Seismic Behavior of Multistory Cross-laminated Timber Buildings

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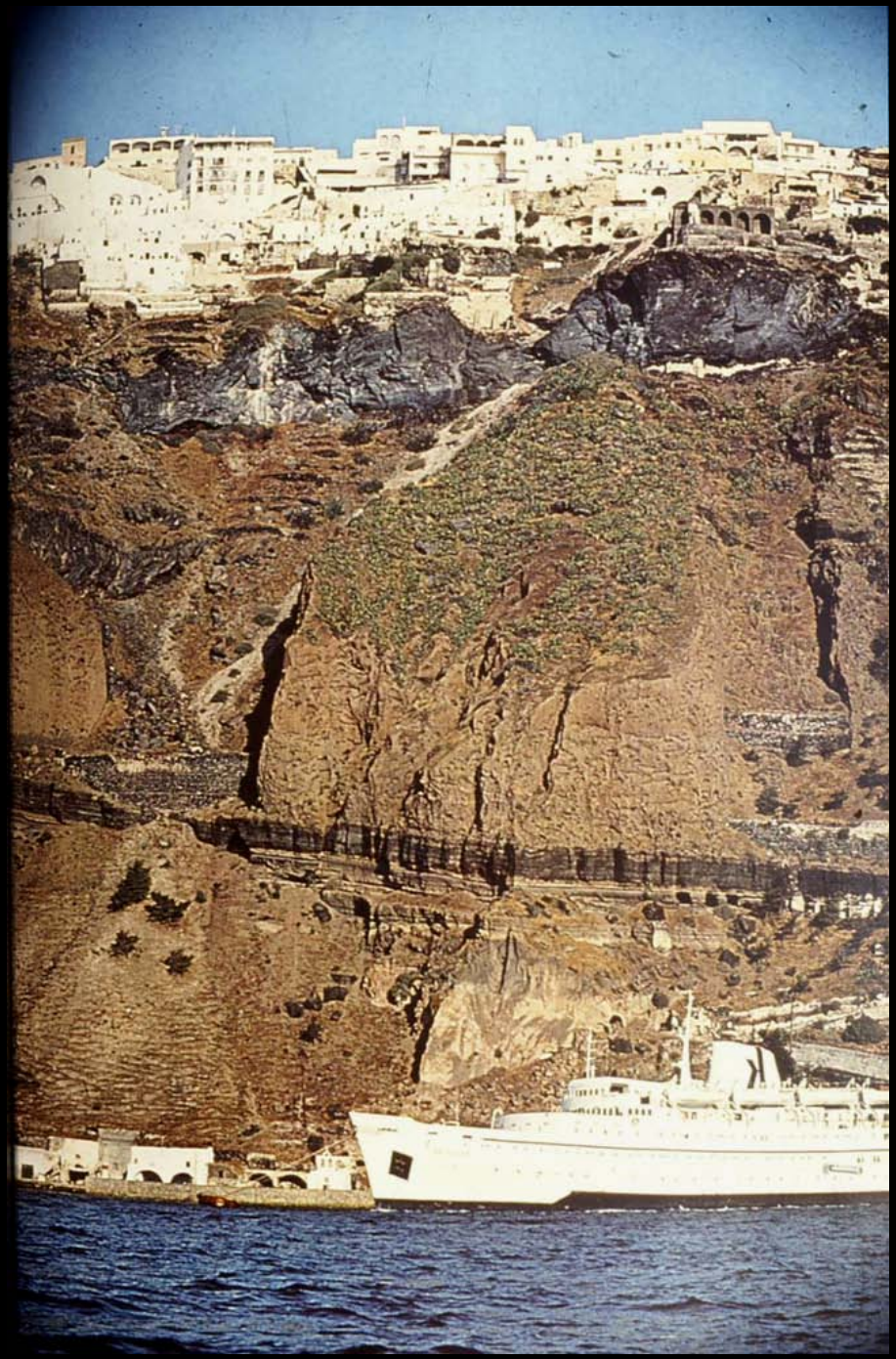
2010 UNECE-SWST International Convention

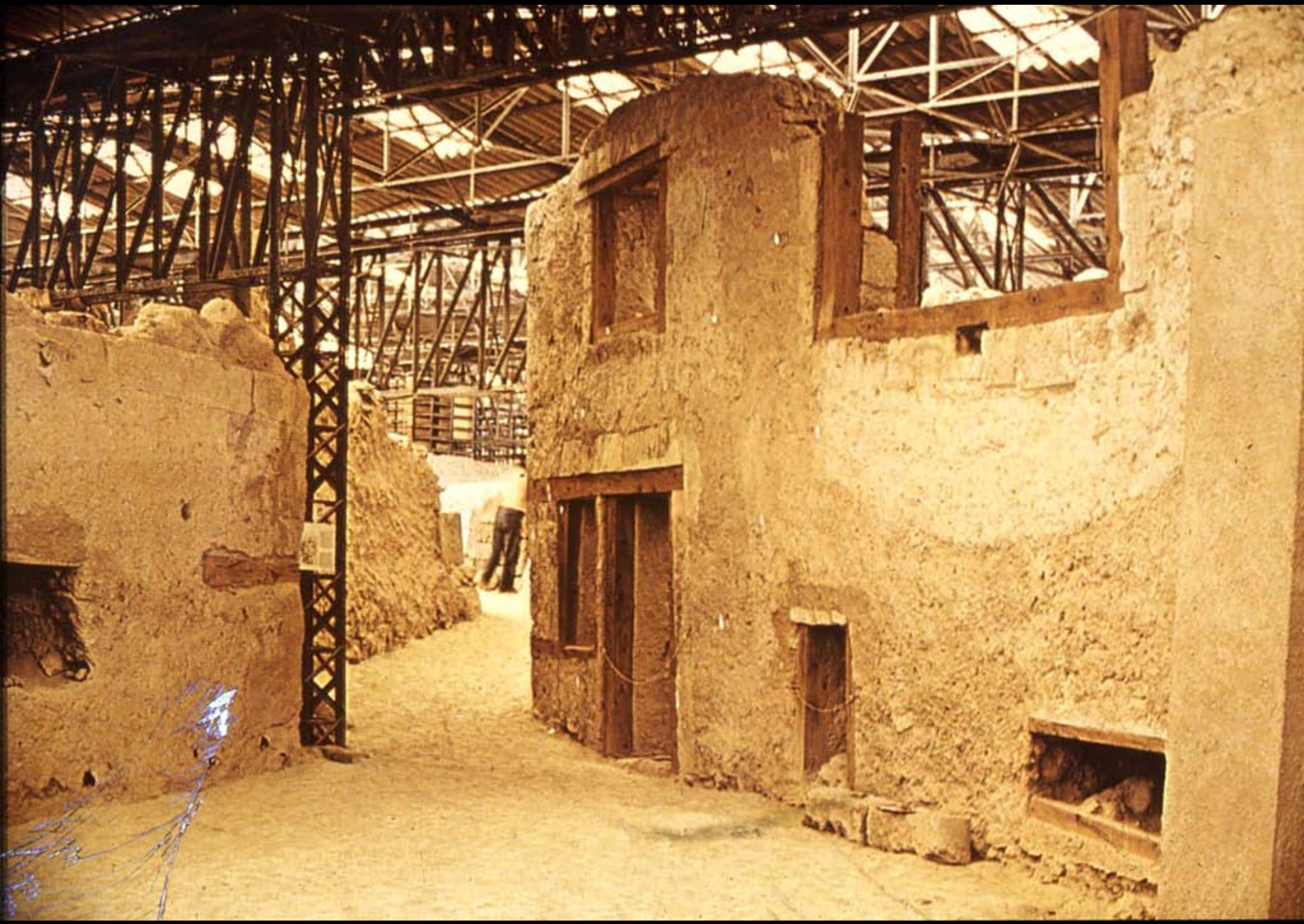
Quakes!
and timber structures….

from San Francisco Museum

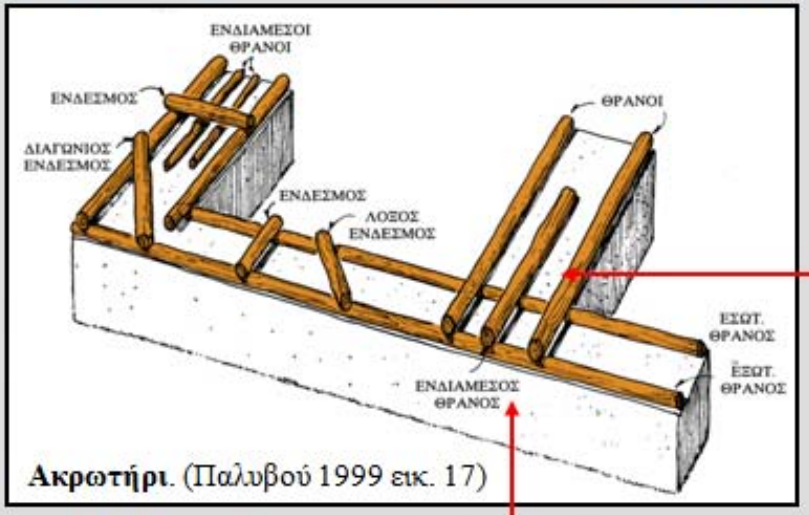
Looking at the past…

ΧΑΡΤΗΣ ΤΗΣ ΣΑΝΤΟΡΙΝΗΣ



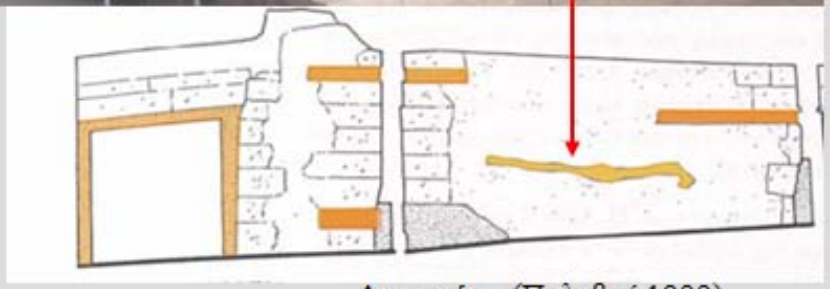


Οριζόντιο ξύλινο σύστημα ενίσχυσης αργολιθοδομών



Ακρωτήρι. (Παλυβού 1999 εικ. 17)

Ακρωτήρι Νεοανακτορική περίοδος (~1700–1450π.Χ.)



