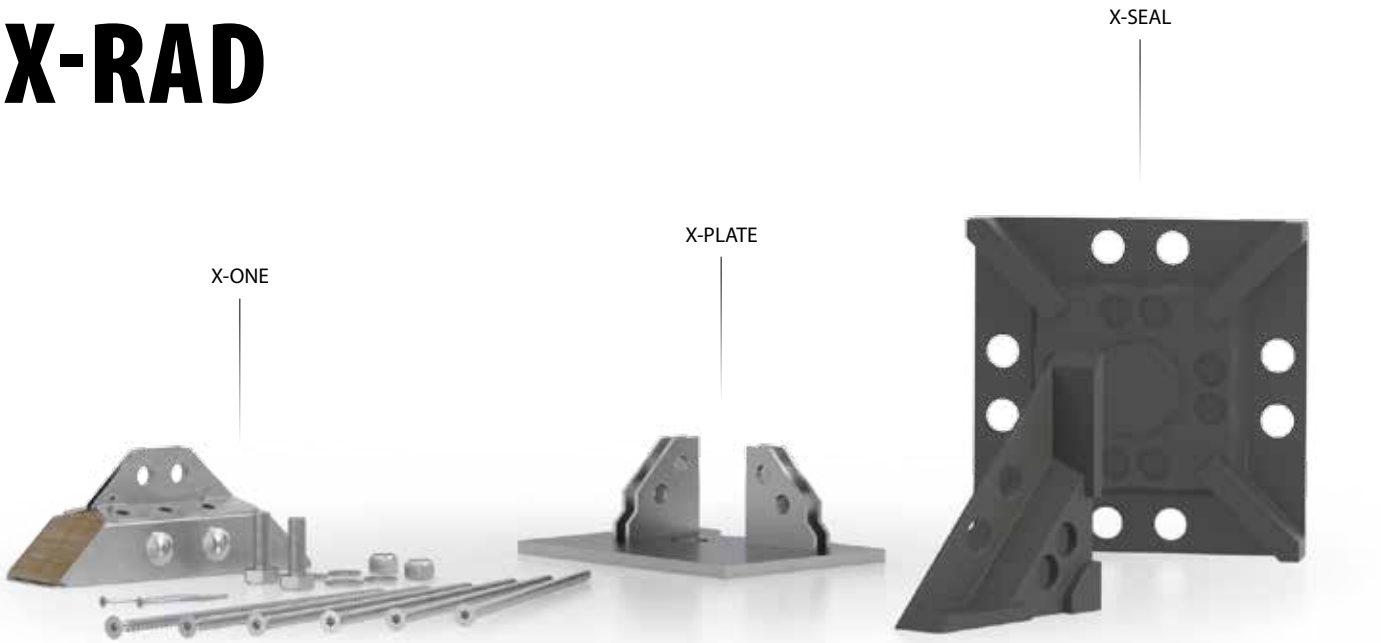
TECHNICAL GUIDE

rothoblaas

X-RAD



X-RAD is a complete connection system for multi-storey CLT buildings. It is made up of 3 parts:
X-ONE universal connector for CLT panels;
X-PLATE complete range of connection plates;
X-SEAL complementary system for air tightening and thermal-acoustic comfort.

It simplifies on-site operations, ensuring precision and quick assembly.
Mechanical, thermal and acoustic behaviour optimised to ensure maximum performance.

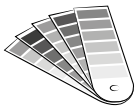
SIMPLE

The greatest advantage can be taken of the CLT panel with X-RAD thanks bolted joints which are extremely practical and quickly made.
For all types of application.

QUICK AND PRECISE

Quick and safe lifting, handling and positioning.
Very fast assembly on the ground and between walls thanks to bolted joints.

COMPLETE SOLUTION

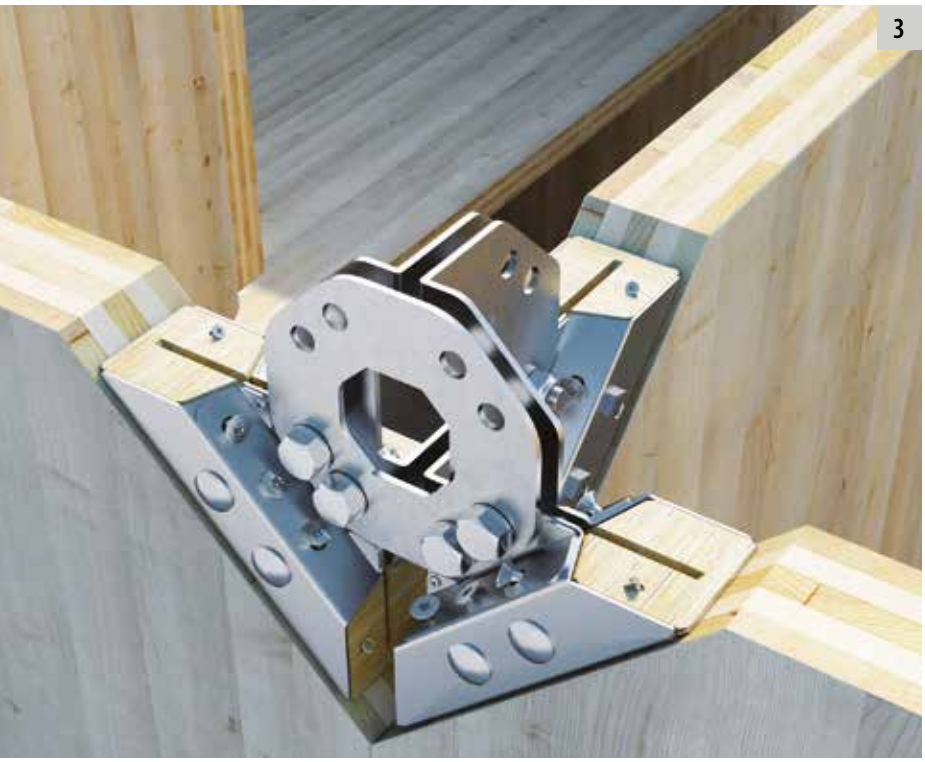


The 3 components work together on-site to obtain the maximum mechanical, thermal and acoustic performance.

1

2

3



4

1. Lifting and handling panels

2. Attaching the wall to the ground

3. Connecting the walls

4. Sealing the connection

CONTENTS

1. INSTALLATION: X-ONE

Description
Positioning
Manual installation
Installation with jig

2. BUILDING: X-PLATE

Description
Ground anchoring
Mounting the walls

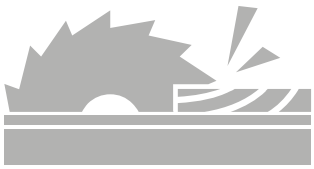
3. BUILDING ENVELOPE: X-SEAL

Description
Thermo-hygrometric behaviour
Acoustic behaviour

4. STRUCTURAL ENGINEERING

Experimental investigations
Finite-element model
Analytical models
Design resistances

CLT MANUFACTURERS



HOME BUILDERS

THERMAL
AND ACOUSTIC
ENGINEERING

1. X-ONE

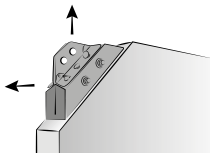
INSTALLATION

ETA 15/0632

X-ONE is the main component of the X-RAD system.
The subject of numerous publications and the winner of prestigious international awards, it is the first connection in the world designed and optimised to make the best use of the mechanical characteristics of 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.

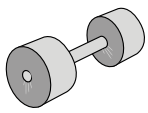
UNIQUE SOLUTION

A single element for the transfer of shear and traction stresses.
A single element for lifting, handling, positioning and fixing.
A single element for CLT panels of thickness 100 mm, 120 mm, 140 mm, 160 mm.



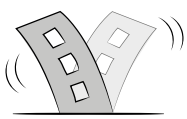
STRONG

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

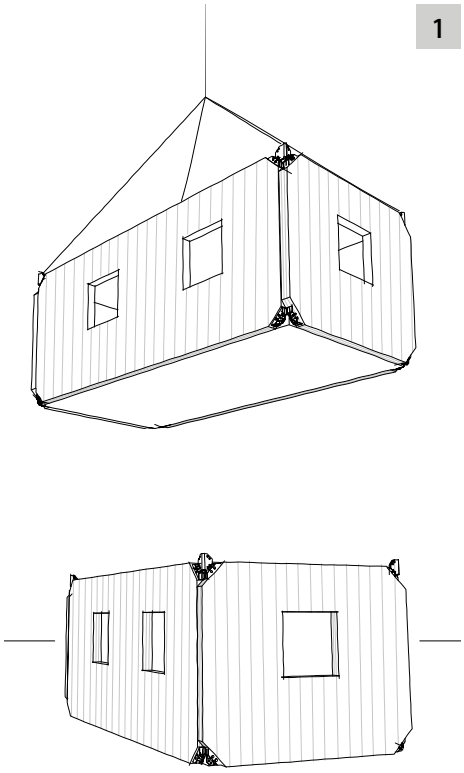


STRUCTURAL SAFETY

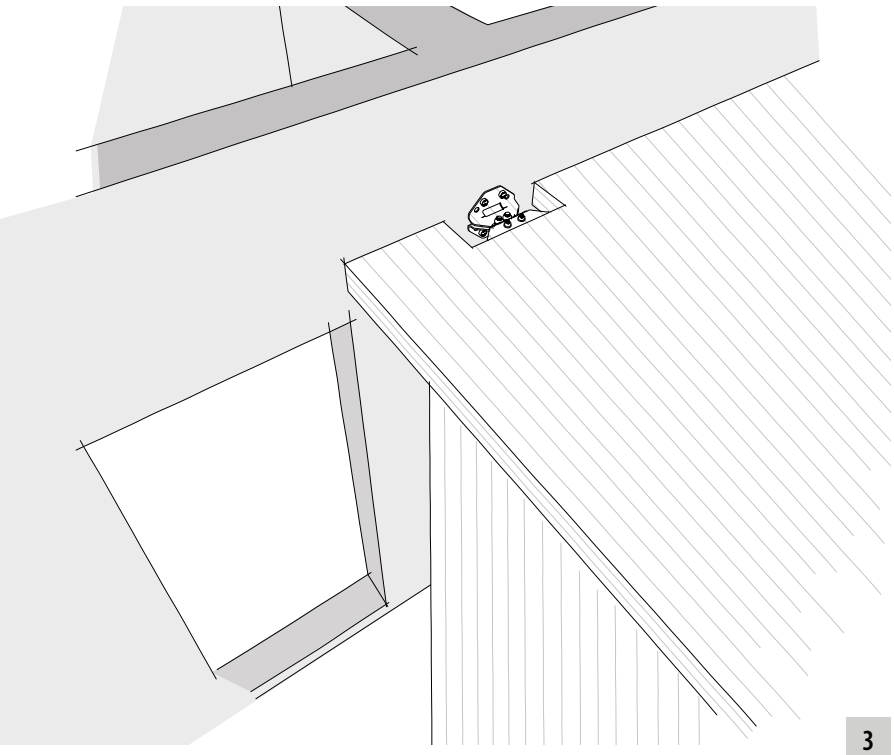
Connection system ideal for seismic design with tested and certified values of ductility (ETA 15/0632)



