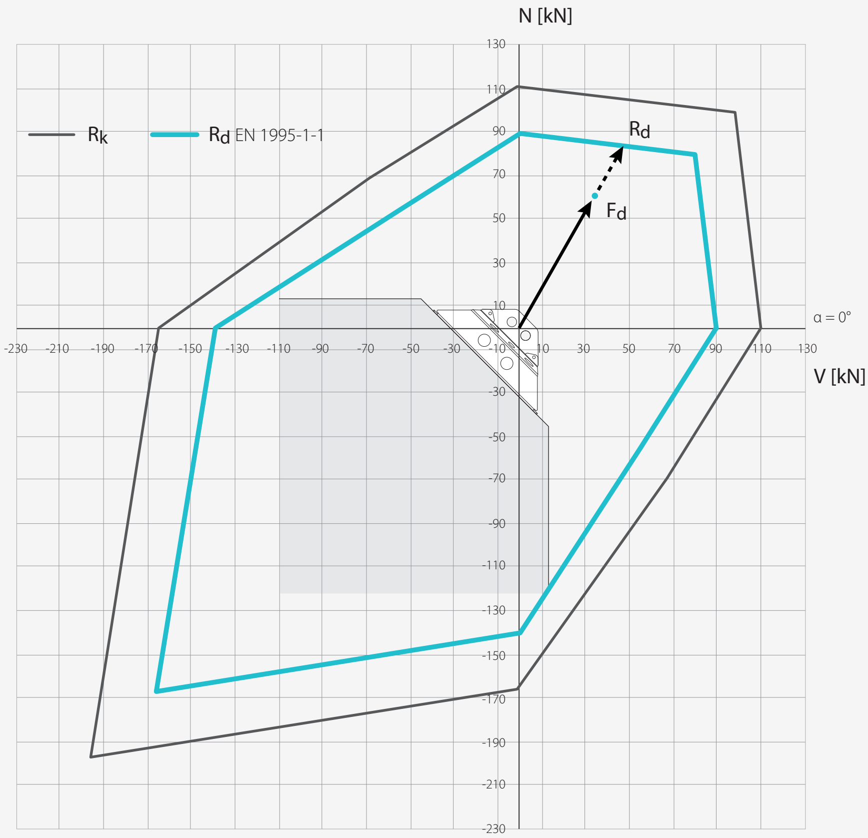
(1) The partial safety coefficients should be taken according to the current regulations used for the calculation.
The table shows the steel-side values in accordance with EN1993-1-8 and the wood-side figures in accordance with EN1995-1-1.

Checks at the Ultimate Limit State are carried out using the **design resistance domain of X-ONE**, defined starting from the characteristic resistance values [1].

The design resistance values are obtained as follows:

steel-side: $R_d = \frac{R_k}{\gamma_M}$ wood-side: $R_d = k_{mod} \cdot \frac{R_k}{\gamma_M}$

with the coefficients k_{mod} and γ_M to be taken according to the failure modes and the current regulations used for the calculation.



Verification of the X-ONE connection is considered achieved when the point representing the stress F_d falls within the design resistance domain:

$$F_d \leq R_d$$

The design domain of X-ONE refers to the resistance values and to the γ_M coefficients shown in the table and for loads with instantaneous duration class (earthquake and wind) [2].

Design resistance domain in accordance with EN1995-1-1 and EN1993-1-8

NOTES: [1] The full report on experimental analysis of the X-ONE connection can be downloaded from www.rothoblaas.com or from the MyProject software.

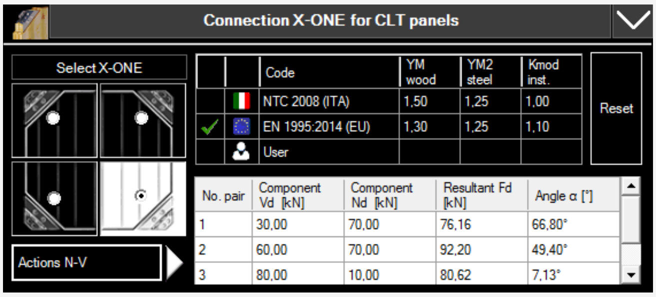
[2] Connection by means of X-ONE works as a connection between CLT walls to prevent their tipping and sliding in the presence of seismic and wind phenomena (instantaneous duration class). The static vertical forces are transmitted directly by wall-wall contact, without stressing the connection.
The use of X-ONE in the presence of loads with brief, medium or permanent duration class ($k_{mod} < 1$) requires a re-assessment of the design domain, because the resistance hierarchy may change. In these cases, in the interests of safety, we suggest treating all design resistances as wood-side resistances, applying opportune k_{mod} and γ_M coefficients.