Ακρωτήρι. (Παλυβού 1999)

By courtesy of P. Touliatos

ΝΟΤΙΟΔΥΤΙΚΗ ΠΕΡΙΟΧΗ ΤΗΣ ΚΡΥΠΤΗΣ ΤΗΣ ΛΙΤΗΣ ΤΗΣ ΙΕΡΑΣ ΜΟΝΗΣ ΔΟΧΕΙΑΡΙΟΥ Αγ. ΟΡΟΥΣ.

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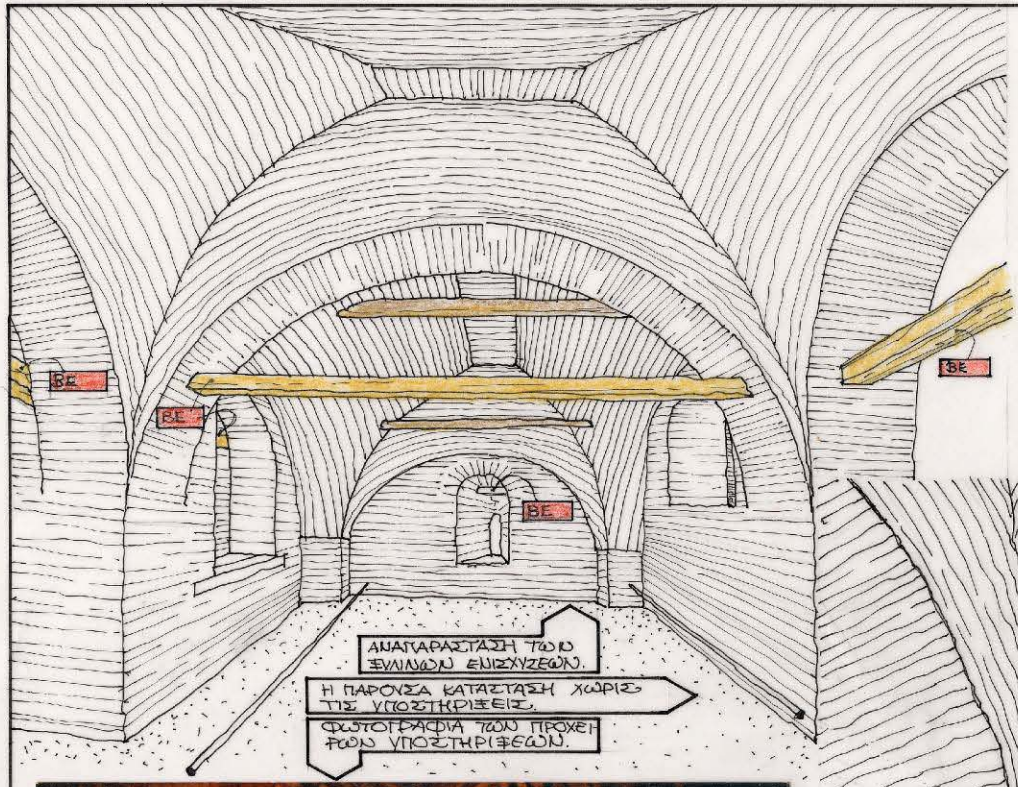
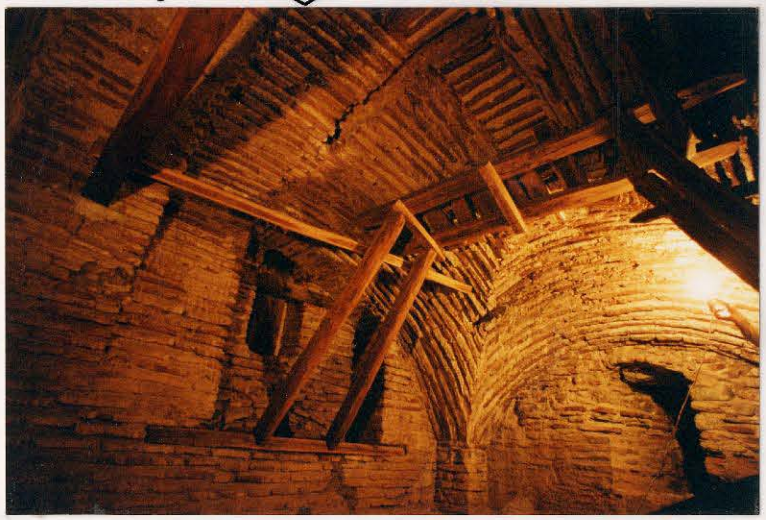
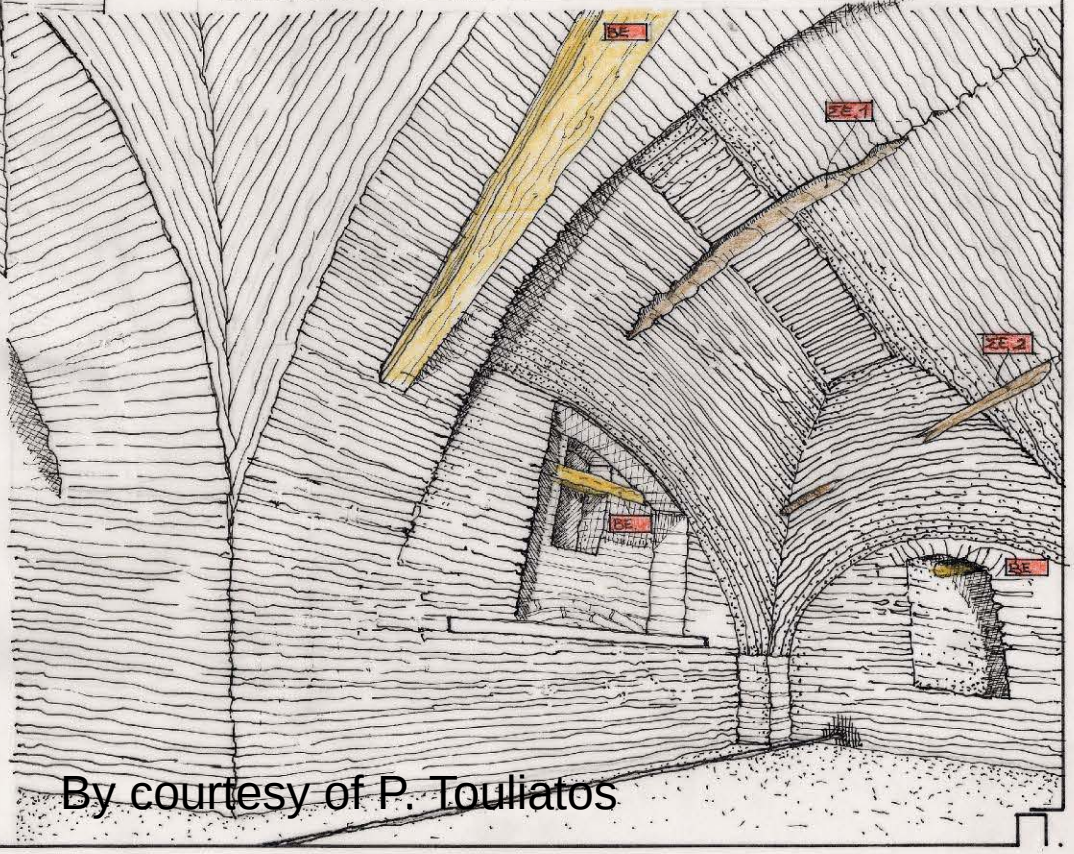
ΣΤΗΝ ΟΡΟΦΗ ΤΗΣ ΘΟΛΟΔΟΜΙΑΣ ΔΙΑΚΡΙΝΟΝΤΑΙ ΤΑ ΙΧΝΗ ΤΩΝ ΣΥΜΠΛΗΡΩΜΑΤΙΚΩΝ ΞΥΛΙΝΩΝ ΕΝΙΣΧΥΣΕΩΝ ΜΕ ΤΟ ΣΥΜΒΟΛΟ [Ξ.Ε]

ΤΟ ΠΡΟΣ ΒΟΡΡΑΝ ΣΥΜΠΛΗΡ. ΞΥΛΙΝΟ ΣΤΟΙΧΕΙΟ ΕΝΙΣΧΥΣΗΣ [ΞΕ.1] ΟΧΙ ΕΝΤΕΛΩΣ ΑΠΟΣΥΝΤΕΘΕΙ ΑΦΗΝΟΝΤΑΣΕ ΕΝΑ ΚΕΝΟ ΣΤΗΝ ΘΟΛΟΔΟΜΙΑ ΠΟΥ ΠΡΟΚΑΛΕΣΕ ΗΔΗ ΑΡΧΕΣ ΑΣΤΟΧΙΩΝ ΚΑΙ ΤΗΝ ΑΝΑΓΚΗ ΜΙΑΣ ΠΡΩΤΗΣ ΥΠΟΣΤΗΡΙΞΗΣ. ΣΧΕΔΟΝ ΣΤΗΝ ΙΔΙΑ ΚΑΤΑΣΤΑΣΗ ΒΡΙΣΚΕΤΑΙ ΚΑΙ Η ΠΡΟΣ ΝΟΤΟ ΣΥΜΠΛΗΡΩΜ. ΞΥΛΙΝΗ ΕΝΙΣΧΥΣΗ [ΞΕ.2]