1

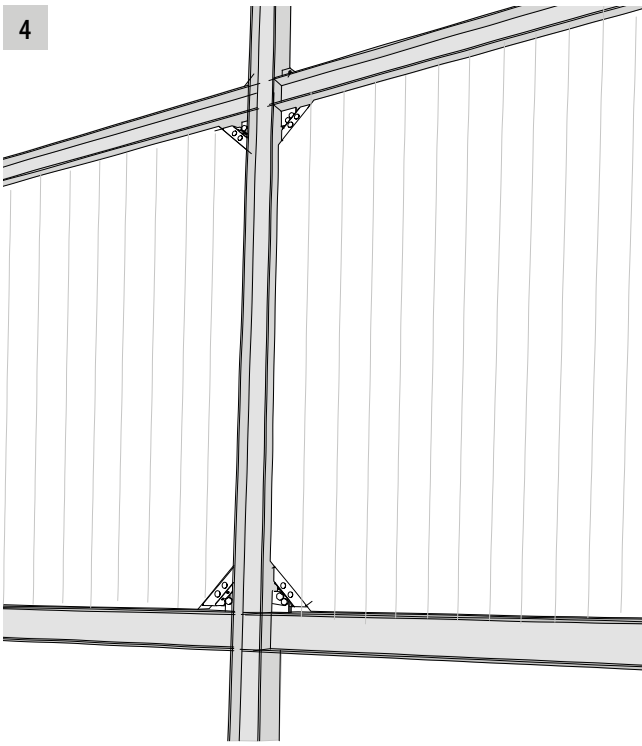


2



3

4



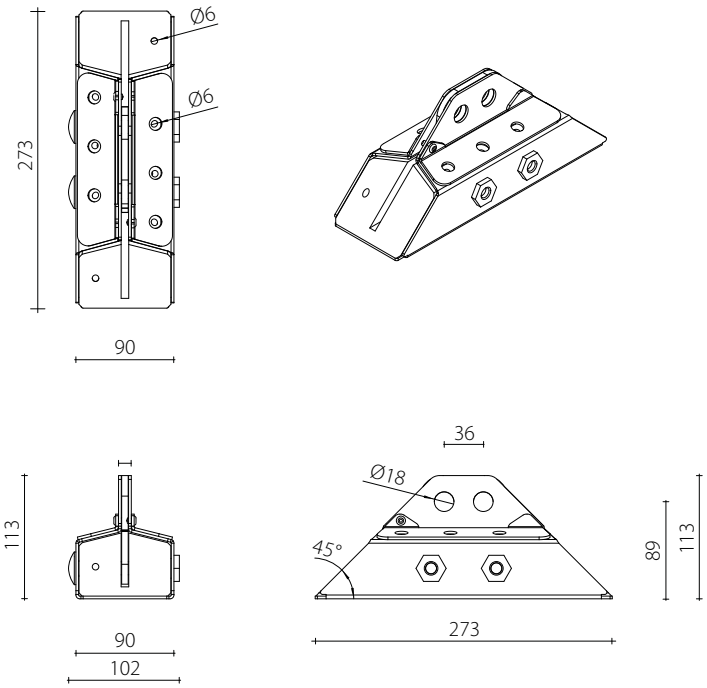
1. Lifting, positioning and connecting prefabricated modules

2. X-ONE in the X-RAD system

3. Transfer of horizontal stresses (earthquake or wind) to the resistant nucleus in CLS

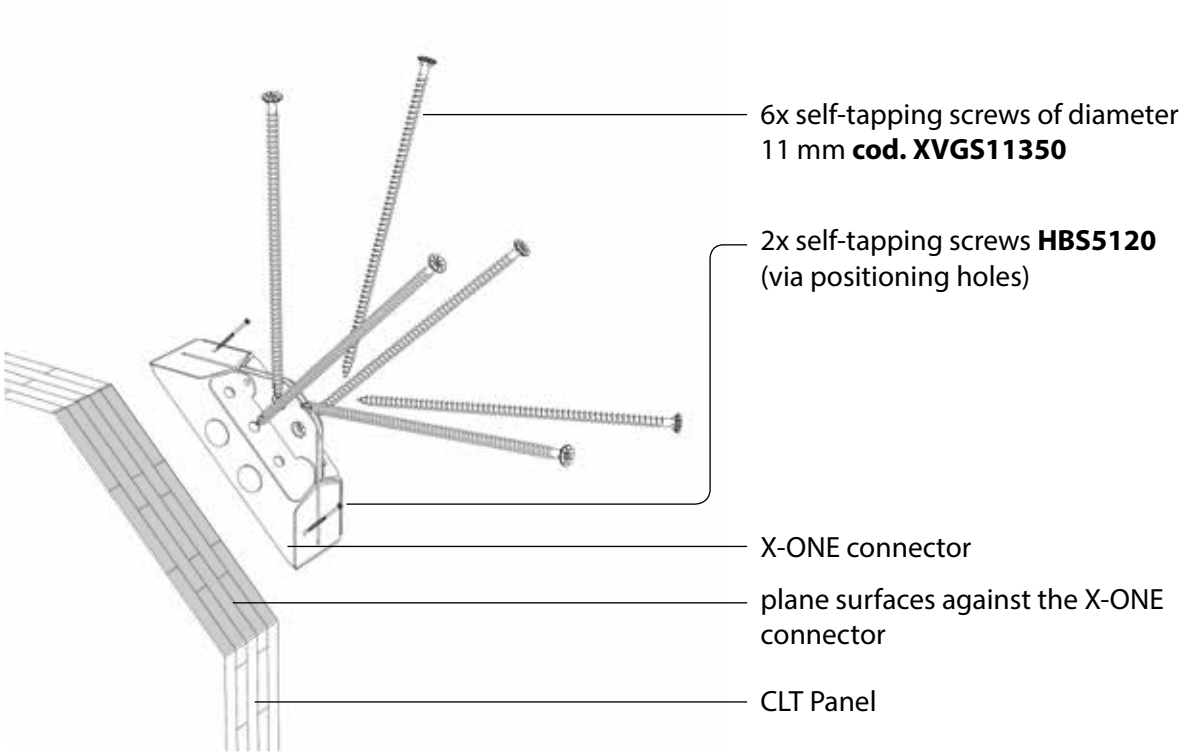
4. Connection of the CLT panel to steel structures

1.1 DESCRIPTION

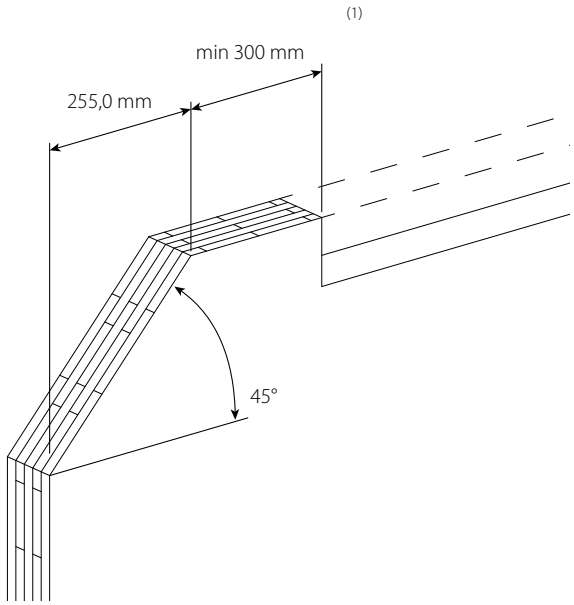


X-ONE is a light and compact connection element, capable of ensuring excellent mechanical performance. Its geometry allows it to be used in the X-RAD system and as a single connection element for particularly demanding applications.

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.

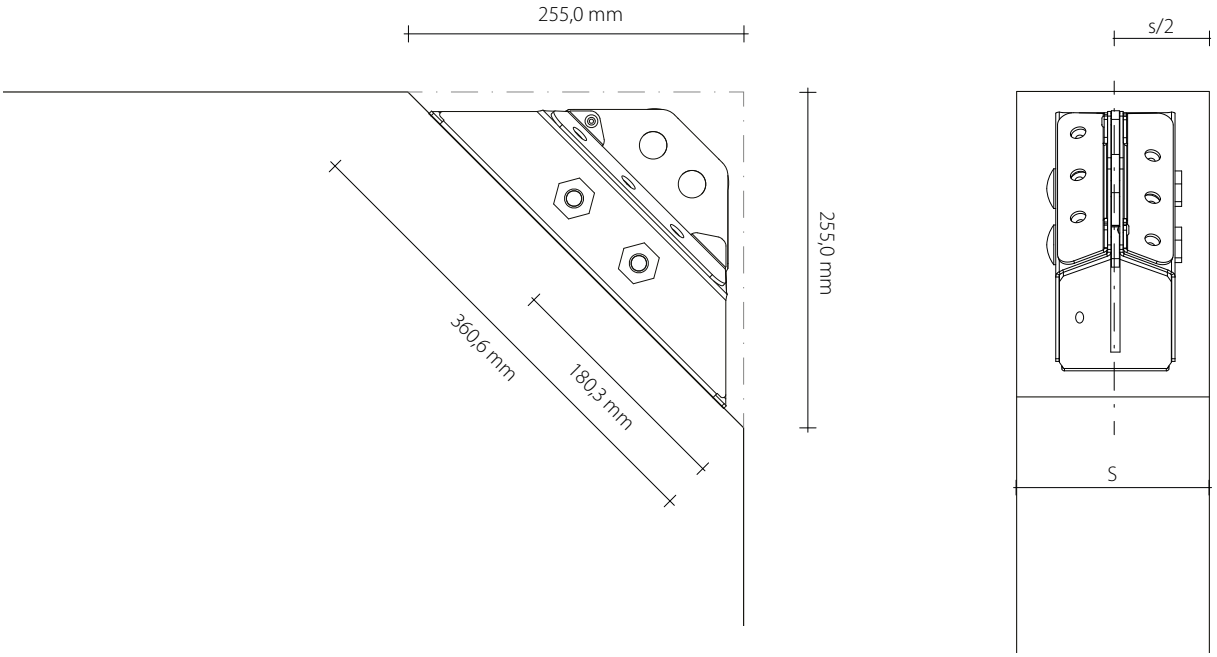


1.2 POSITIONING



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.

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.



(1) We recommend not making cuts in and processing the CLT panel within a radius of 300 mm from X-ONE, in order to avoid damaging the fastening screws and cutting tools.

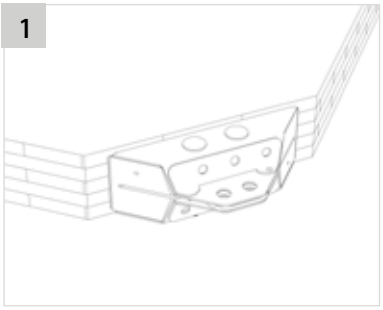
1.3 MANUAL INSTALLATION

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

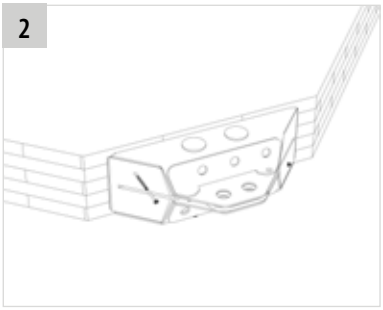
1. Position X-ONE on the fastening surface
2. Fix X-ONE temporarily to the CLT panel using 2 HBS5120 screws in order to prevent movement of the component during the definitive fastening operations.
3. Proceed to the definitive fastening of X-ONE with 6 XVGS11350 connectors.

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

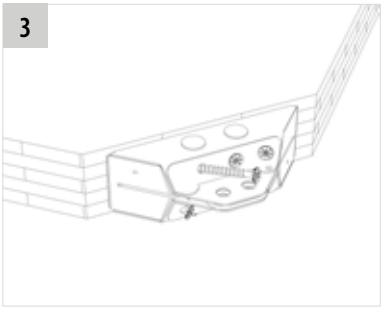
1



2



3

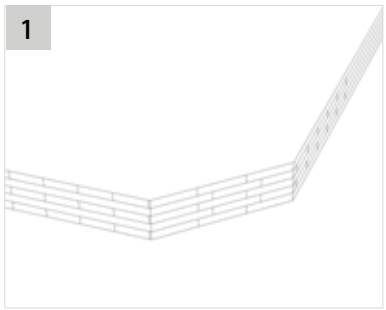


1.4 FASTENING WITH JIG

The pneumatic system enables X-ONE to be positioned quickly and precisely. The steps are the following:

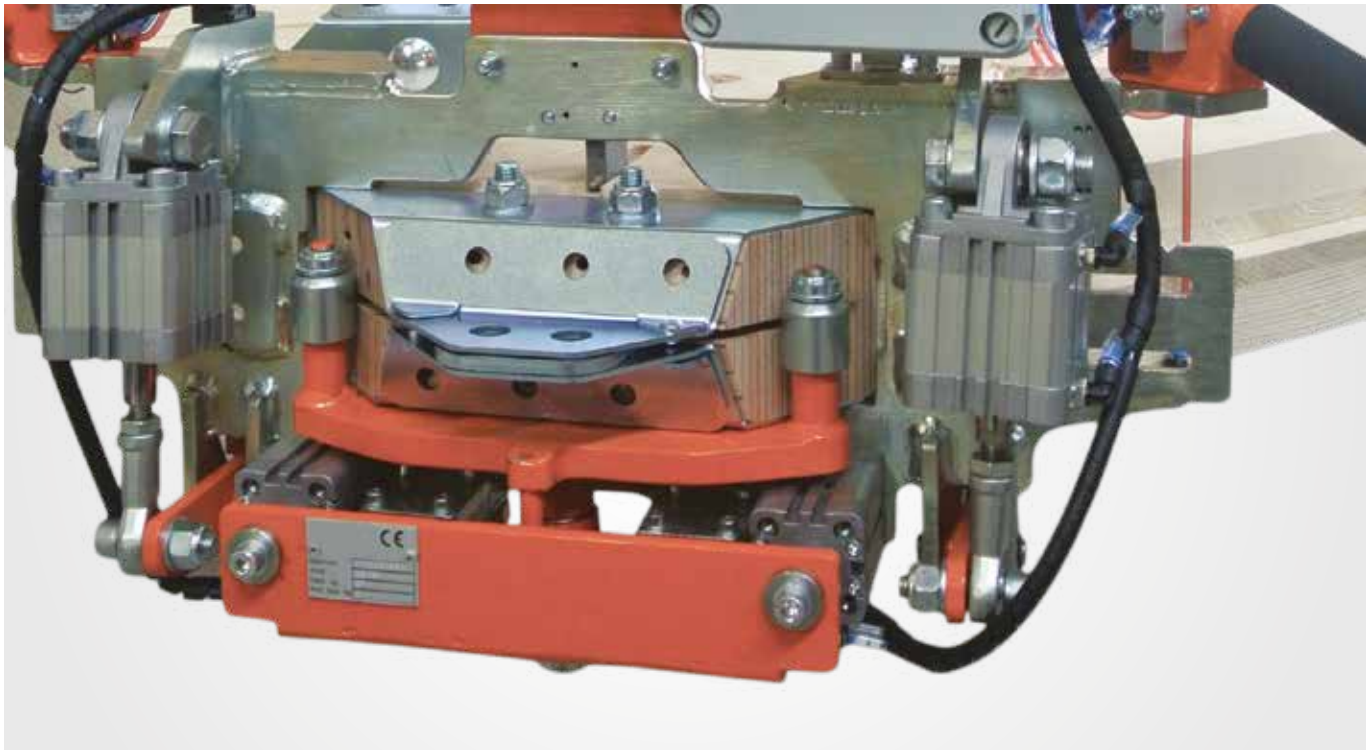
1. Bring the side tracks close to the orthogonal sides of the panel so as to bring the body of the jig against the oblique side. Lock the jig on the panel.
2. Position X-ONE in the special housing on the pneumatic jig and lock it into position.
3. Fasten X-ONE to the panel with 6 XVGS11350 connectors.

1



2

3



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

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

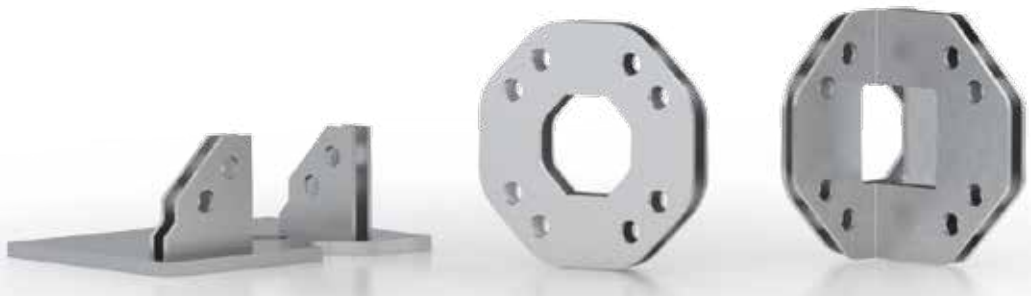
	code	d_1 [mm]	L [mm]	b[mm]	TX	pcs/box
HBS SCREWS	HBS5120	5	120	60	25	100

	code	description	pcs/box
JIG-ONE ASSEMBLY SUPPORT	JIGONE	pneumatic jig for X-ONE assembly	1

2. X-PLATE

BUILDING

EN 1090



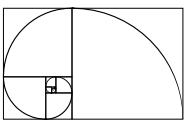
X-PLATE is the range of certified steel plates made up of:
X-BASE, welded plates for connecting the walls to the ground
X-MID, bent plates for connection in elevation of the walls
X-TOP, bent plates for connection in elevation of the walls to roof level
X-PLATE enables the CLT panels to be mounted at the building site.
The connectible panel thicknesses vary from 100 mm to 160 mm.
X-BASE plates introduce a new concept of ground alignment and creating the attachment to the ground, making the mounting of the walls extremely precise and quick, with a saving in building times of between 40% and 60%.

SIMPLE

The panels are mounted at the site through
the simple tightening of steel bolts

COMPLETE

The range meets every on-site need, from attachment to the ground,
to connection between walls at different levels
and with different thicknesses, to closure of the walls at roof level

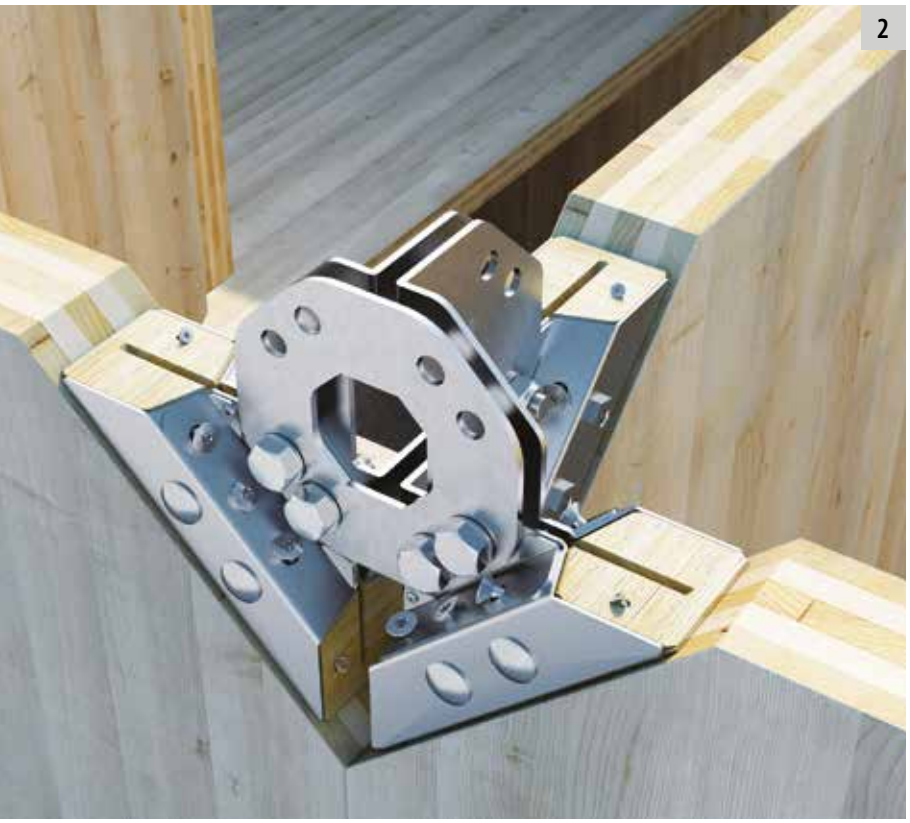


CERTIFIED

High quality guaranteed by the design of the X-PLATE components
by Rotho Blaas and by the CE marking according to EN1090

1

3



2

1. The base plates are positioned by tracing reference holes

2. The panels are quickly connected to each other using X-PLATE

3. Possibility of inserting passing bar for high traction stresses

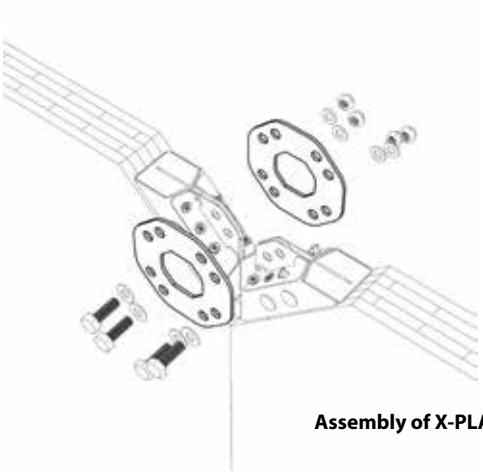
2.1 X-PLATE CODES

X-ONE makes the CLT panel a module provided with holes for fastening.
X-PLATE enables the modules to become buildings.
Panels with a thickness of 100 mm, 120 mm, 140 mm and 160 mm can be connected.
The panels can be aligned, form a right angle, or be arranged to form a T or an X.
X-PLATE is the solution for every building-site situation.
The X-PLATE plates are identified according to their placing at the level of the building (X-BASE, X-MID, X-TOP),
according to the relative position between the panels connected on the floor (O, I, T, X, G, J)
and according to the thickness of the panels connected in elevation
(100 mm – 100 mm, 120 mm – 100 mm, 120 mm – 120 mm, etc…).

X-PLATE CODE COMPOSITION

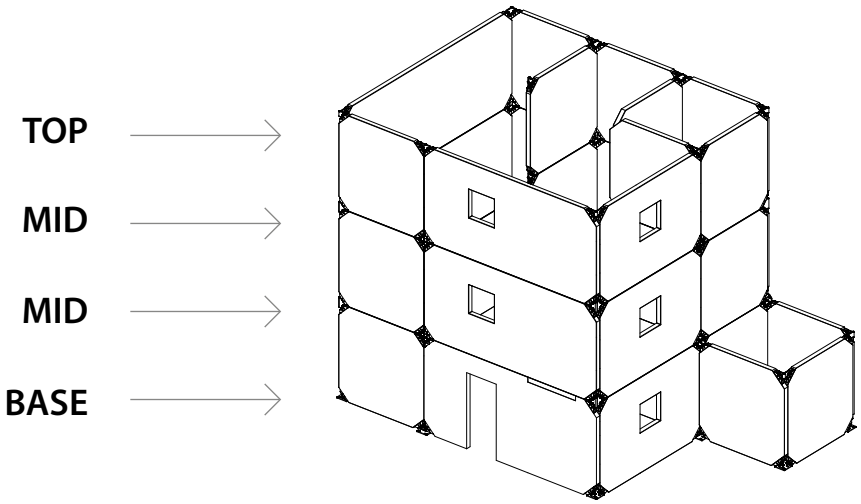
code = **building level** + **form** + **panel 1 thickness** + **panel 2 thickness**