CALCULATION WITH MY PROJECT

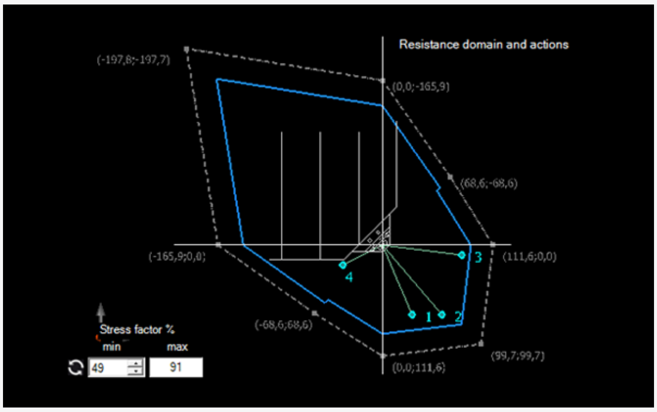
EXAMPLE OF VERIFICATION WITH X-ONE CONNECTOR

1. Selection of the module for verification of the X-ONE connector from the verification modules available (connections with screws, retractable junctions, structural reinforcements, thermo-hygrometric verifications).

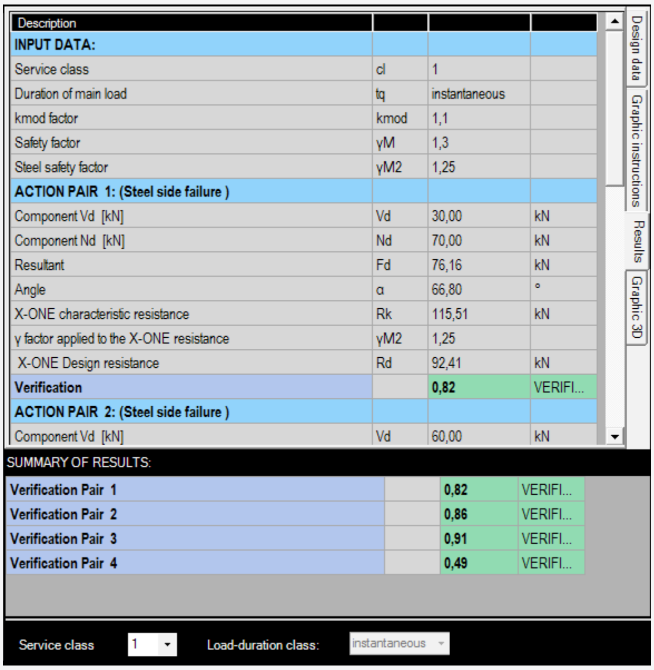
2. Selection of the calculation standard (NTC 2008, EN 1995 or user).
   Definition of the type of CLT panel top.
   Input of nodal loads (possibility of inserting infinite pairs of shear-tension forces, directly imported from the modelling software calculation table).



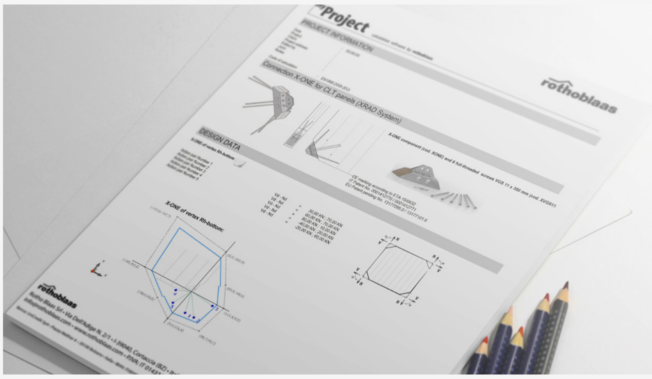
3. Resistance domain and graphic output of results (position of stress values with respect to the perimeter of the domain and indication of the percentage of use).



4. Summary report of the numerical results with indication of the safety coefficients adopted based on the failure mode and verification degree specification for each stress pair input.