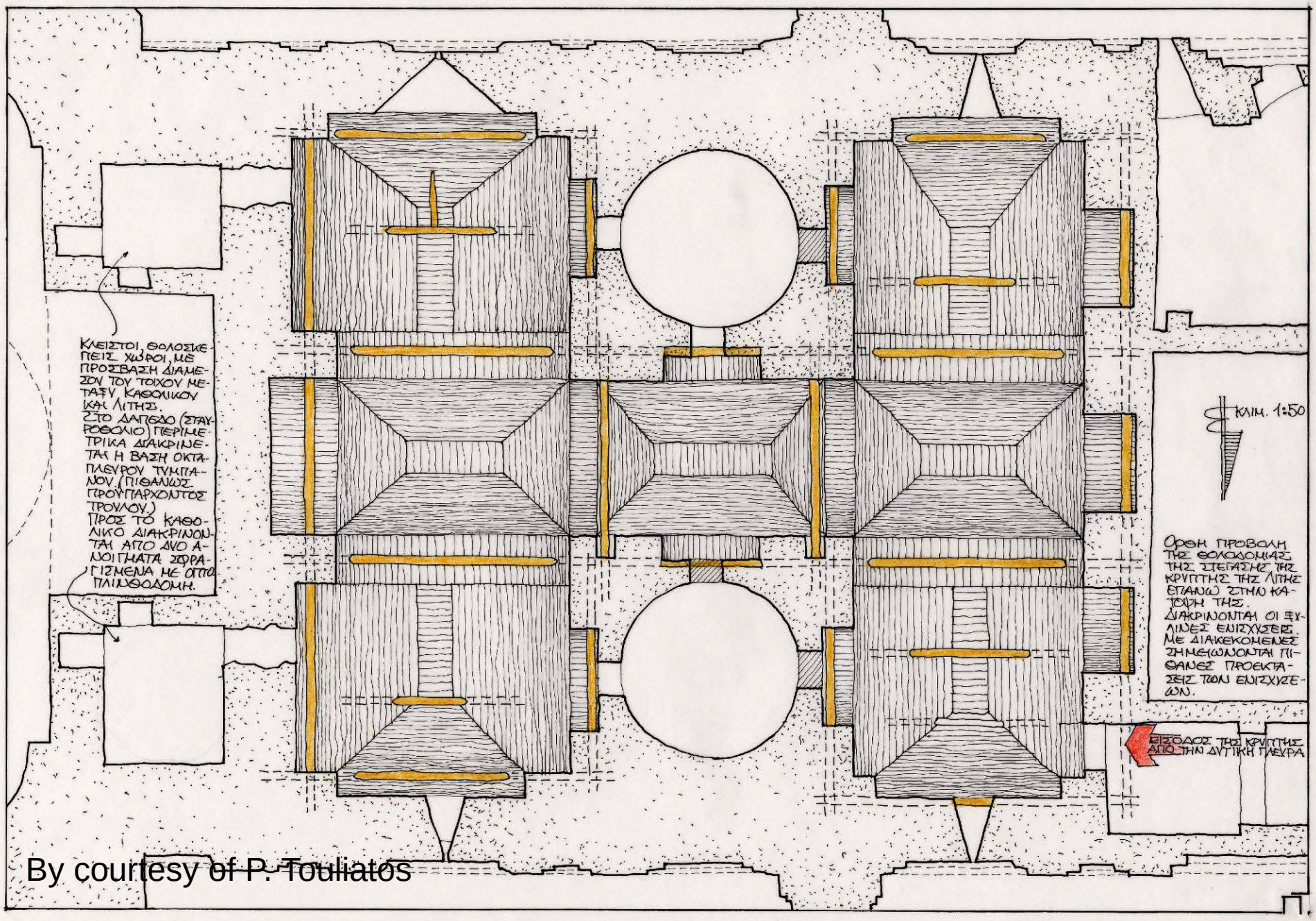
ΣΤΟ ΔΑΠΕΔΟ ΔΙΑΚΡΙΝΟΝΤΑΙ ΟΙ ΔΥΟ ΣΙΔΗΡΟΙ ΕΛΚΥΣΤΗΡΕΣ. ΤΟΠΟΘΕΤΗΜΕΝΟΙ ΜΕΤΑ ΤΟΥΣ ΣΕΙΣΜΟΥΣ ΤΗΣ ΤΡΙΤΗΣ ΔΕΚΑΕΤΙΑΣ ΤΟΥ 20ΟΥ ΑΙΩΝΑ ΠΟΥ ΟΜΩΣ ΒΡΙΣΚΟΝΤΑΙ ΧΑΛΑΡΩΜΕΝΟΙ.