MT140120 = **M** + **T** + **140** + **120**



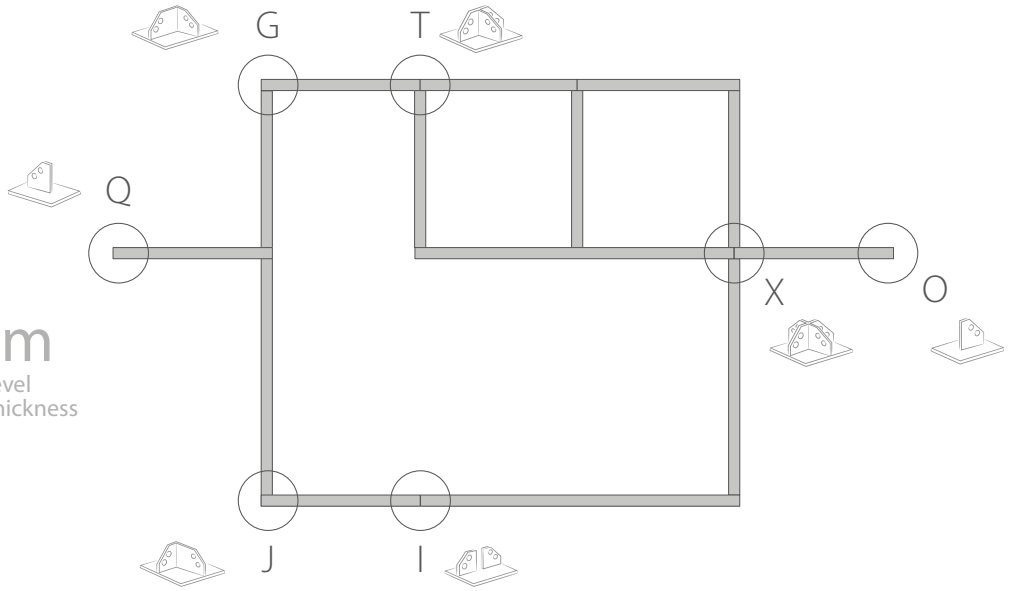
Assembly of X-PLATE MID

building level

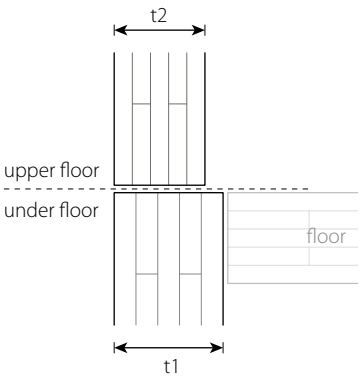


form

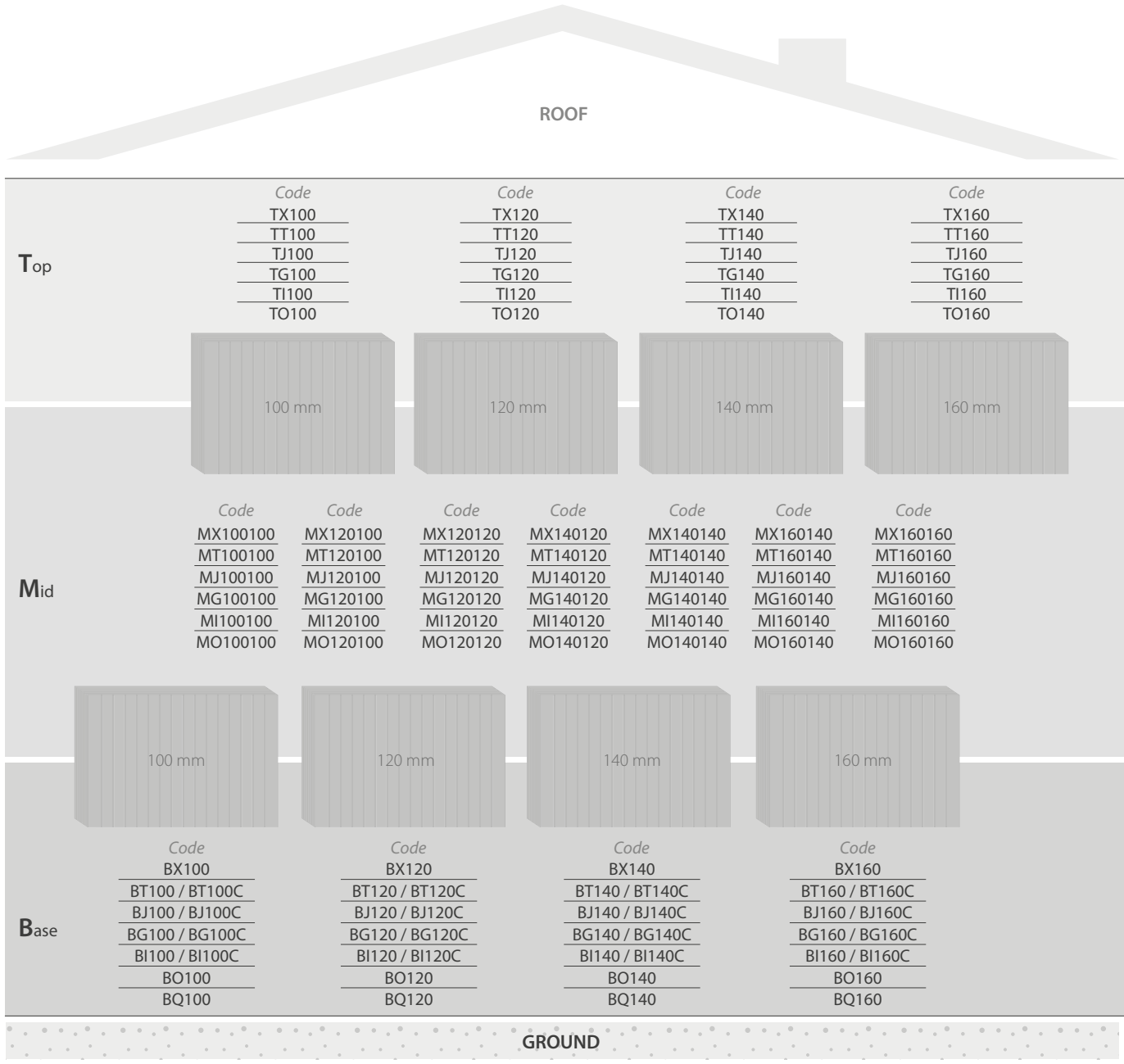
same level
same thickness

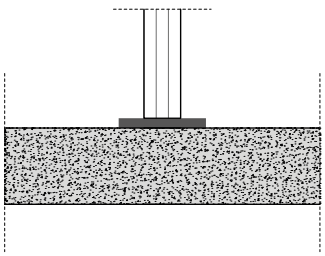


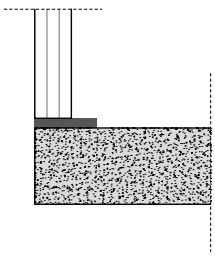
thickness

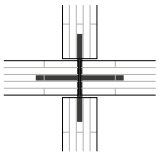
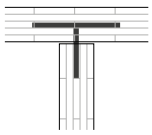
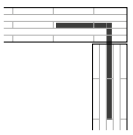
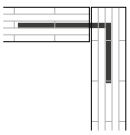
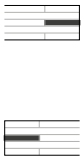
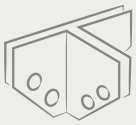
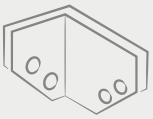
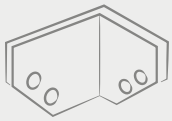
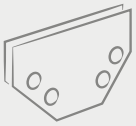
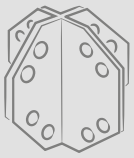
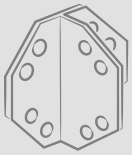
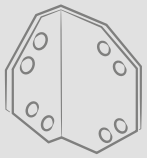
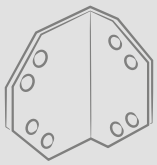
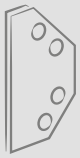
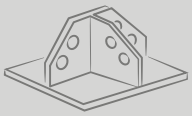
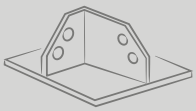
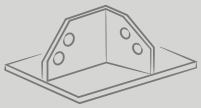
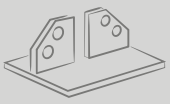
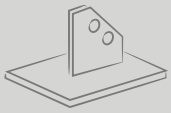


t1	t2
100mm	100mm
120mm	120mm
140mm	140mm
160mm	160mm



X-PLATE BASE	example code
	BI100

X-PLATE BASE C	example code
	BI100C

form **X**	form **T**	form **J**	form **G**	form **I**	form **O / Q**
					 O Q
 *TX* 4 XONE 24 XVGS11350	 *TT* 3 XONE 18 XVGS11350	 *TJ* 2 XONE 12 XVGS11350	 *TG* 2 XONE 12 XVGS11350	 *TI* 2 XONE 12 XVGS11350	 *TO* 1 XONE 6 XVGS11350
 *MX* 8 XONE 48 XVGS11350	 *MT* 6 XONE 36 XVGS11350	 *MJ* 4 XONE 24 XVGS11350	 *MG* 4 XONE 24 XVGS11350	 *MI* 4 XONE 24 XVGS11350	 *MO* 2 XONE 12 XVGS11350
 *BX* 4 XONE 24 XVGS11350	 *BT* 3 XONE 18 XVGS11350	 *BJ* 2 XONE 12 XVGS11350	 *BG* 2 XONE 12 XVGS11350	 *BI* 2 XONE 12 XVGS11350	 *BO* 1 XONE 6 XVGS11350

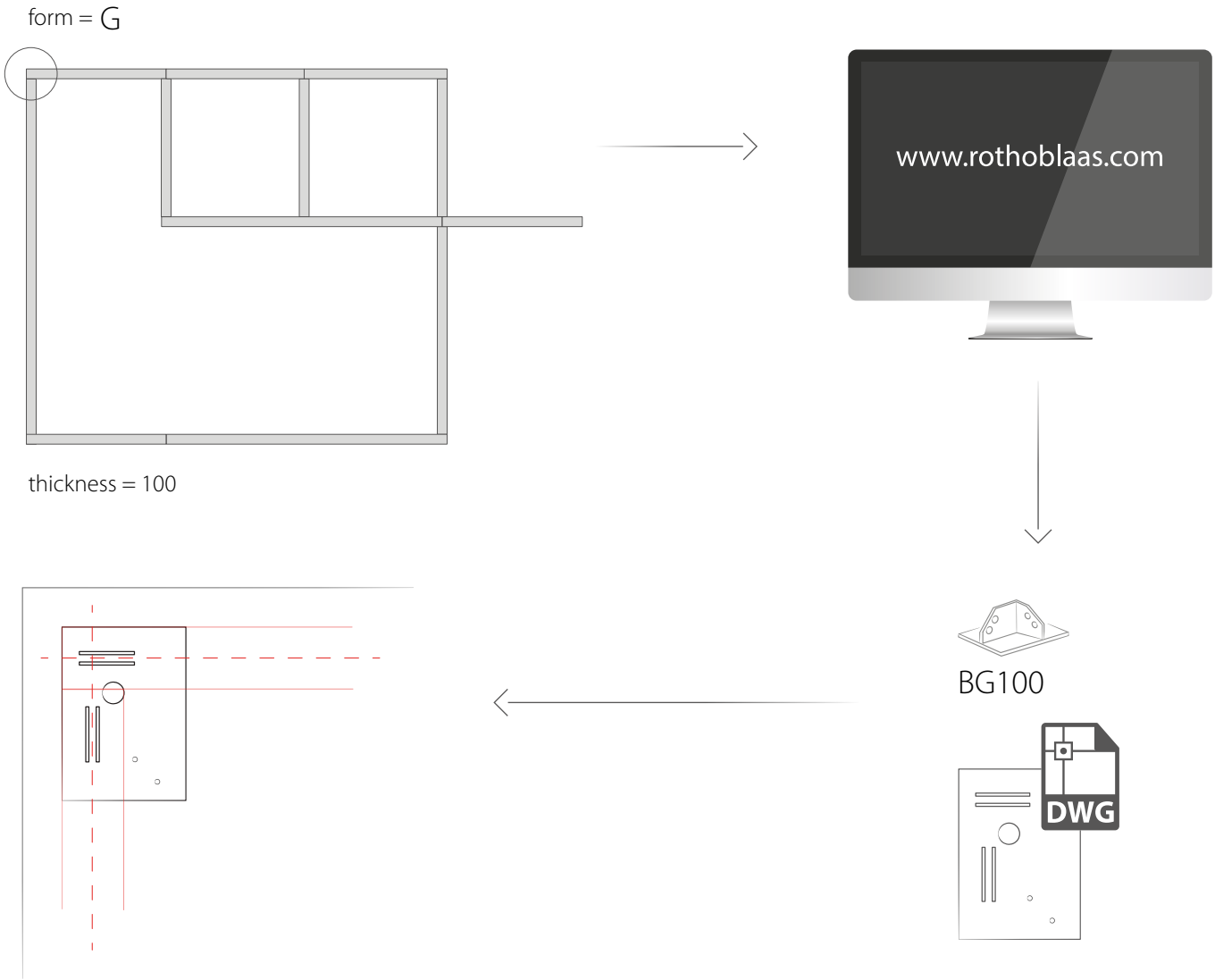
X-BOLT	**code**	**d** [mm]	**L** [mm]	**pcs/box**
Hexagonal head bolt bright zinc plated with Nut Strenght grade 8.8	XBOLT1260	12	60	50
	XBOLT1660	16	60	25
	XBOLT1665	16	65	25

X-ULS	**code**	**bar**	**d_{INT}** [mm]	**d_{EXT}** [mm]	**s** [mm]	**pcs/box**
Washer UNI15714 8.8	XULS13243	M12	13	24	3	500
	XULS17304	M16	17	30	4	500

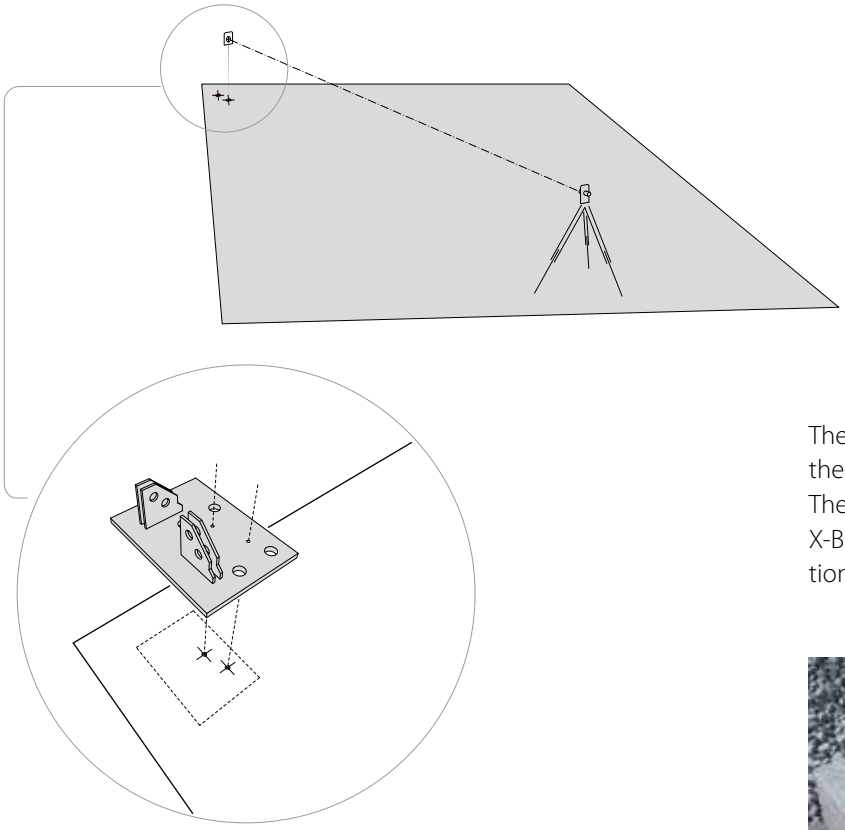
2.2 GROUND ANCHORING

X-RAD increases the advantages of wooden buildings to the highest levels.
The positioning of the X-BASE plates on the foundation, carried out according to the procedure, ensures the maximum precision and enables very quick mounting of the walls.