5. Full report with product rendering, initial assumptions, input data, graphs, synthetic and extensive verifications.



myProject
calculation software by rothoblaas

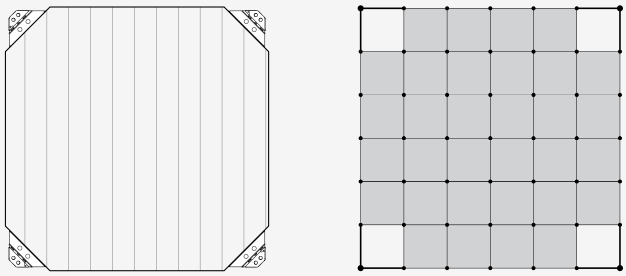
GUIDELINES FOR MODELLING THE X-RAD SYSTEM

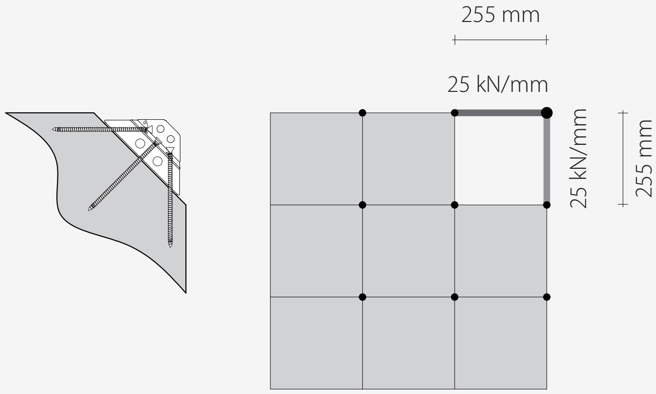
STEP 1

Modelling starts with the definition of the base panel and the X-ONE connectors at the corners. The CLT panel can be modelled with "shell" elements as the rigidity of the CLT / X-RAD system is controlled by the deformability of the connection.

STEP 2

The connector can be modelled with two square steel connecting rods with side measuring l = 5.51 mm and length 255 mm ("frame" elements placed at the corners of the panel). So a final X-RAD rigidity is obtained of k = 25 kN/mm.



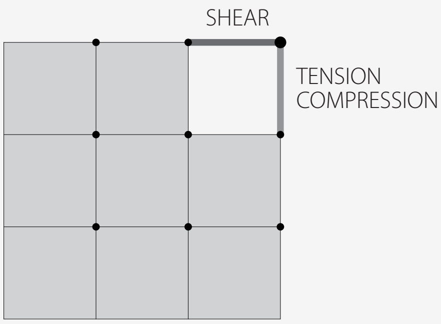


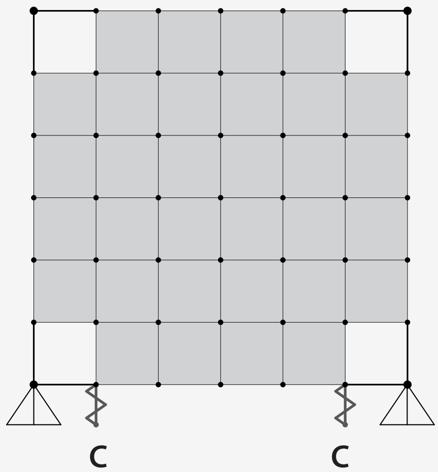
STEP 3

The representation of each X-RAD with two connecting rods allows a traction/compression force to be linked to the vertical frame element and a shearing force to the horizontal frame element.

STEP 4

In order to simulate contact between panel-panel and panel-foundation, nonlinear gap springs are defined. These have infinite compression rigidity and no traction.

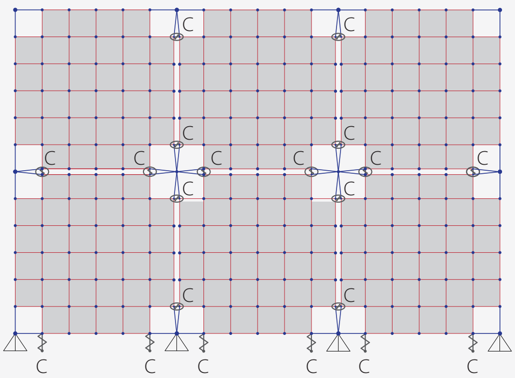




NOTE: The full guidelines for modelling the X-RAD system can be downloaded from www.rothoblaas.com or from the MyProject software. These guidelines give an example of a possible sequence of useful tips to help you model CLT structures with the X-RAD system. It is the responsibility of the designer to define and study in depth the modelling process details needed for proper structural design.