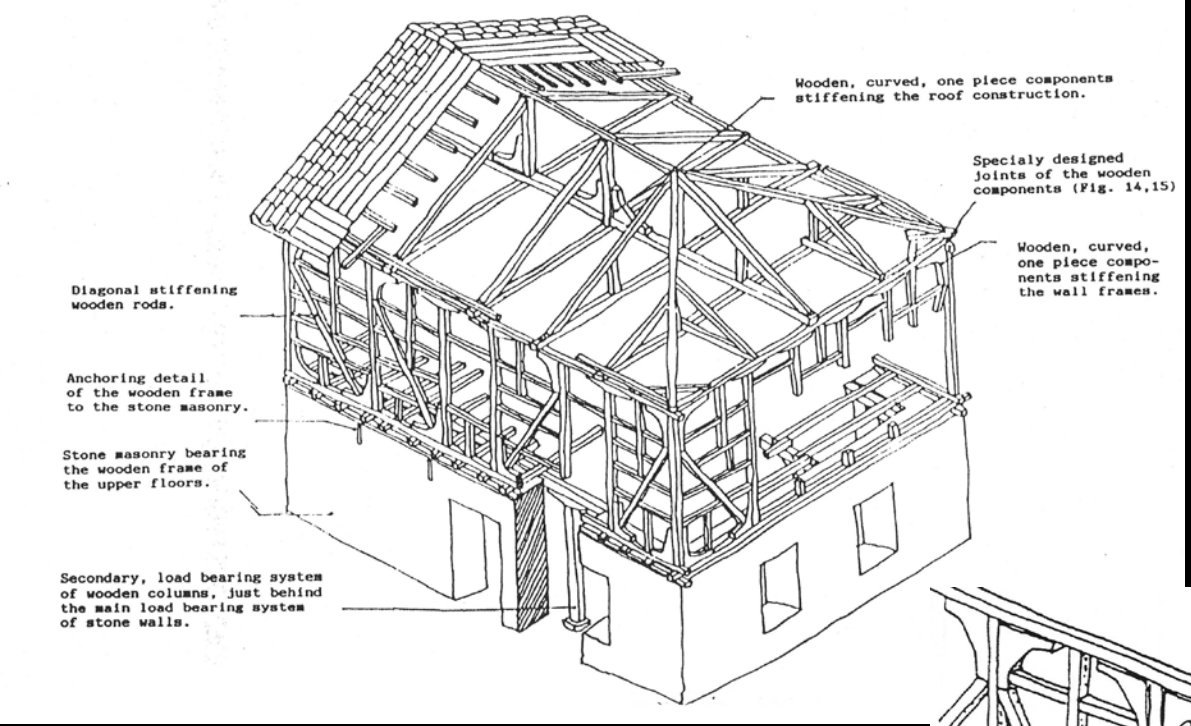


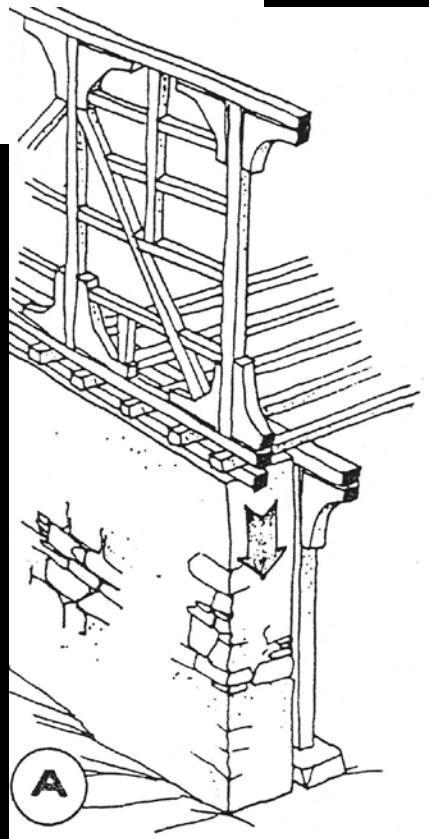


By courtesy of P. Touliatos



By courtesy of P. Touliatos


Wooden, curved, one piece components stiffening the roof construction.
Specialy designed joints of the wooden components (Fig. 14,15)
Wooden, curved, one piece components stiffening the wall frames.
Diagonal stiffening wooden rods.
Anchoring detail of the wooden frame to the stone masonry.
Stone masonry bearing the wooden frame of the upper floors.
Secondary, load bearing system of wooden columns, just behind the main load bearing system of stone walls.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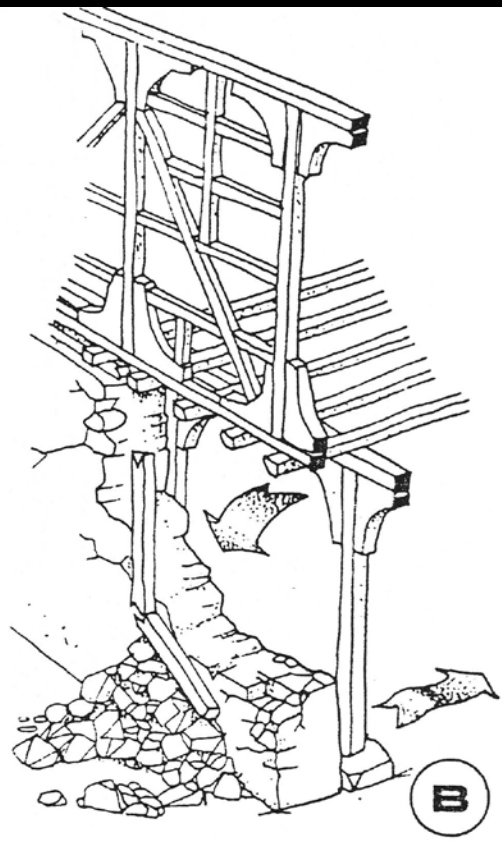
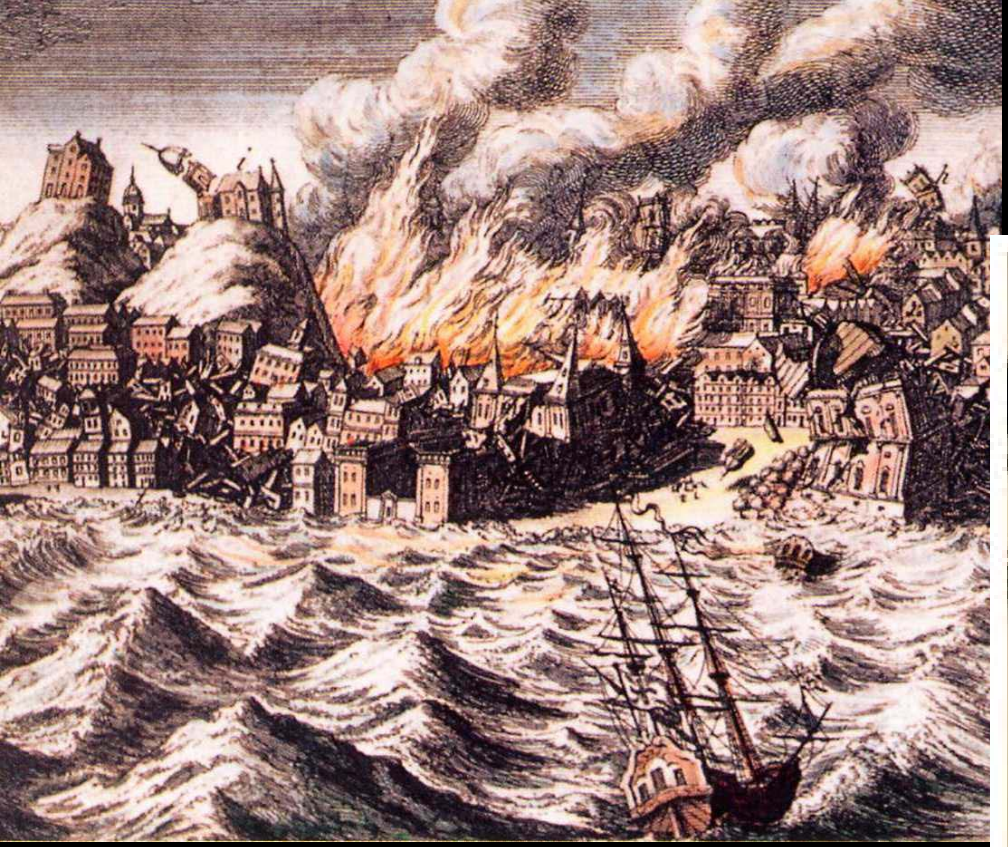
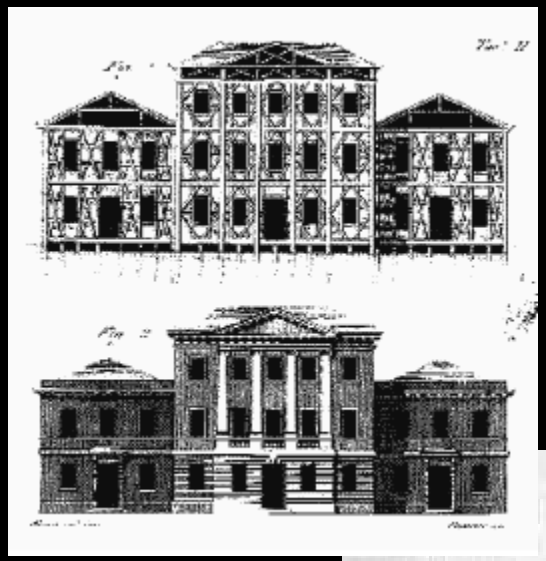
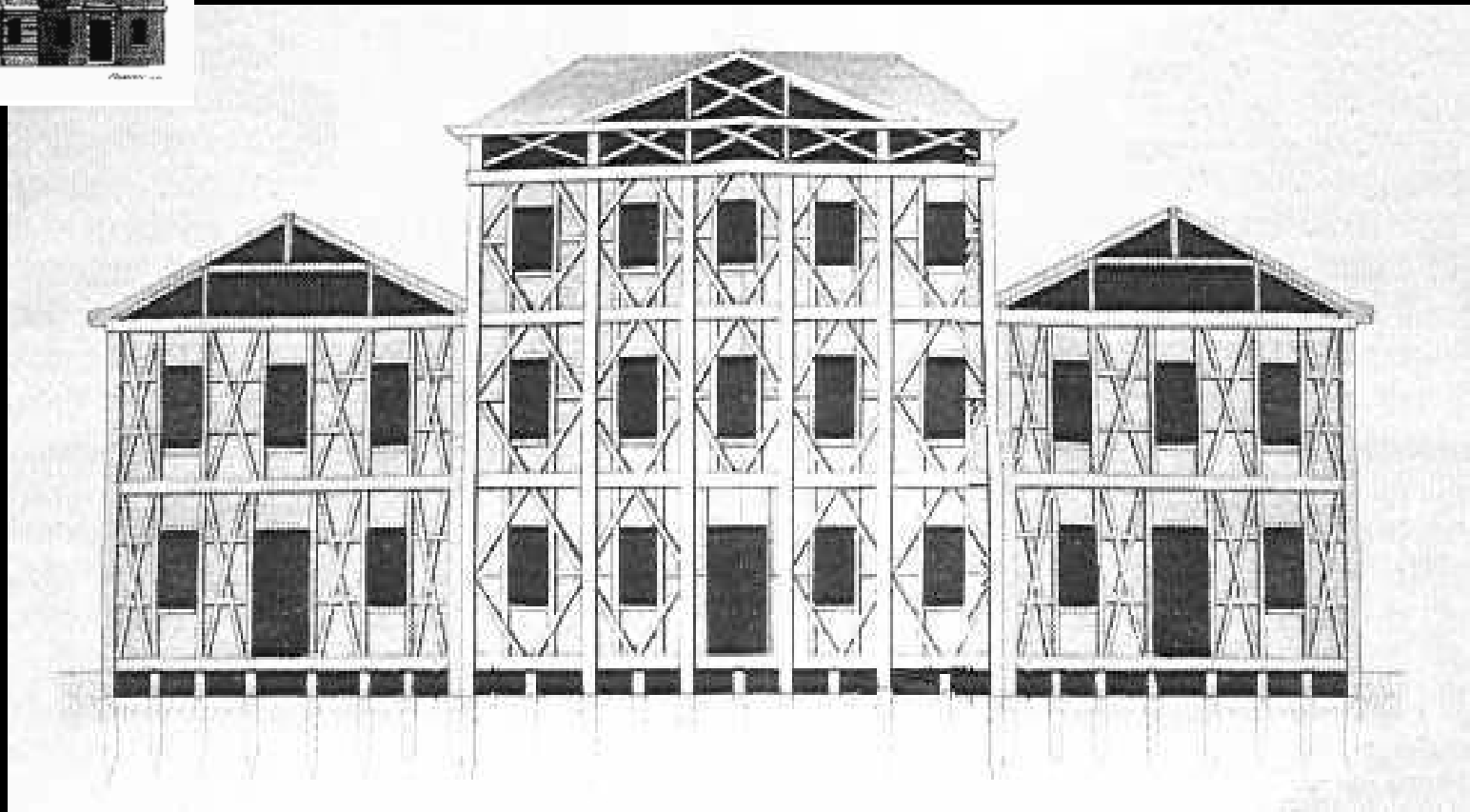

B







By courtesy of R. Langenbach

By courtesy of R. Langenbach

by M.Yasumura

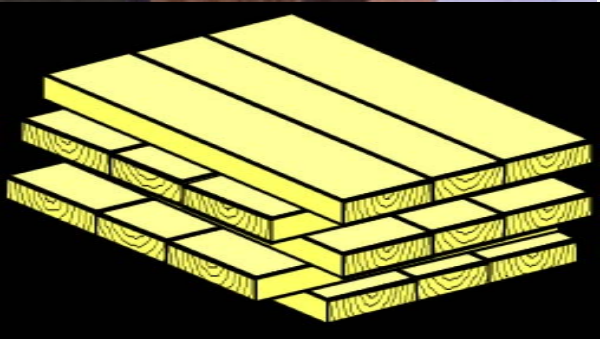
Looking at the future…

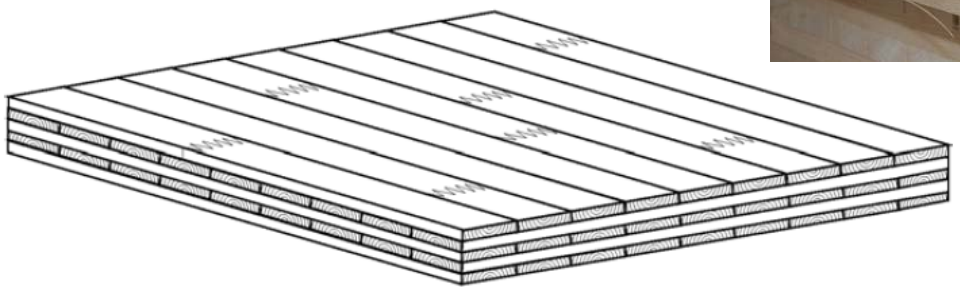
New: XLAM SYSTEM

The XLAM system (in which XLAM stands for cross-laminated solid timber boards) was developed in Germany around 12 years ago and it's rapidly spreading in most European countries such as Austria, Switzerland, Italy and Nordic Countries