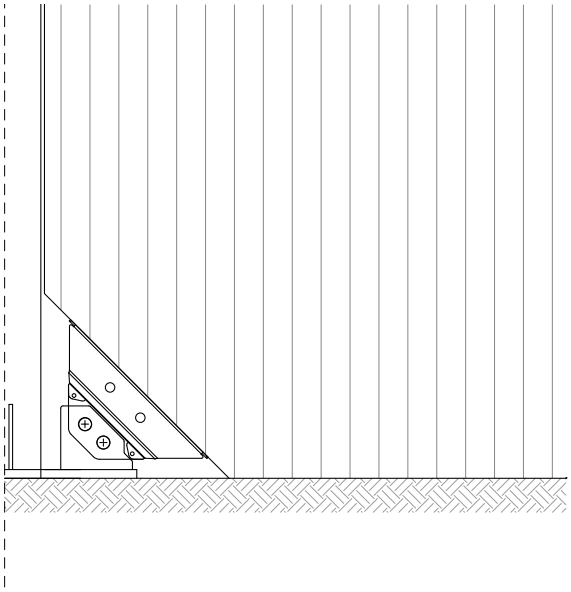
Designs of the X-BASE plates available from www.rothoblaas.com



The reference points for the tracing and the holes to be made for the fastening to the ground are correctly positioned in the floor 0 plan.

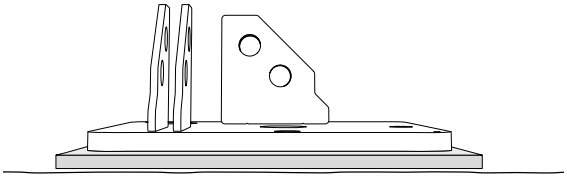


The reference holes of each X-BASE are placed over the points traced.
The reference holes make it possible to identify X-BASE precisely, avoiding any mistakes in the positioning.



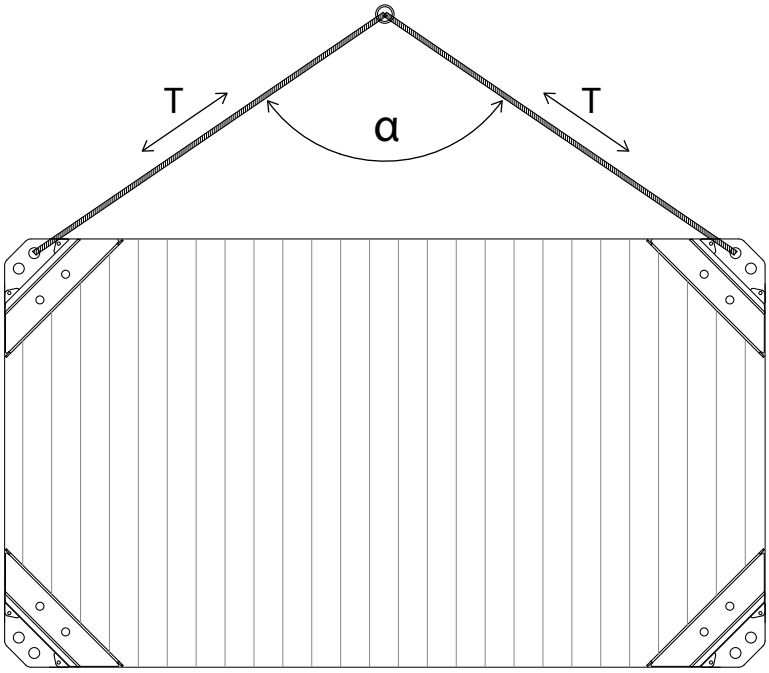
The positioned X-BASES are all placed on the same level at the height provided for by means of the spacers. X-PLATE is fastened to the ground by fixing of the traction bar, which enables subsequent adjustment of the position, and subsequent placing of the shear anchors.

The CLT panel correctly positioned on X-BASE will be aligned with the bottom edge of the plate. To allow space between the foundation and the bottom edge of the panel special spacers can be inserted at the X-BASE levelling stage.



2.3 MOUNTING THE WALLS

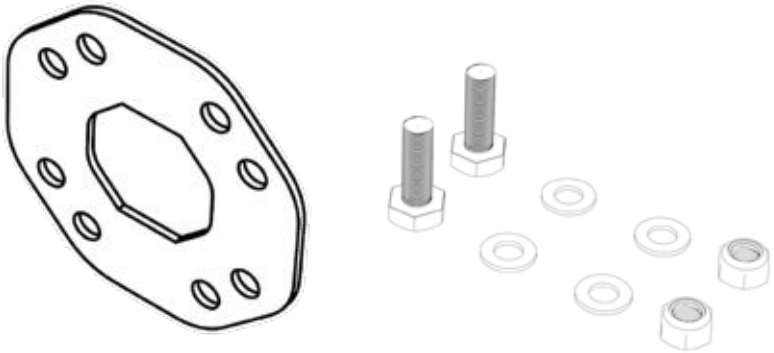
The CLT walls are assembled by positioning bolted steel plates, developed to make structural nodes in all geometric configurations and for all combinations of thicknesses of CLT panels.
The standardised plates enable very quick mounting and structural safety, as they are CE EN1090 marked.

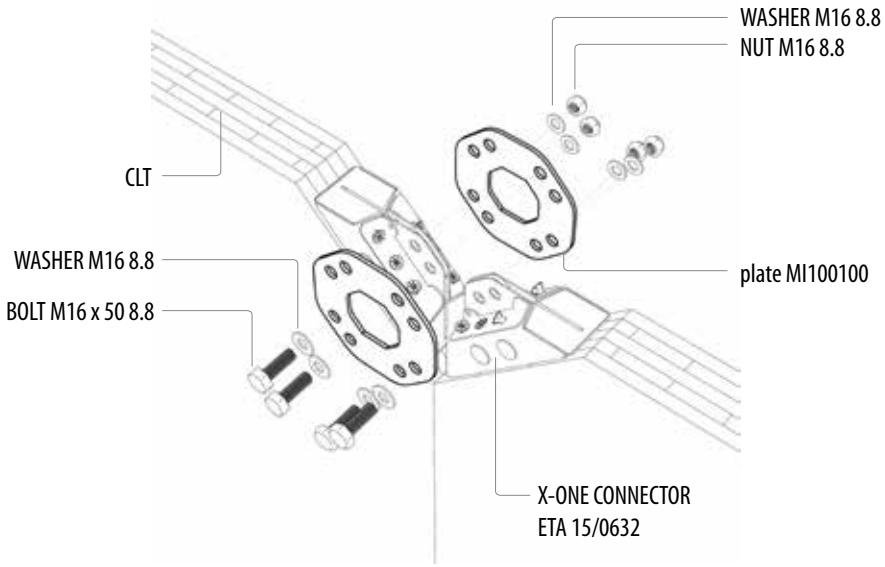


In function of the weight of the panel and the angle between the lifting ropes **(α)**, it is possible to compare the force acting on each hook point **(T)** with the global value of characteristic resistance **(R_k)** of each X-ONE (applying the appropriate security factors).

α	CLT panel weight								R_k X-ONE
	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	103,48 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	101,86 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	100,24 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	98,62 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	97,00 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	104,65 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	112,30 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	119,95 kN

Process of certification in progress for the X-RAD connection system under the terms of the machines directive 2006/42/EC for additional use both as a lifting point for transporting CLT panels in the production facilities and for mounting the panels on-site.



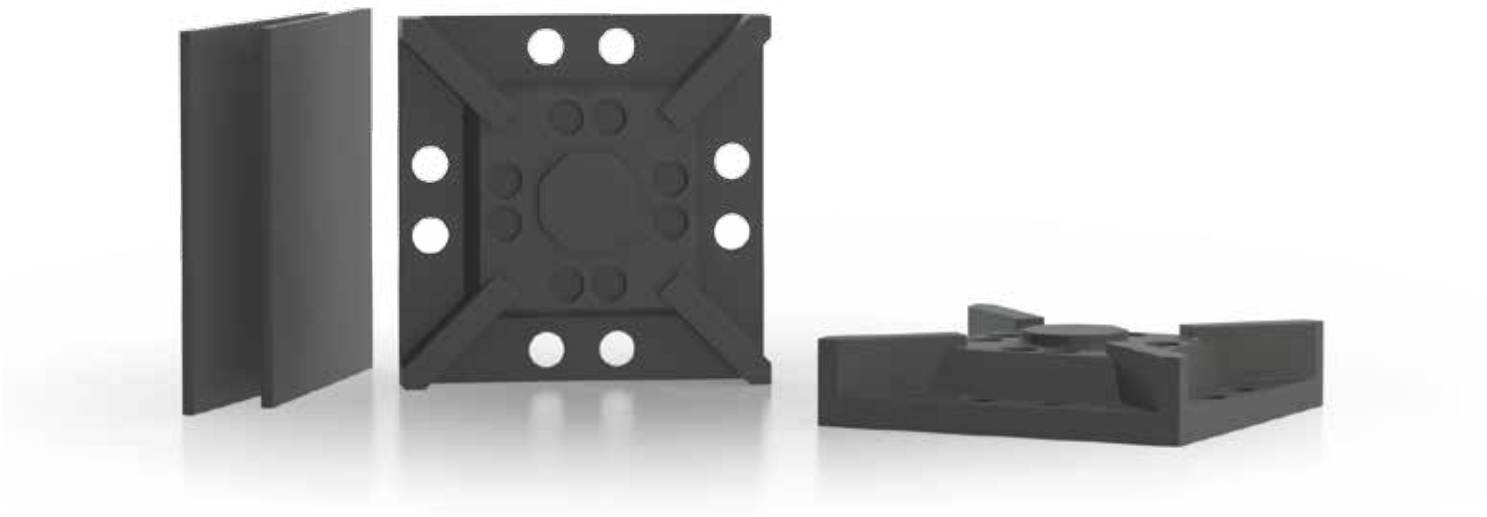


RELATED PRODUCTS

code	description	pcs/box
GEKO	slab puller	1
GIR4000	assembly support 4000 mm	1
ANT	handling lever	1
CRICKET	torque wrench	1

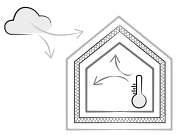
3. X-SEAL

BUILDING ENVELOPE



X-RAD is an innovative system that requires intelligent, fast and practical solutions also to optimise thermo-hygrometric and acoustic performance.
For this reason X-SEAL has been developed. This is a pre-shaped closure that is suited to the morphology of the X-ONE and X-PLATE components.
X-SEAL guarantees air and wind tightening, reduces the transmission of acoustic vibrations through the air and attenuates the single-point thermal bridge.

HERMETIC



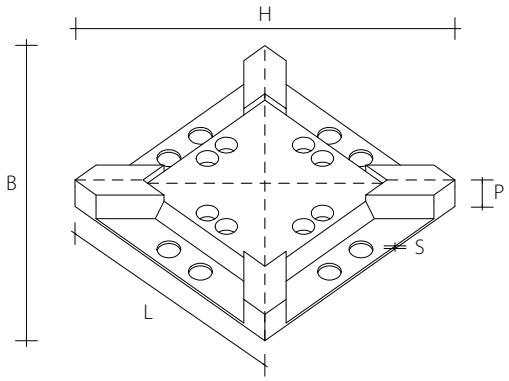
Thanks to the structure in polyethylene with closed cells, it ensures a good acoustic performance, and a seal against air and wind, as well as waterproofing, protecting the heart of the X-RAD system.