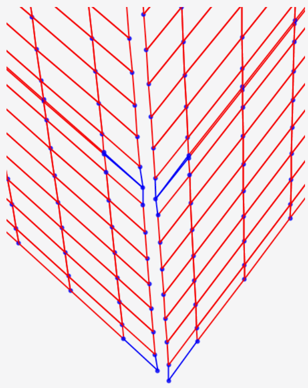
STEP 5

A spring (C) is provided at each end of the panel, both vertically and horizontally, to simulate contact between CLT panels. The springs at the base of the walls simulate contact between the panel and the foundation.



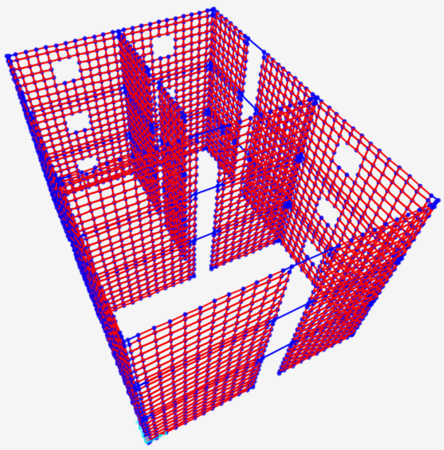
STEP 6

The wall panels arranged at right angles are supposedly free. Plates that in reality will connect the orthogonal walls are entered as a construction connection outside the calculation.



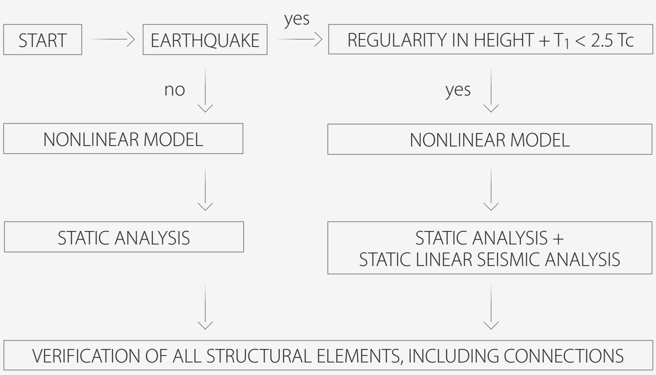
STEP 7

Final definition of the FEM model.



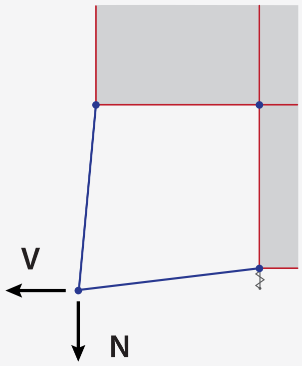
STEP 8

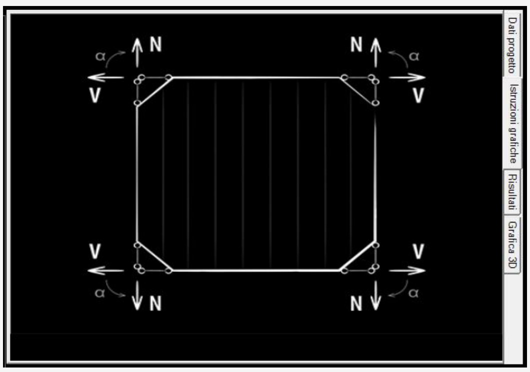
The analysis considers a solution method for the nonlinear finite element model, given the presence of springs that only work with compression.



STEP 9

The stresses deriving from the analysis, which can be obtained in each node from reading the forces of the two connecting rods simulating the X-ONE connector, can be exported to the MyProject software for automatic verification of all connections.



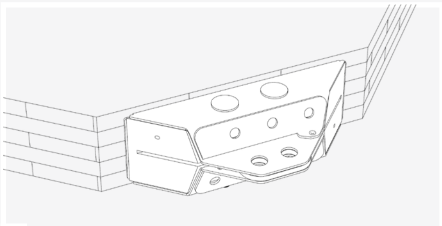


MANUAL INSTALLATION

For use of X-ONE not in series and for applications which do not provide for the use of the manual or automatic template, it is possible to install X-ONE manually.