XLAM SYSTEM

The XLAM is a European innovative wood based material in which timber boards, made of home-grown wood species (mainly Spruce) are assembled in layers and glued together crosswise in order to form massive wood wall and floor panels





XLAM SYSTEM : Advantages

- The cross lamination method gives a material with high stability and good overall mechanical properties, good thermal insulation, and a fairly good behaviour in case of earthquake or fire

- The XLAM system allows both for single unit housing and multi-storey buildings. The construction process is very quick and possible even for non-highly-skilled manpower

XLAM SYSTEM : Advantages

- XLAM panels are extremely strong and stiff whatever is the timber quality, therefore they allow the use of medium-low grades of home-grown sawn wood

London

architects Waugh Thistleton

Trentino

Trentino land 0.62 M ha

Trentino FOWL 0.34 M ha

Share of FOWL 55 %

Capacity of sustainable exploitation 500 000 m^3


PEFC

The SOFIE Project

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The scope of the project is to define the performance and the potential of a construction system for multi-storey buildings whose load-bearing elements are wooden panels made of cross-laminated boards (XLam) through testing, analysis and study of every single aspect

(seismic, fire, building physics, durability).

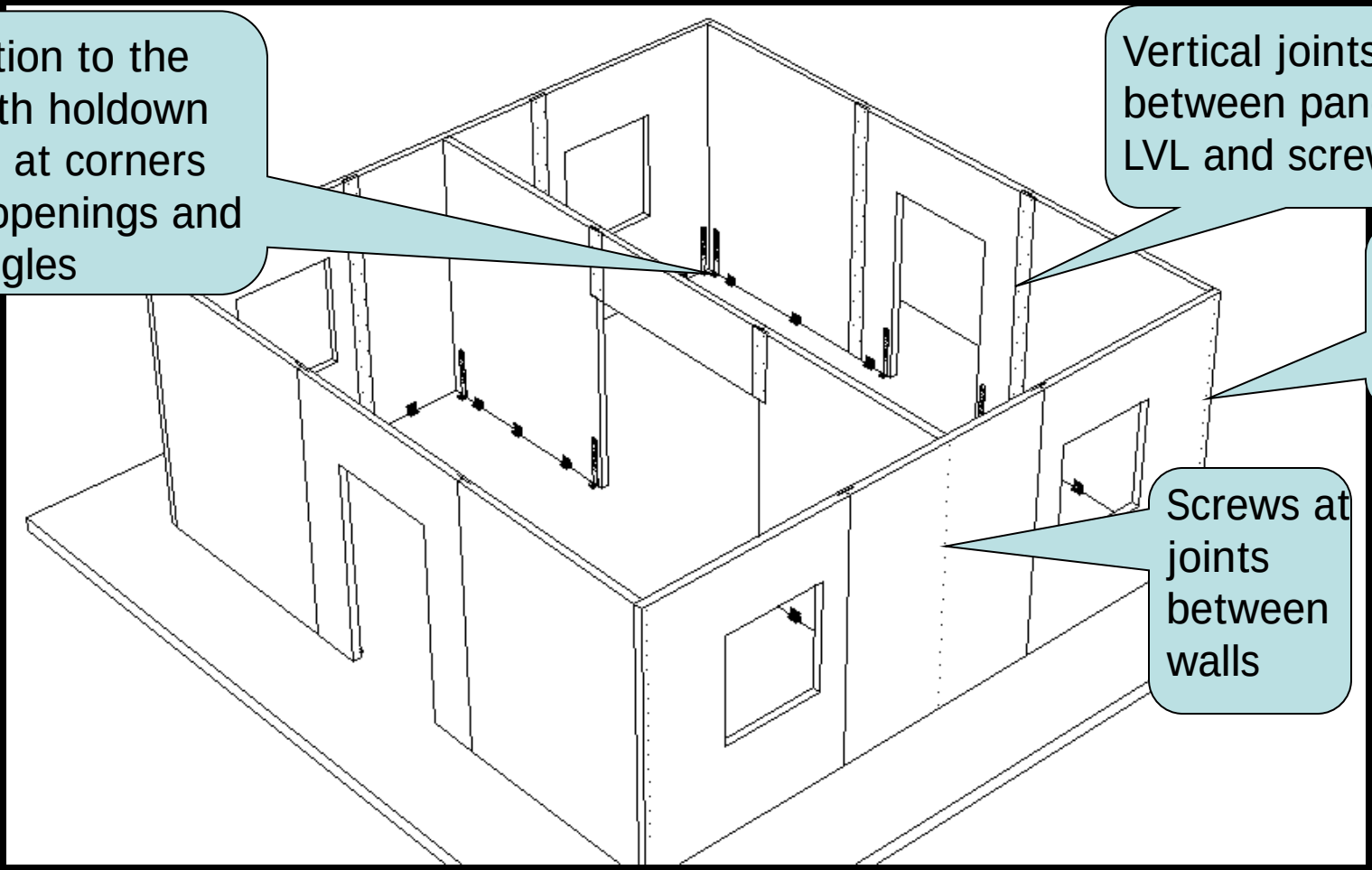
The project is funded by the Autonomous Province of Trento (Italy)