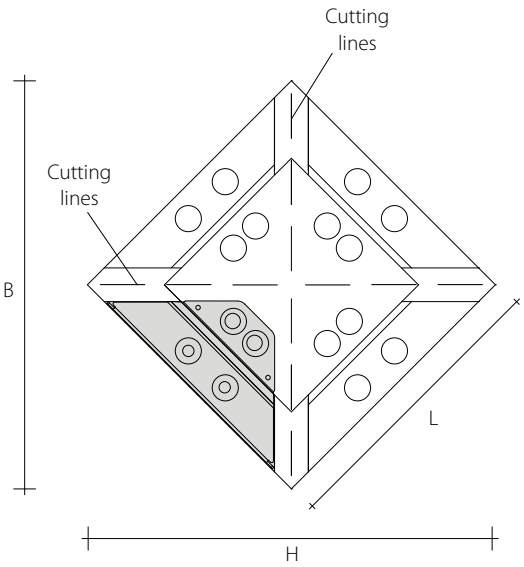
PRE-SHAPING

Thanks to the shape which perfectly fits X-ONE and X-PLATE, the quick closure of the construction node is optimal and does not need further filling materials.

PRACTICAL

The use of X-SEAL in combination with the range of Rothoblaas acrylic belts ensures quick execution and a perfect preservation over time of the seal characteristics against air and wind.

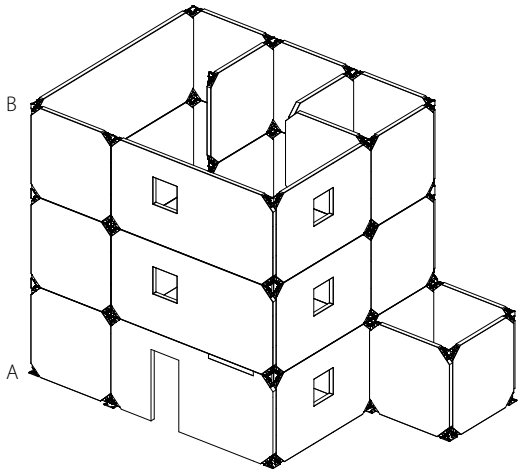




X-SEAL	**code**	**P** [mm]	**L** [mm]	**B** [mm]	**H** [mm]	**pcs/box**
	XSEAL100	50	361	511	511	10
	XSEAL120	60	361	511	511	10
	XSEAL140	70	361	511	511	10
	XSEAL160	80	361	511	511	10
SEAL STAR	**code**	**P** [mm]	**L** [mm]	**B** [mm]	**H** [mm]	**pcs/box**
	SEALSTAR	45	361	511	511	10
SEAL PLATE	**code**	**s** [mm]	**B** [mm]	**H** [mm]		**pcs/box**
	SEALPLATE05	5	511	511		10
	SEALPLATE10	10	511	511		10
FLEXI-BAND	**code**		**width** [mm]	**length** [m]		**pcs/box**
	D52114		60	25		10
	D52116		100	25		6

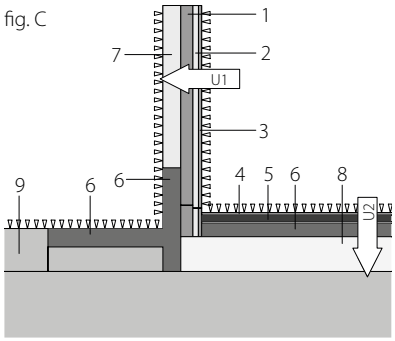
3.1 THERMO-HYGROMETRIC PERFORMANCE

The thermal analysis of the X-RAD system is carried out in order to quantify and verify the thermal bridge associable with the single-point element so that it can be used in the calculation of the building's thermal performance.
The most unfavourable conditions on which to concentrate the study and the verification are the attachment to the ground of the X-PLATE BASE element near to the corner **(A)** and the node of the wall and roof slab attachment, X-PLATE TOP **(B)**.
The study is carried out using a FEM – 3D model and the calculation software Psi-Therm 3D.
An overview of the study with some of the results is provided below.
To obtain the report of the complete study or for further information contact the Rothoblaas Technical Office.

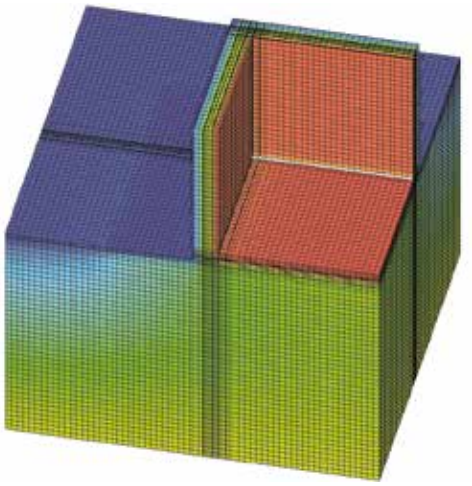


The stratigraphy of reference considered represents a possible standard situation which we can find in current building practice.
The 3D simulation of the thermal bridge is done with X-RAD in the configuration without X-SEAL and with X-SEAL.
In the picture **(fig. C)** we can observe the construction package and the materials considered.
The choice of specific materials makes it possible to contextualise the checks and does not exclude the use of different products. Reference can be made to the complete test report to assess the different executive choices.

fig. C



1. 10 cm CLT
2. 5 cm wood-fibre insulation
3. Plasterboard
4. Wood floor
5. Concrete screed
6. XPS extruded polystyrene 12 cm
7. 12 cm wood-fibre insulation
8. Concrete
9. Ground



The thermal simulations are conducted varying the thicknesses of the insulation (12 cm, 16 cm and 24 cm), trying to identify possible values that would also roughly identify possible energy classes and the related performance.
The simulations are carried out in 3 different climatic contexts that reflect the most frequent weather conditions in the northern and southern temperate zones, referring to a minimum average temperature of the coldest month (Te).

For the report of the complete study and further information contact the Rothoblaas Technical Office.

The analysis provided various data and information, including isotherms, the X (Chi) value and the fRsi value.

X (Chi) represents the additional thermal flow of the three-dimensional thermal bridge with respect to the transmittance of the construction elements involved and two-dimensional thermal bridges of the attachments between them. The value is universal and independent of the climate data, but is affected by the insulation of the construction elements (see final report available at Rothoblaas Technical Office).
Reference standard: EN 10211
fRsi represents the universal instrument for calculating the internal surface temperature (Tsi) in any place. While the fRsi is universal for calculated node, the internal surface temperature depends on the external climate. Using the Tsimin the danger of mould and condensation is assessed.
Reference standard: EN 13788

NODE 1: GROUND ANCHORING

coefficient	description	value
X Chi (16 cm)	Thermal flow	-0,330 W/node
$fRsi_{(Te=-5°C)}$	Temperature factor	0,801

Node 1 thermal flow: X Chi value

insulation	wall thermal-transmittance	value
12+5 cm	0,190 W/m²K	-0,380 W/node
16+5 cm	0,160 W/m²K	-0,330 W/node
24+5 cm	0,121 W/m²K	-0,260 W/node

Node 1 mould danger: Tsi

temperature (Te)	Tsi 12 cm insulation	Tsi 16 cm insulation	Tsi 24 cm insulation
fRsi-average	*0,801*	*0,811*	*0,824*
-5,0°C	15,2°C	15,5°C	15,8°C
0,0°C	16,0°C	16,2°C	16,5°C
5,0°C	16,8°C	16,9°C	17,1°C

NODE 2: SLAB-ROOF ATTACHMENT

coefficient	description	value
X Chi (16 cm)	Thermal flow	-0,142 W/node
$fRsi_{(Te=-5°C)}$	Temperature factor	0,744

Node 1 thermal flow: X Chi value

insulation	wall thermal-transmittance	value
12+5 cm	0,190 W/m²K	-0,380 W/node
16+5 cm	0,160 W/m²K	-0,330 W/node
24+5 cm	0,121 W/m²K	-0,260 W/node

Node 1 mould danger: Tsi

temperature (Te)	Tsi 12 cm insulation	Tsi 16 cm insulation	Tsi 24 cm insulation
fRsi-average	*0,744*	*0,766*	*0,800*
-5,0°C	13,6°C	14,1°C	15,0°C
0,0°C	14,9°C	15,3°C	16,0°C
5,0°C	16,2°C	16,5°C	17,0°C

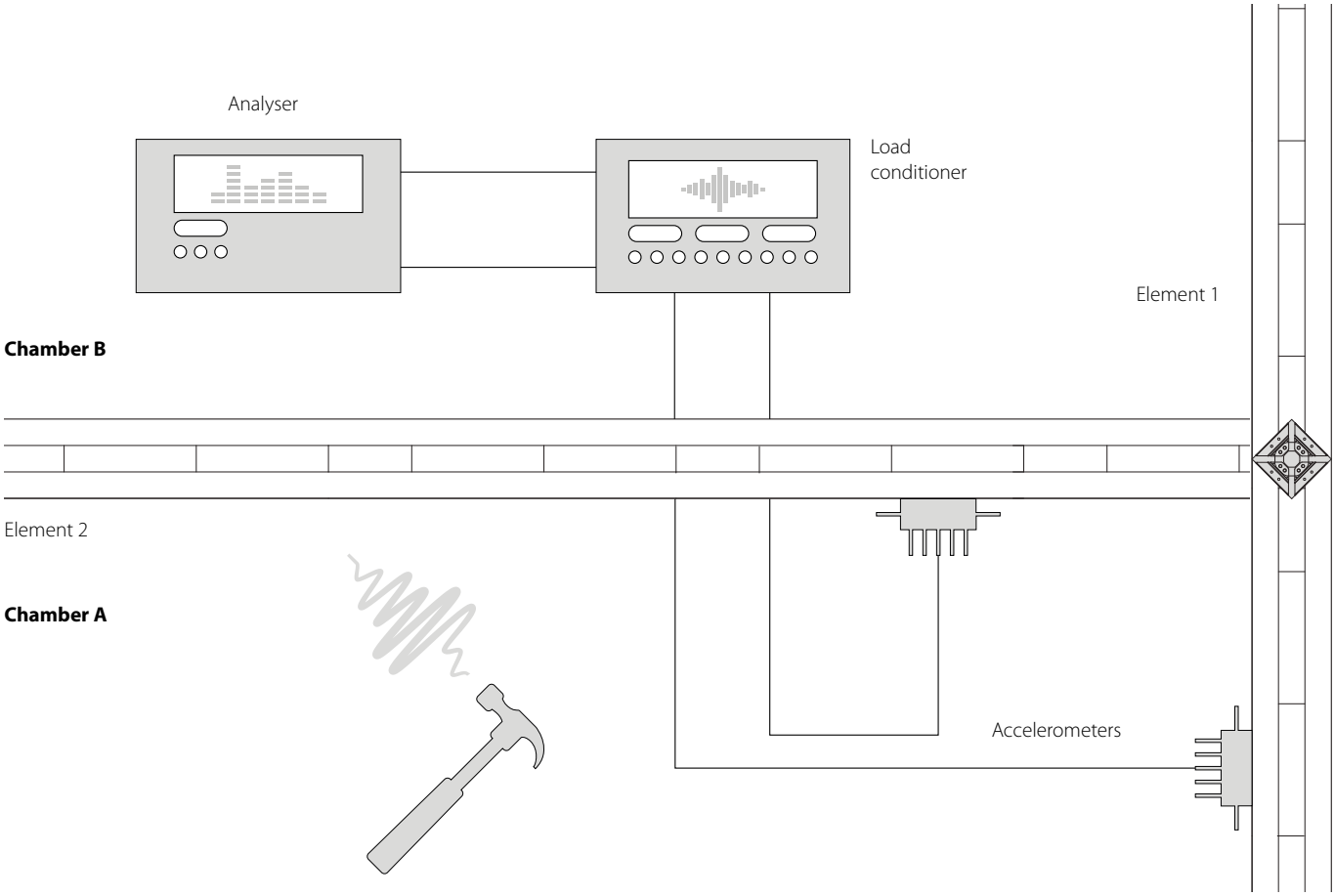
3.2 ACOUSTIC PERFORMANCE

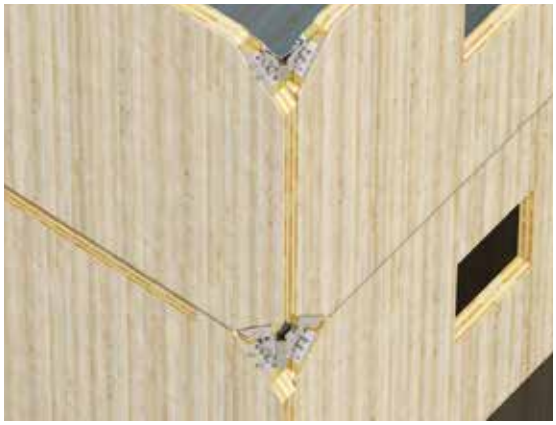
With X-RAD the structural nodes are concentrated in single and distinct points. As regards the acoustics a targeted and calibrated study was carried out on this new building concept in order to achieve the acoustic characterisation of the structural nodes created with X-RAD.
X-SEAL avoids direct acoustic transmission through the air caused by the "emptying" of the mass of the node due to the 45° cut on the CLT panel.
The structural lateral transmission through the X-ONE and X-PLATE heavy elements by quantifying the energy transmitted via vibration of the structural elements constituting the joint is made in accordance with the EN 12354 standard and divided into several steps:

• Measurement of the vibration reduction index (Kij and Dnvij) according to the ISO 10848 standard: required by EN 12354-1 for forecast calculation of the acoustic performance of installed building components. In particular the vibration reduction index expresses the sound power transmitted by structural vibration between two elements, walls or slabs, connected together.