1. place X-ONE on the corner surface of the panel
2. fix X-ONE temporarily to the CLT panel using 2 HBS5120 screws in order to prevent movement of the component during the definitive fastening operations
3. proceed to the definitive fastening of X-ONE with 6 XVGS11350 connectors

At the end of the definitive fastening, the positioning screws can be removed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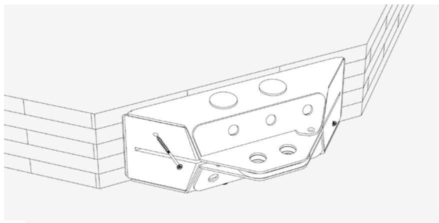
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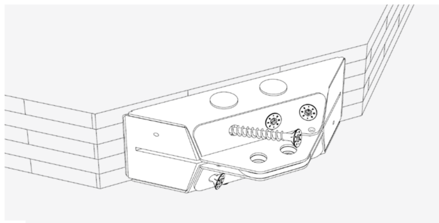

3

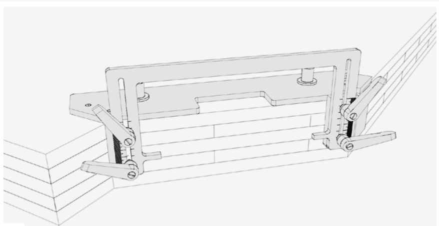
INSTALLATION WITH MANUAL AND AUTOMATIC TEMPLATE

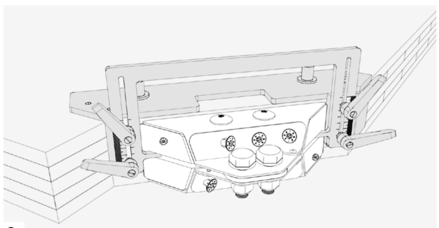
MANUAL TEMPLATE

The manual template system enables X-ONE to be positioned quickly and precisely. IT can be used for thicknesses between 100 and 220 mm. The steps are the following:

1. bring the template close to the corner of the panel so as to bring the template against the oblique side. Fasten the template to the panel with the screws already installed in the template body.
2. position X-ONE in the special housing and fasten X-ONE to the panel with 6 XVGS11350 connectors

The side supports of the template are fastened with bolts so that they can be easily removed for installations in non-standard or particularly complex positions.
See the installation on the geometry of the base nodes in figures 1 and 2 below.

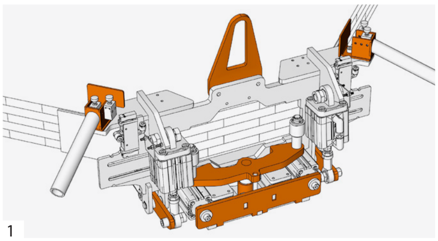

1


2

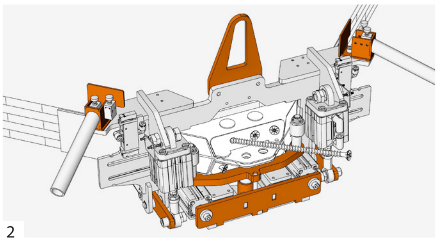
AUTOMATIC TEMPLATE

The automatic template system is the ideal solution for assembling X-ONE in industrial manufacturing processes of CLT panels.
It can be used for panels with a thickness between 100 and 160 mm. The steps are the following:

1. bring the side tracks close to the orthogonal sides of the panel so as to bring the body of the template against the oblique side. Lock the template on the panel
2. position X-ONE in the special housing on the pneumatic template, lock it into position and fasten X-ONE to the panel with 6 XVGS11350 connectors