PROVINCIA AUTONOMA DI TRENTO

www.progettosofie.it

IVALSA
TREES AND TIMBER INSTITUTE

XLAM SYSTEM : Construction and details



XLAM SYSTEM : Construction and details

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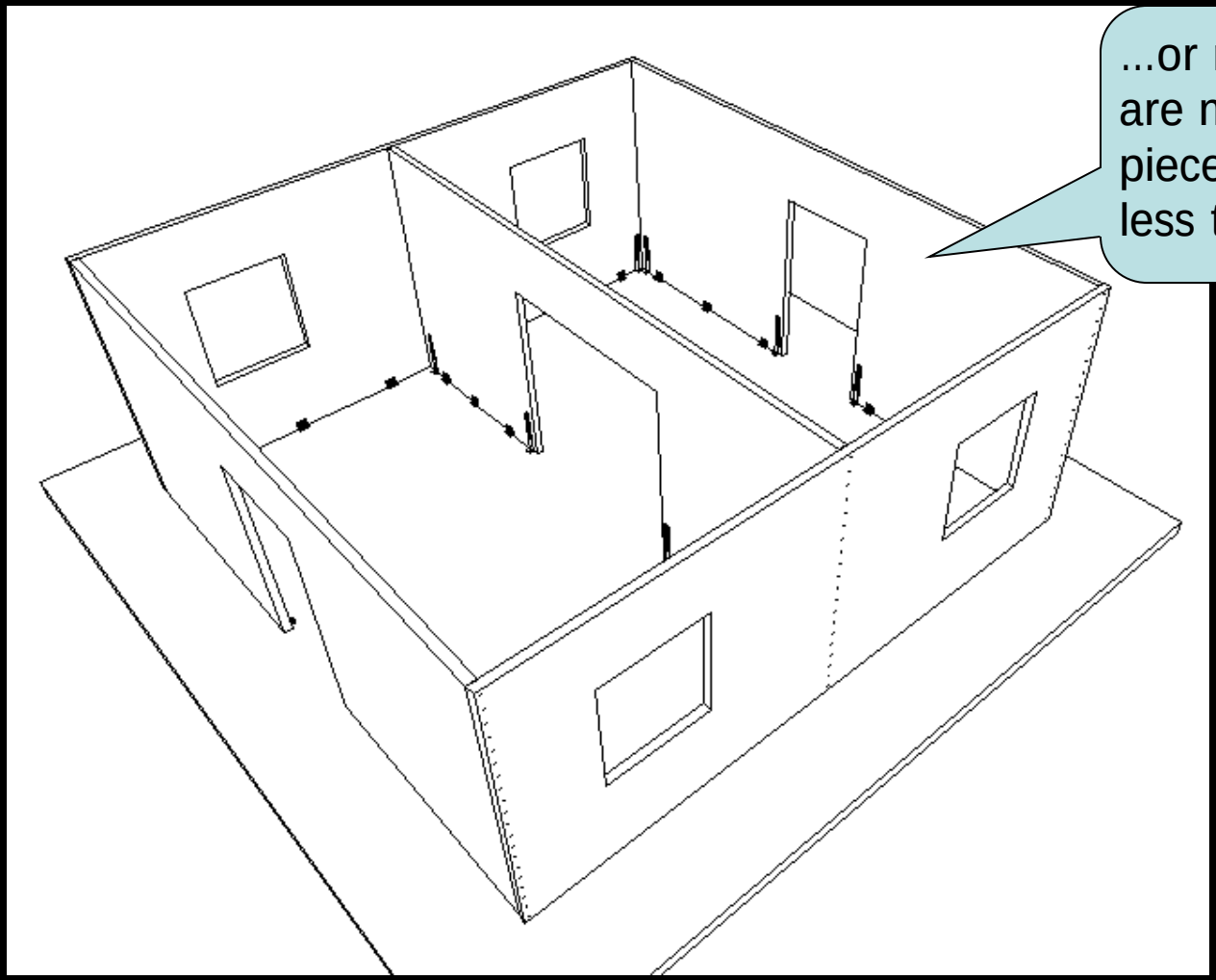
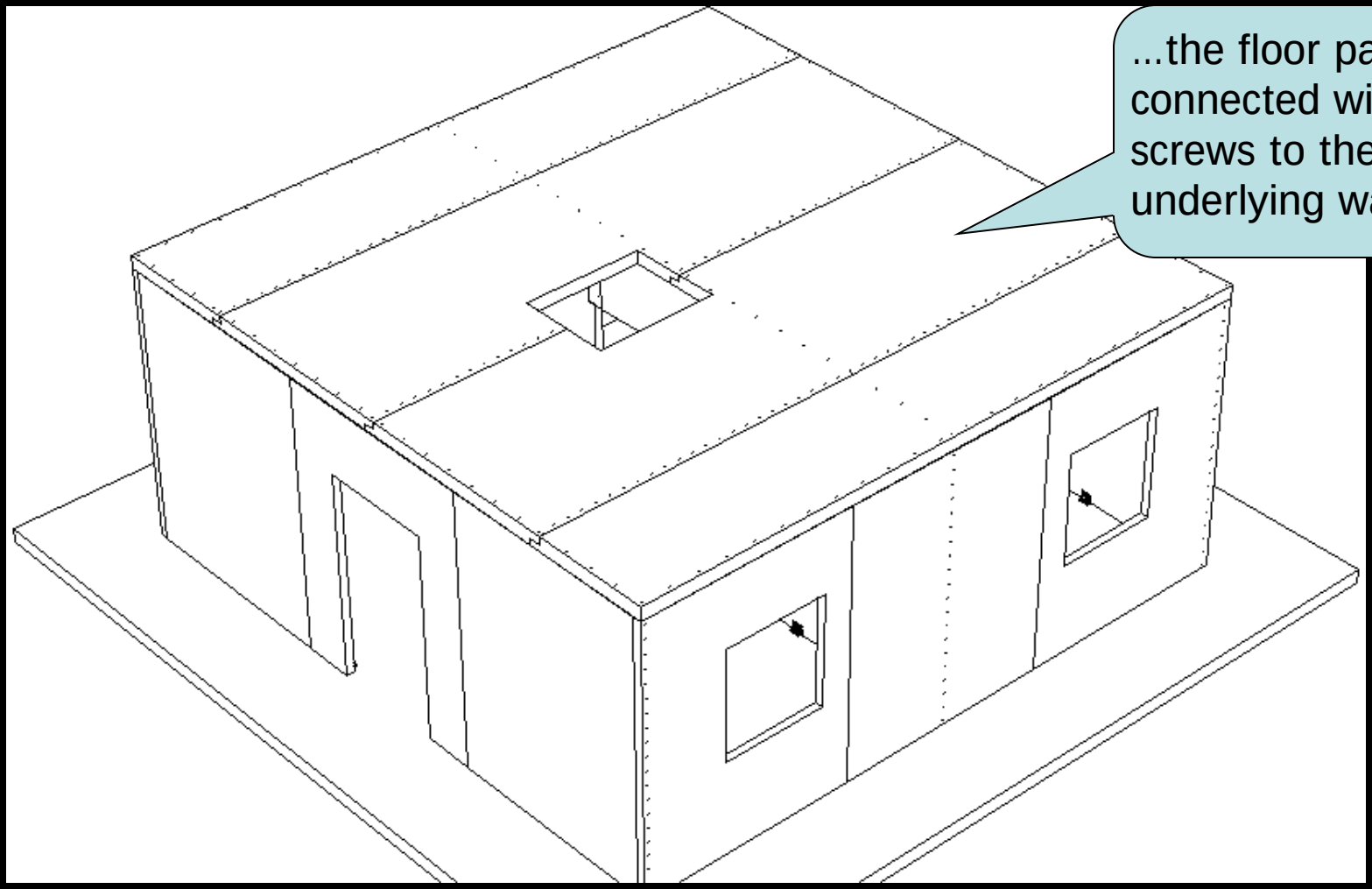
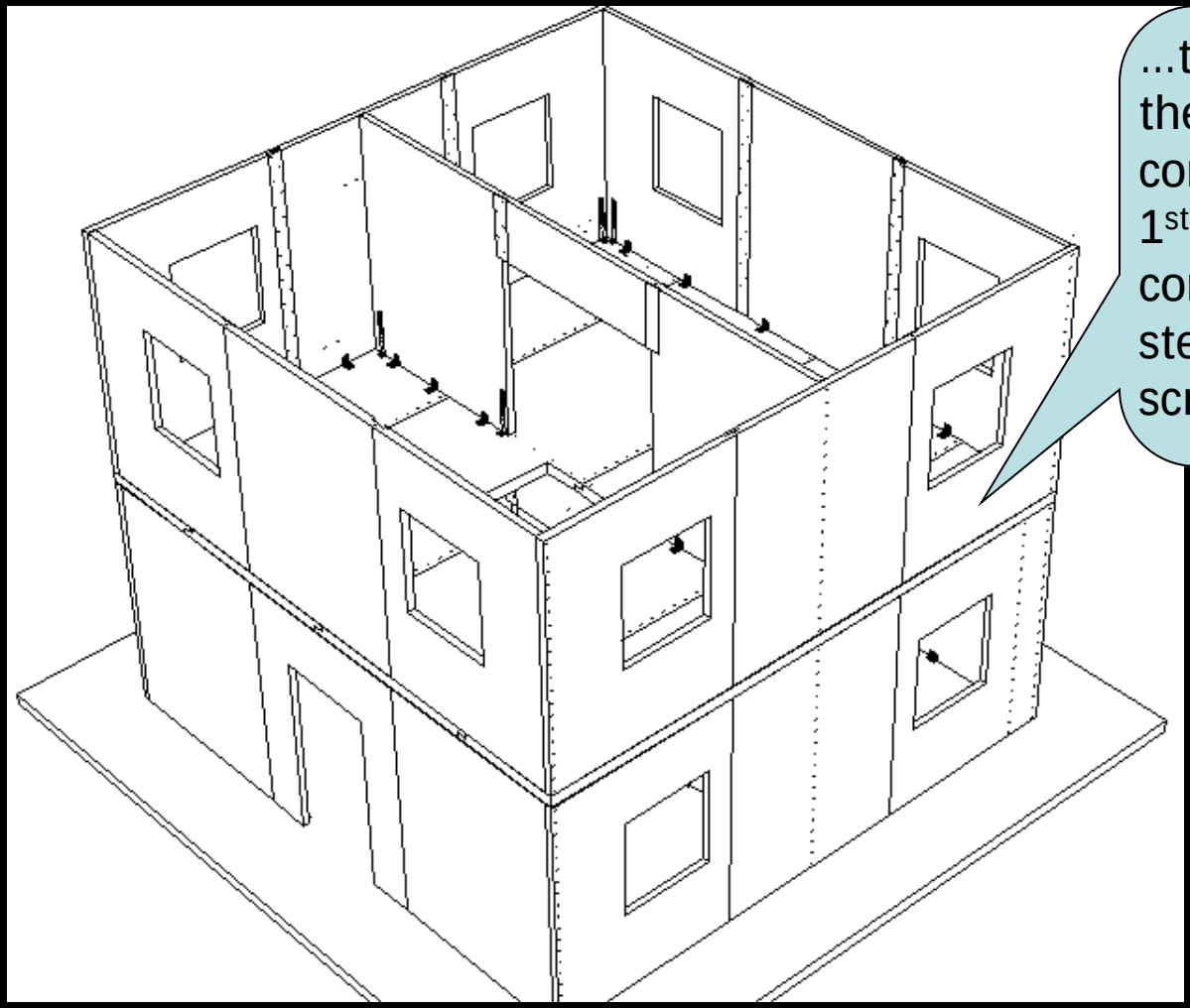