• Comparison between the X-RAD joint and the traditional solutions (Titan, WHT and similar).

• Drawing up of the abacus of the joints for the acoustic design according to EN 12354: Kij and Dnvij values already characterised, calculated and verified to be inserted as per the European standards.

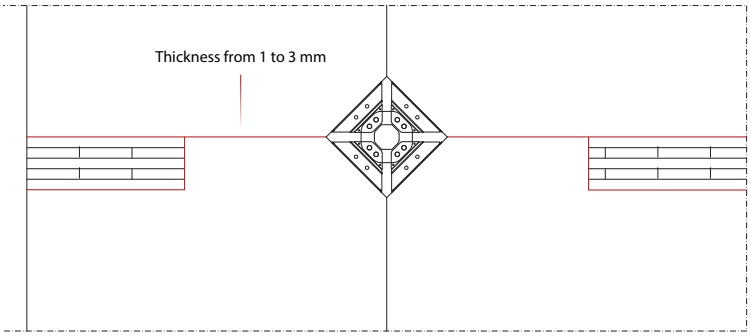




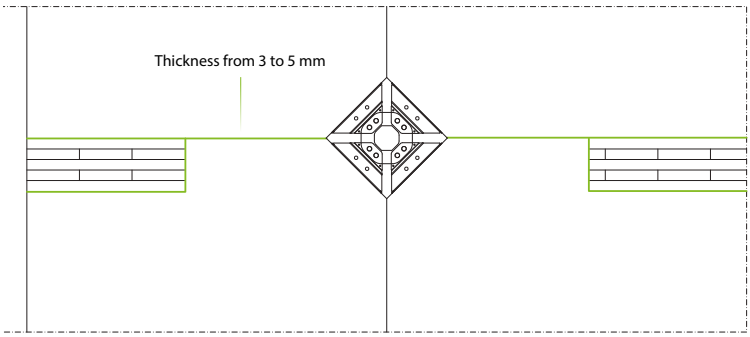
ATTENTION TO DETAIL

Thanks to the precise location of the structural nodes at the tops of the CLT walls, X-RAD enables the non-interposition of the slabs between the walls. This entails significant benefits from the acoustic point of view, which increase with the adoption of specific profiles.

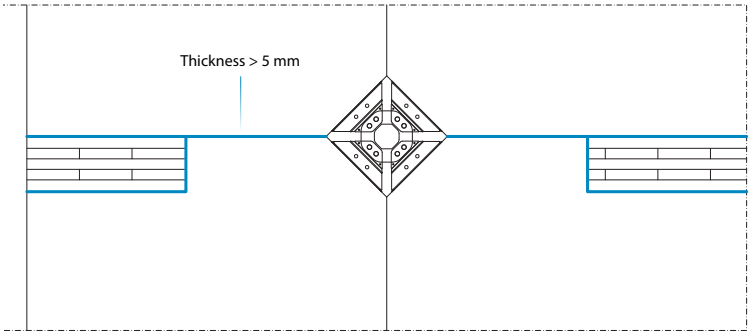
• Sealing profiles in EPDM and butyl
Air tightening, protection of the layer of insulation and elimination of any aerial acoustic bridges.



• Resilient acoustic profiles in EPDM
Hermetic closure of the attachment between the structural elements and damping of the acoustic vibrations between slab and wall. The resilient layer created dampens the sound wave otherwise transmitted by the structure vertically and horizontally.



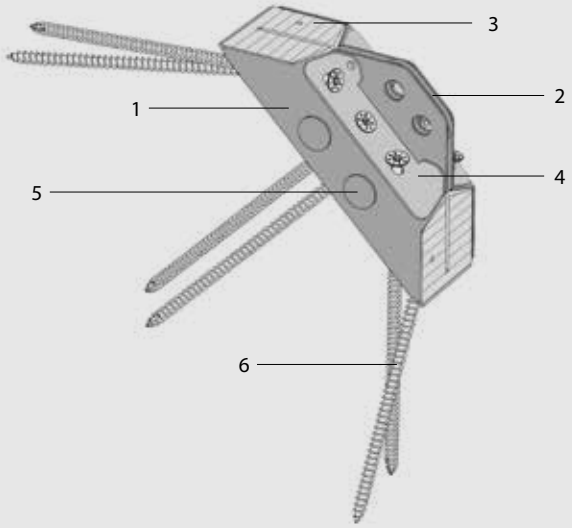
• Resilient acoustic profiles in PUR
Hermetic closure of the attachment between the structural elements and damping of the sound vibrations irrespective of the static or dynamic load applied, maintaining great elasticity and performance over time.



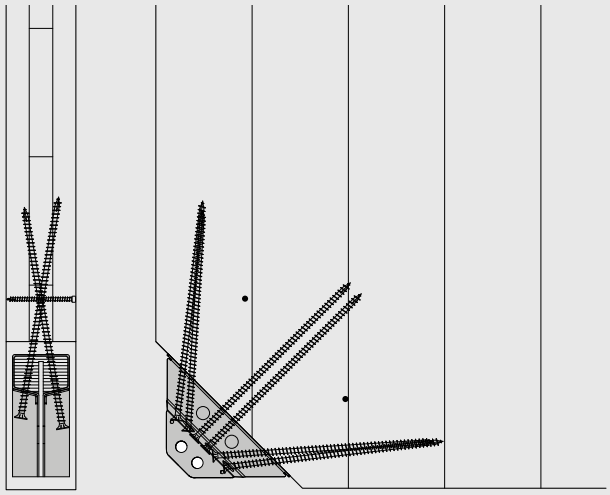
All these materials must be provided for at the stage of designing and cutting the panels.

4. 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 subject of the study is therefore 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



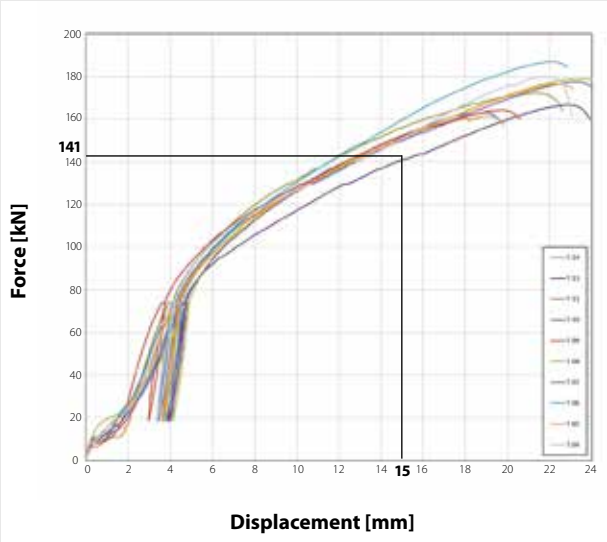
Placing of connectors with variable inclination

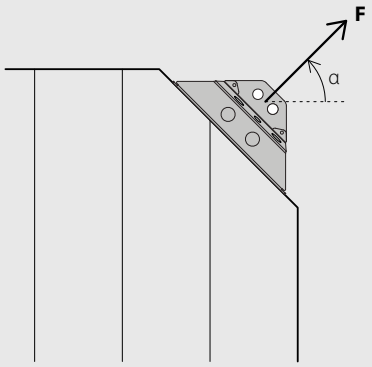
In order to determine the failure domain of X-ONE in a stress field variable between 0° and 360° (in the CLT panel plane) the component is studied according to 3 approaches.
- **Experimental investigations:** load tests on the connection with different stress directions
- **Analysis of the finite elements (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).

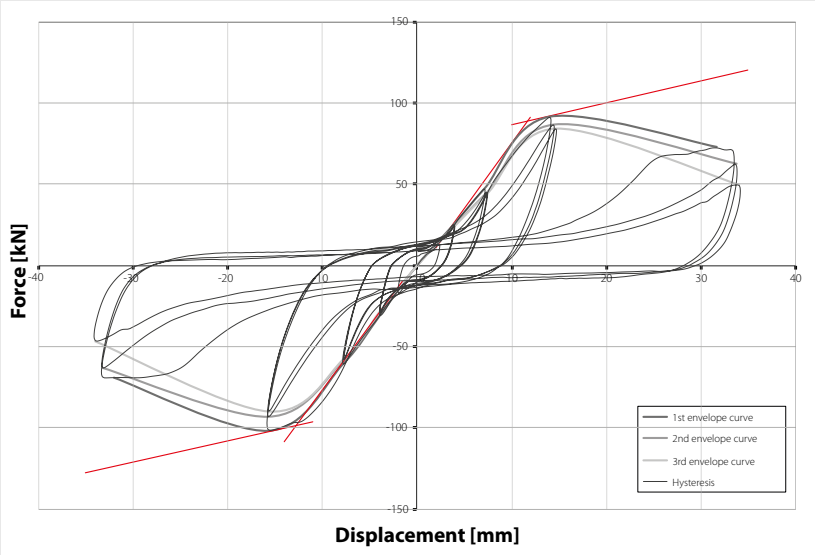
4.1 EXPERIMENTAL INVESTIGATIONS

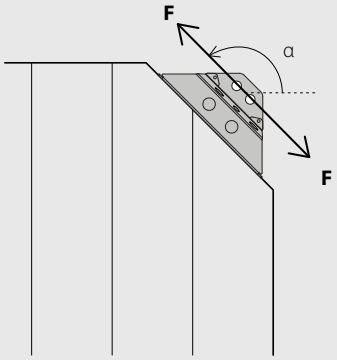
The laboratory tests were carried out in three different research centres:
• *TU-GRAZ (Lignum Test Centre of the University of Graz - AT)*: monotonic tests to identify the resistance and rigidity parameters contained in ETA 15/0632
• *CNR-IVALSA (Trees and Timber Institute in San Michele A.A - IT)*: 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





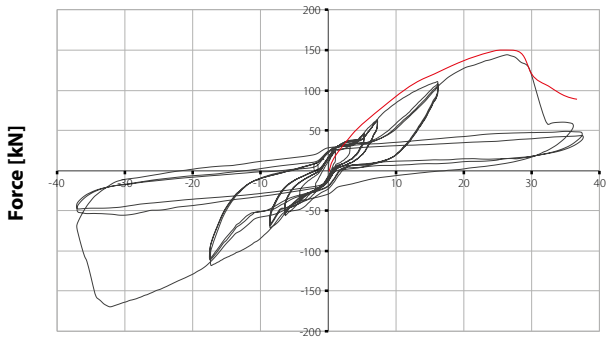
Example of output from monotonic test:
force-movement for stress curves α = 45°





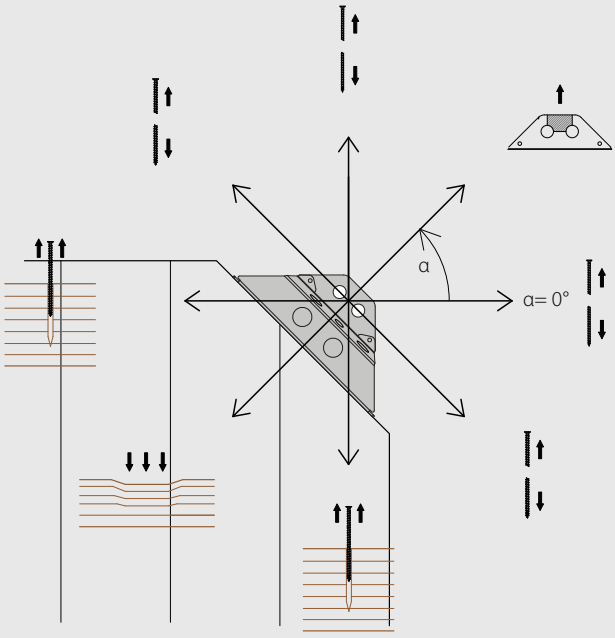
Example of output from cyclical test:
force-movement for stress diagram α = 135° - 325°

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 X-RAD. 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

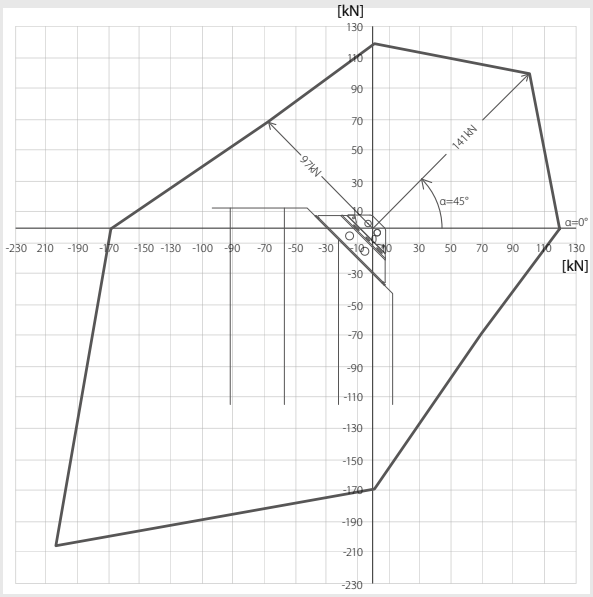
In all the tests performed the connection was taken to breakage in order to observe the behaviour of the system as the stress direction applied changed.