1



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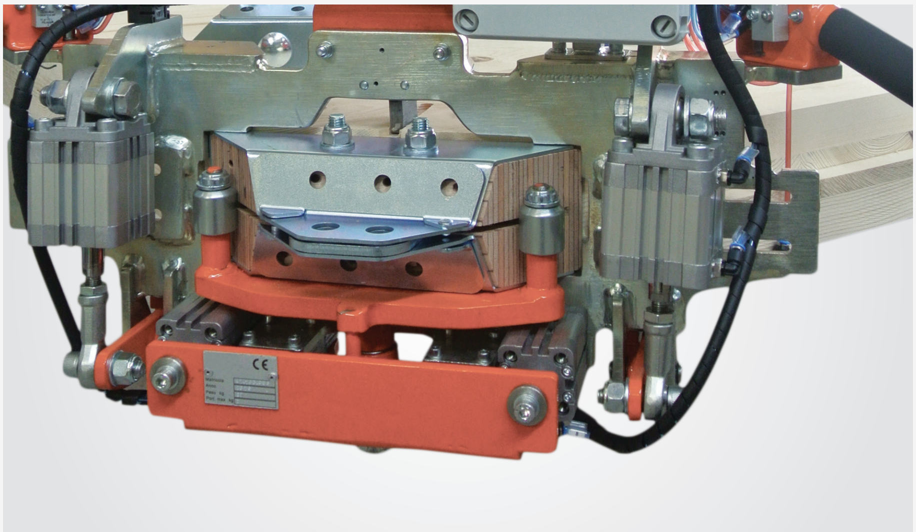


CODES AND DIMENSIONS

HBS SCREW

code	d_1 [mm]	L [mm]	b [mm]	TX	pcs/box
HBS5120	5	120	60	25	100

MANUAL TEMPLATE

code	description	pcs/box
ATXONE	manual template for mounting X-ONE	1

AUTOMATIC TEMPLATE

code	description	pcs/box
JIGONE	automatic template for mounting X-ONE	1

INSERTS

code	Insert	colour	L [mm]	pcs/box
TX5050	TX50	green	50	5
TX50150	TX50	green	150	1

SCREW GUN

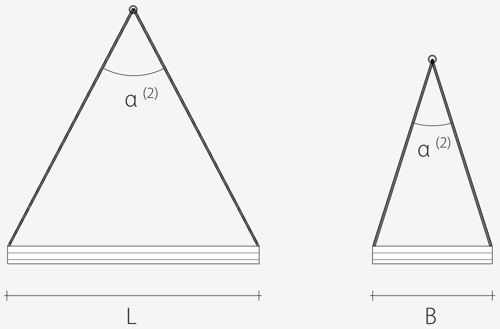
code	description	pcs/box
MA91A140	ASB cordless percussion drill 18 M bl	1
MA094450	A-DMV twisting moment x3	1

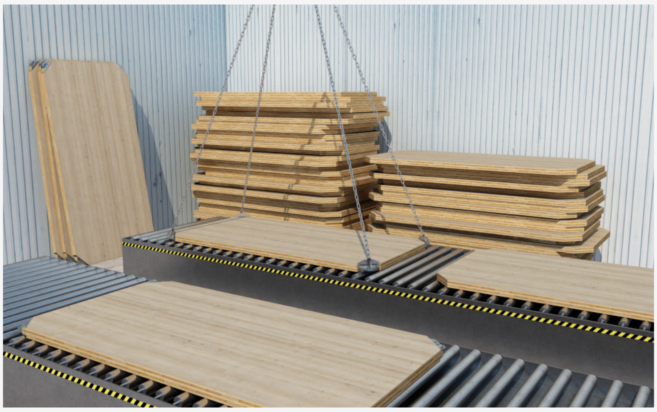
TRANSPORTING THE WALLS

HORIZONTAL LIFTING

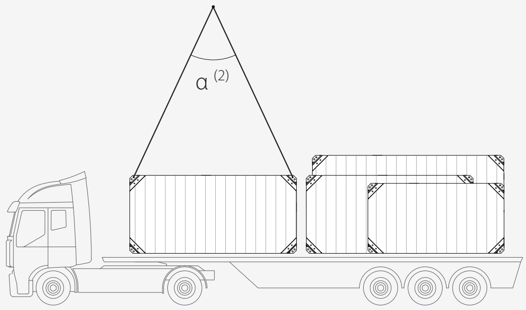
A specific lifting system has been developed to lift panels on which X-ONE connectors have been installed, including from the horizontal plane (process of certification in progress under the terms of the machinery directive 2006/42/EC) [(1)].