...or more often walls are made of one piece if total length is less than 7-10 m

XLAM SYSTEM : Construction and details

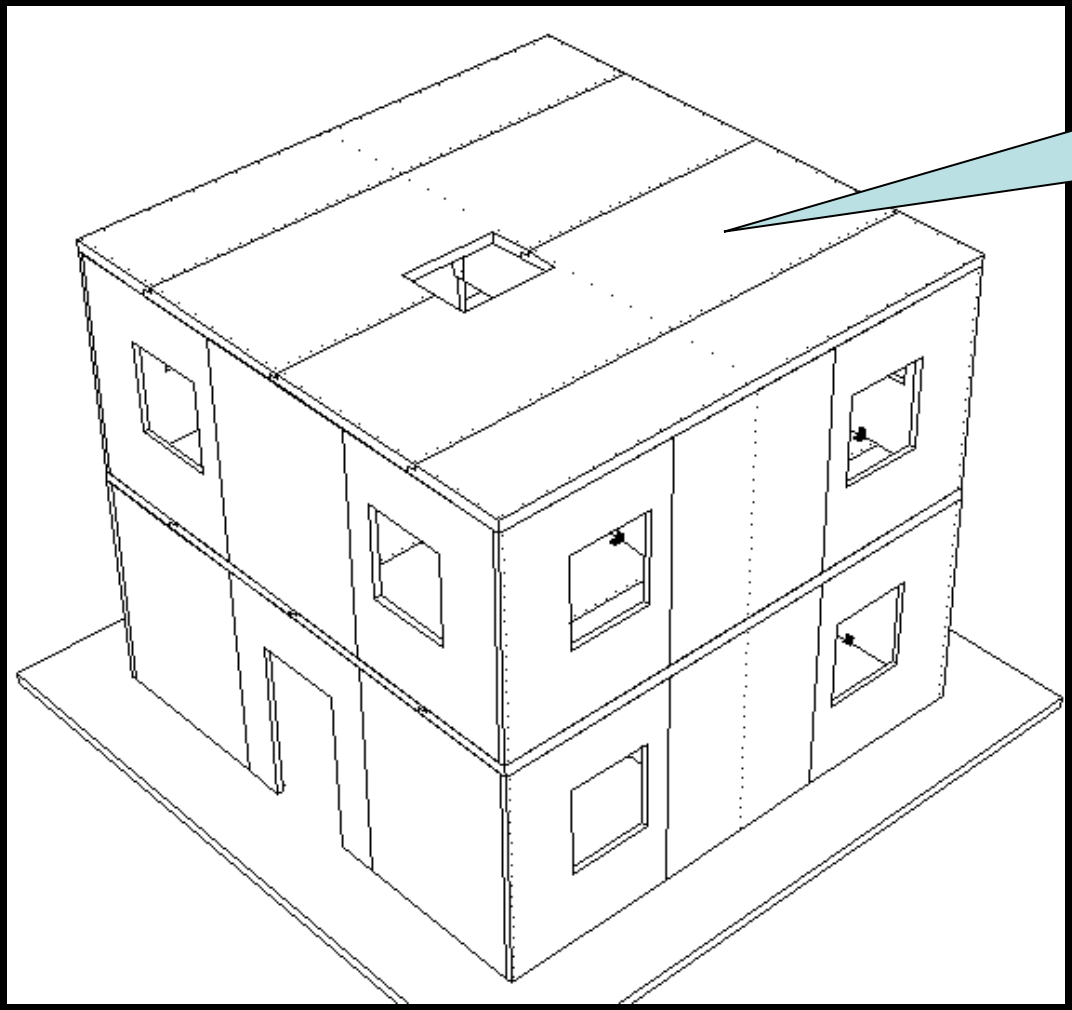


XLAM SYSTEM : Construction and details



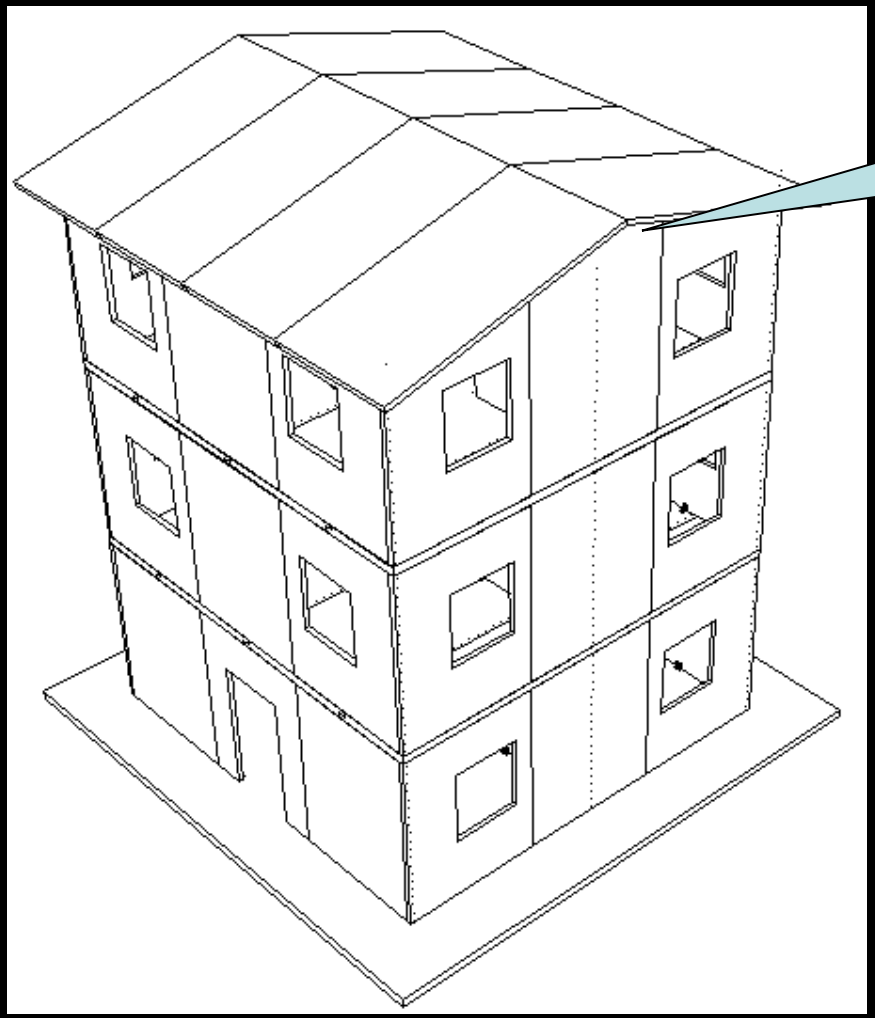
...the wall panels of the second floor are constructed over the 1st floor and connected again with steel connectors and screws

XLAM SYSTEM : Construction and details



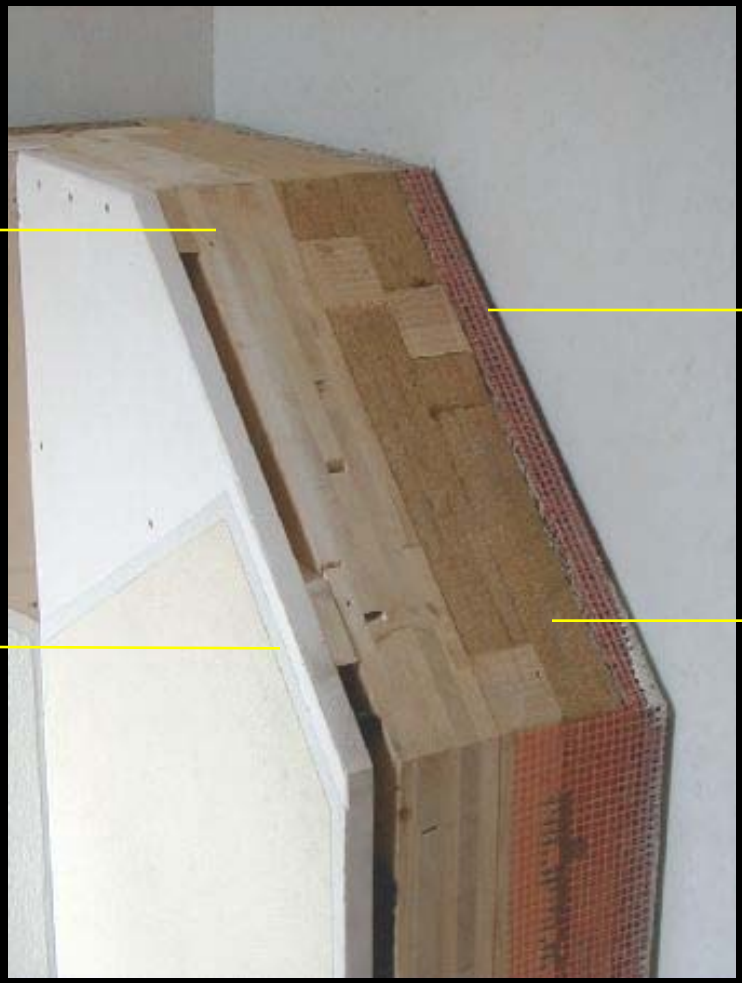
...the 2nd floor is connected in the same way