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

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

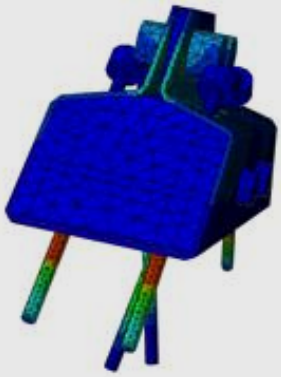
At the end of the experimental phase the resistance diagram of the connection was defined through interpolation of the data collected.



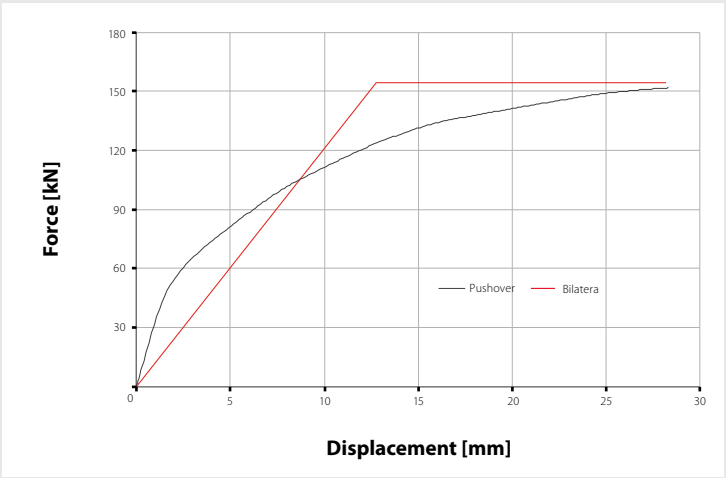
Experimental resistance domain

4.2 FINITE ELEMENT ANALYSIS

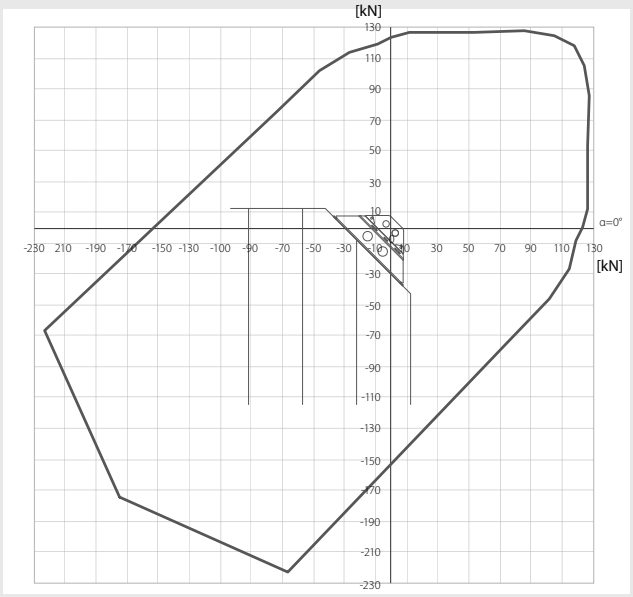
The results collected in the experimental tests and observation of breaking characteristics led to the creation and validation of a finite-element model, capable of describing the overall behaviour of the X-ONE connection subject to movements in different directions.
Analyses of the push-over type were 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

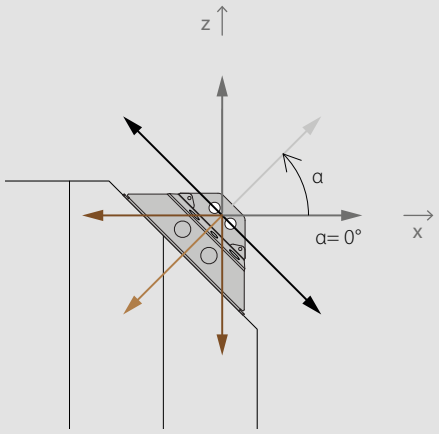


Resistance domain obtained from the FEM simulations

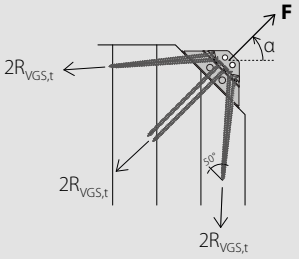
The points representing maximum resistances found by the FEM analyses enable the definition of a further resistance domain for the connection

4.3 ANALYTICAL MODELS

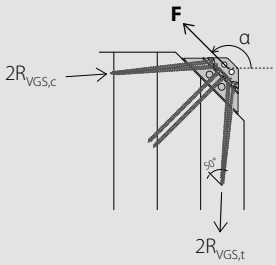
The experimental campaign and the finite-element model show how the X-ONE+CLT panel system has different ways of failure on changes in the stress direction. For the purposes of defining calculation models, 8 main stress directions were identified within a x-z reference system, in which the behavioural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



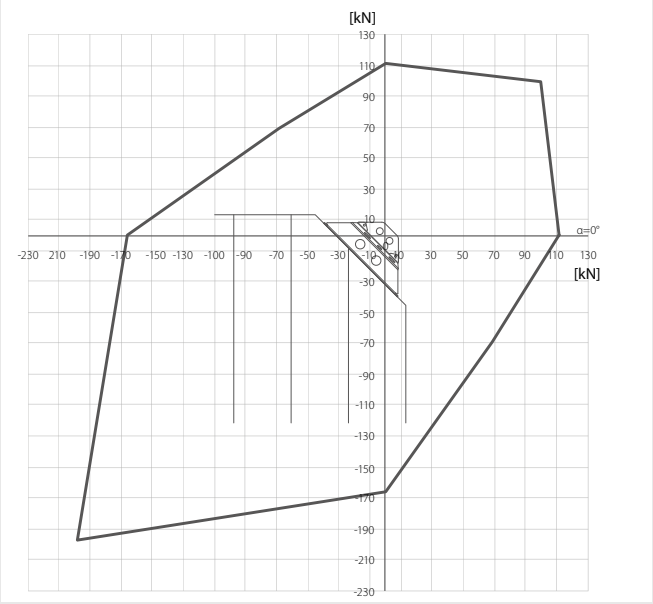
Starting from observation of the experimental collapse characteristics, the balance configurations of the connection were identified for each stress direction in accordance with the static theorem of the limit analysis. By way of example the resistant mechanisms for two configurations are shown:



Configuration for α = 45°



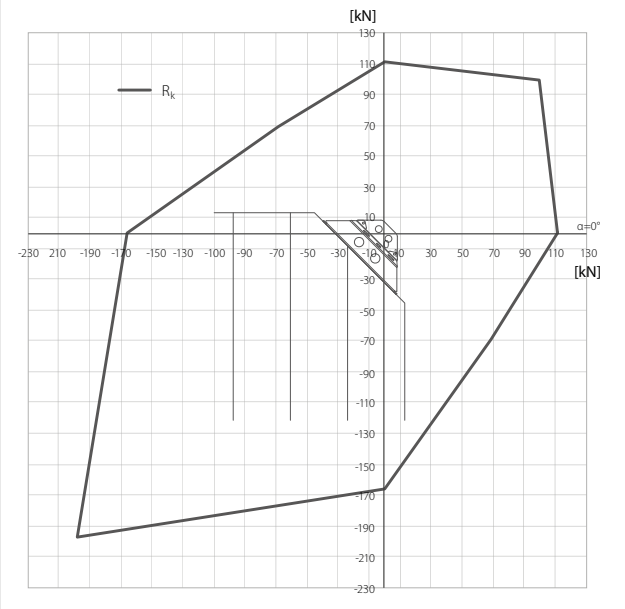
Configuration for α = 135° - 315°



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

4.4 DESIGN RESISTANCES



Characteristic resistance domain

On the basis of the considerations made previously, 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**.

The connection study phase led, through a system design in accordance with the concepts of resistance hierarchy, with the over-sizing of a number of elements constituting X-ONE, facilitating in this way 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)

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 R_k [kN]	components of resistance V_k [kN]	components of resistance N_k [kN]	failure mode		partial safety factor [1] 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	estrazione filetto VGS	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	$\gamma_{M2} = 1,25$

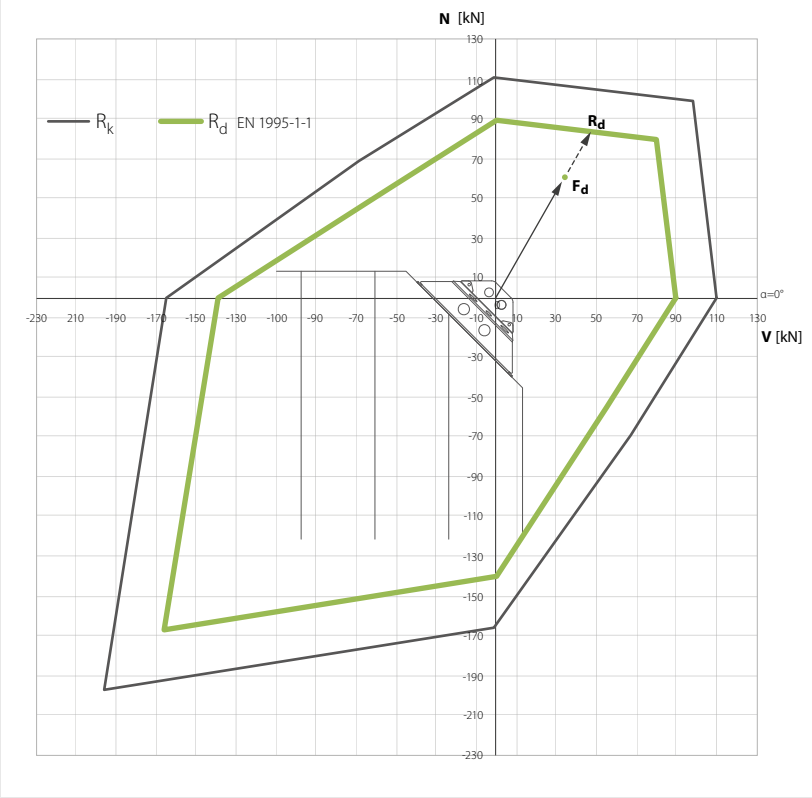
In order to obtain the maximum performances of X-ONE connector and to avoid the splitting of the wood panel, it is recommended to insert 2 full thread connectors VGZ perpendiculars to the CLT panel (picture right - page 28)

[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

Starting from the characteristic resistance values, the **design resistance domain of X-ONE** is defined, in order to carry out checks at the Ultimate Limit State.
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.



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

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

$$\mathbf{F_d \leq R_d}$$

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) [(1)].

[(1)] 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.

NOTES

e-mail: support-xrad@rothoblaas.com

rothoblaas

Rotho Blaas srl - I-39040 Cortaccia (BZ) - Via Dell'Adige 2/1

Tel. +39 0471 81 84 00 - Fax +39 0471 81 84 84

info@rothoblaas.com - www.rothoblaas.com

8 033564 769122

8 01XRADTG1EN

1500556_03