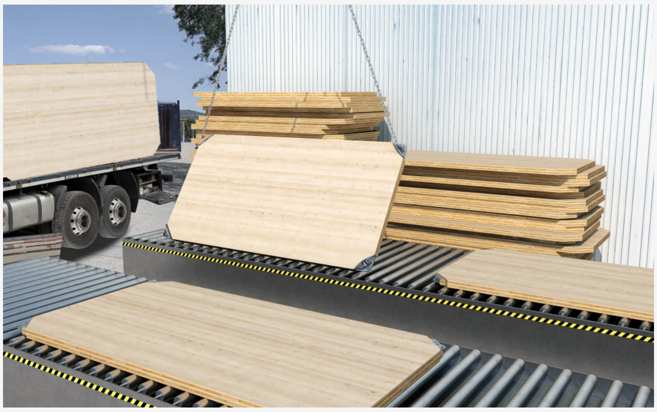
HANDLING PANELS AT THE END OF THE PRODUCTION CYCLE





TRANSPORTING AND LOADING CLT PANELS ONTO TRANSPORT VEHICLES





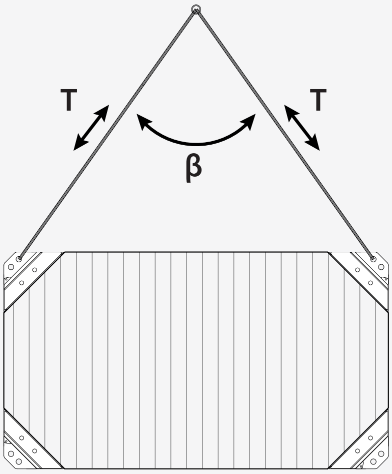
X-LIFT

code	description	pcs/box
XLIFT	X-ONE lifting support	1

NOTE: To ensure safe lifting operations and to prevent the wood from splitting due to orthogonal stresses to the fibres, it is recommended to insert VGZ full thread connectors perpendicular to the CLT panel (see page 24).

VERTICAL LIFTING

The CLT walls are assembled on site by positioning bolted steel plates, developed to make structural nodes in all geometric configurations of the panels. With the X-RAD system the CLT panels are lifted, handled and mounted directly from the transport vehicles to the structure under construction, thus avoiding drop-off and storage phases.
The X-RAD system is certified according to machinery directive 2006/42/EC for additional use as a vertical lifting point for transporting CLT panels [(1)].



In function of the weight of the panel and the angle between the lifting ropes **(β)**, it is possible to compare the force acting on each hook point **(T)**. By applying the appropriate security factors, it is therefore possible to compare the stress acting on the lifting point with the resistance of X-ONE.

	CLT PANEL WEIGHT							
β	**600 kg**	**800 kg**	**1000 kg**	**1200 kg**	**1400 kg**	**1600 kg**	**1800 kg**	**2000 kg**
50°	T = 3.31 kN	T = 4.41 kN	T = 5.51 kN	T = 6.62 kN	T = 7.72 kN	T = 8.82 kN	T = 9.93 kN	T = 11.03 kN
60°	T = 3.46 kN	T = 4.61 kN	T = 5.77 kN	T = 6.92 kN	T = 8.08 kN	T = 9.23 kN	T = 10.39 kN	T = 11.54 kN
70°	T = 3.66 kN	T = 4.88 kN	T = 6.10 kN	T = 7.32 kN	T = 8.54 kN	T = 9.76 kN	T = 10.98 kN	T = 12.20 kN
80°	T = 3.91 kN	T = 5.22 kN	T = 6.52 kN	T = 7.83 kN	T = 9.13 kN	T = 10.44 kN	T = 11.74 kN	T = 13.05 kN
90°	T = 4.24 kN	T = 5.65 kN	T = 7.07 kN	T = 8.48 kN	T = 9.89 kN	T = 11.31 kN	T = 12.72 kN	T = 14.14 kN
100°	T = 4.66 kN	T = 6.22 kN	T = 7.77 kN	T = 9.33 kN	T = 10.89 kN	T = 12.44 kN	T = 14.00 kN	T = 15.55 kN
110°	T = 5.23 kN	T = 6.97 kN	T = 8.71 kN	T = 10.46 kN	T = 12.20 kN	T = 13.94 kN	T = 15.69 kN	T = 17.43 kN
120°	T = 6.00 kN	T = 8.00 kN	T = 10.00 kN	T = 12.00 kN	T = 14.00 kN	T = 16.00 kN	T = 18.00 kN	T = 20.00 kN

NOTES: [(1)] When lifting with hooks for ropes or chains, it is recommended to use high resistance omega grills with pin Ø = 16 mm.
[(2)] If the α angles are excessive, use lifting slingbars.