XLAM SYSTEM : Construction and details



...the contruction is then completed very quickly

XLAM SYSTEM : Construction and details



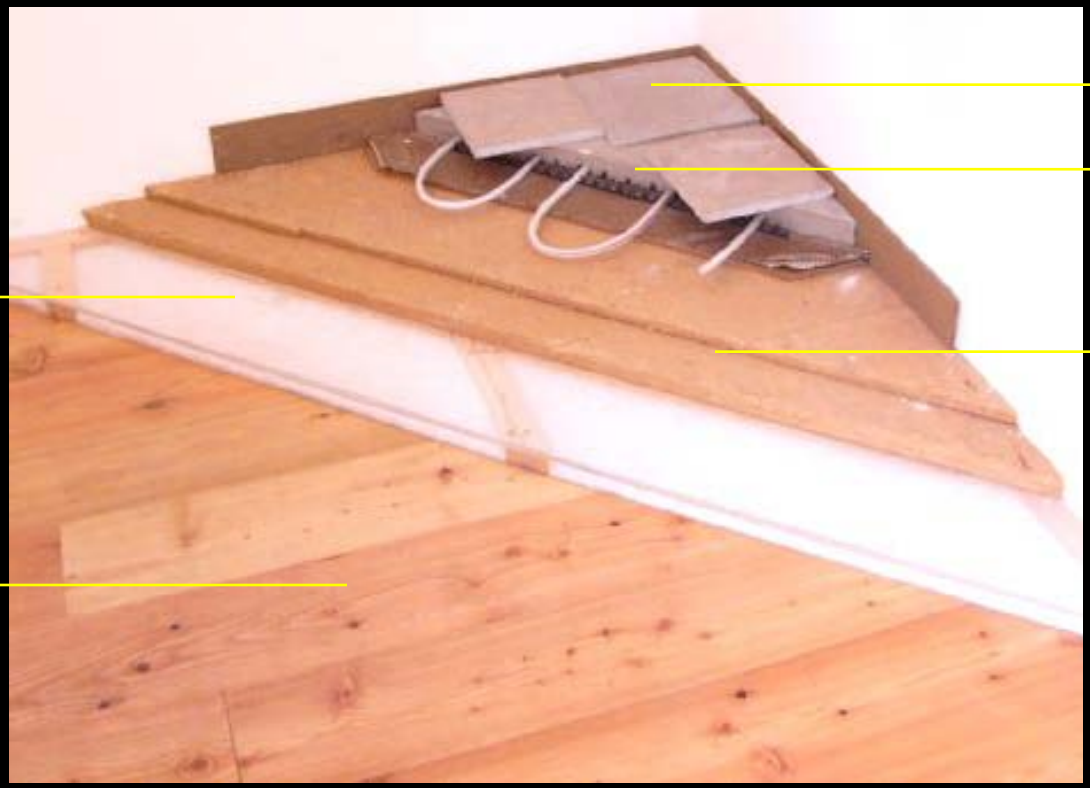
Cross Laminated wall panel

Plaster Board

Double Gypsum wall board

Wood fibre

XLAM SYSTEM : Construction and details



Flooring

Light concrete topping

Layer of sand

Double Wood fibre layer

Cross Laminated floor panel

XLAM SYSTEM : Construction and details

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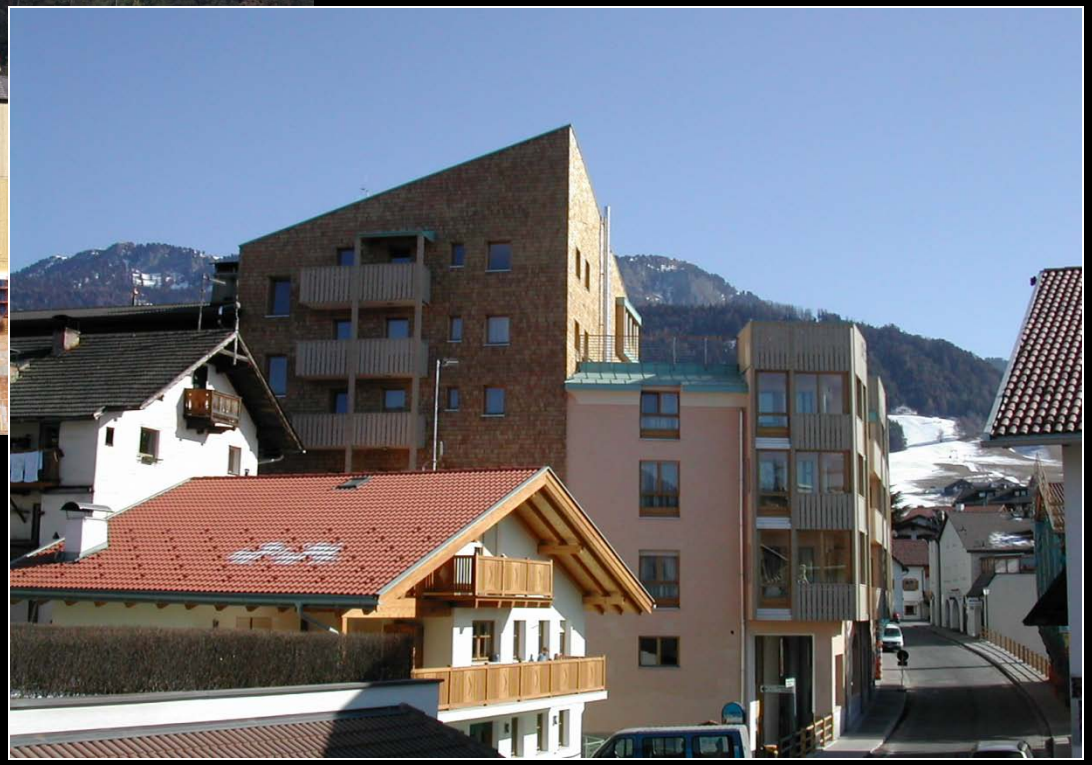
XLAM SYSTEM : Construction and details

7 STOREY BUILDING

First 7 storey wooden building ever built in italy



Hotel LAMM

Castelrotto (BZ)

North-East of Italy

(Trentino-Alto Adige)

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In plane Cyclic Tests on walls and connections

Pseudo-dynamic tests on one storey specimen

Univ. of Trento

Shaking Table Test on a full-scale 7mx7mx10m of height 3 storeys XLam building

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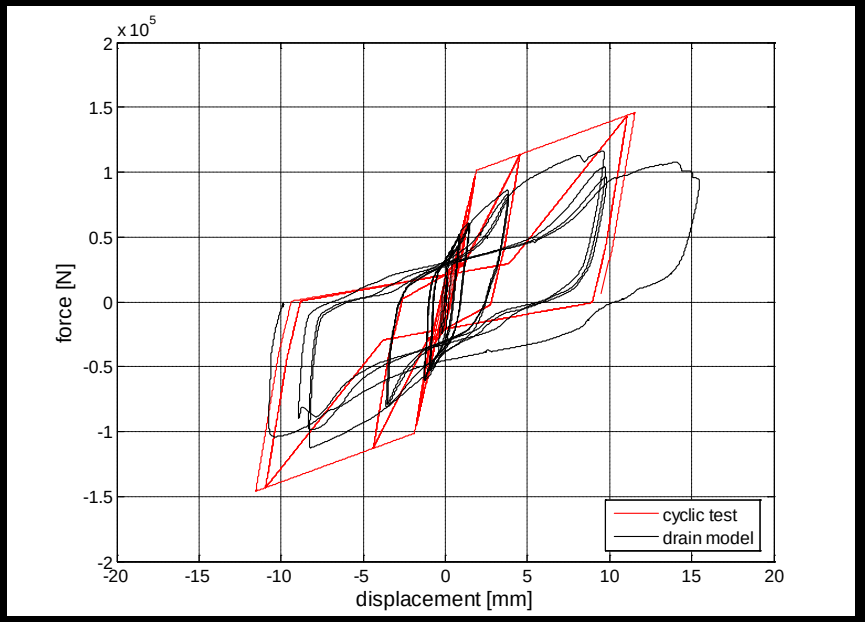

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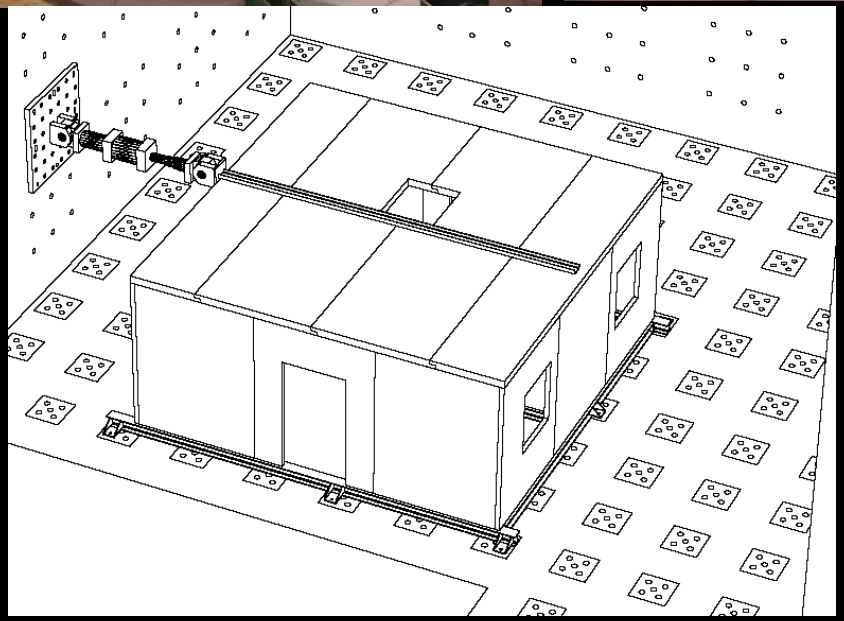

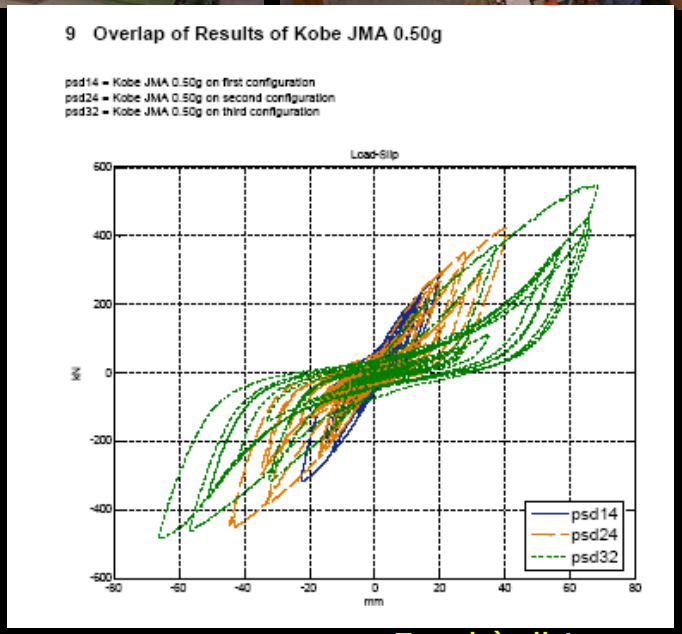

Seismic Test on Shaking Table Facility in Tsukuba, Japan in July 2006

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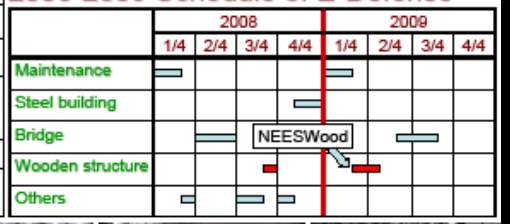
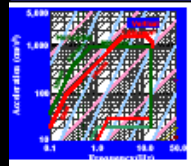
The Largest Shake Table in the World "E-Defense"

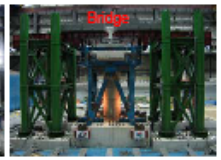
National Research Institute for Earth Science and Disaster Prevention

Table Size	20m x 15m	
Payload	12MN(1200ton)	
Shaking Direction	X, Y - Horizontal	Z - Vertical
Max. Acceleration (at Max. Loading)	900cm/s²	1500cm/s²
Max. Velocity	200cm/s	70cm/s
Max. Displacement	±100cm	±70cm

2008-2009 Schedule of E-Defense

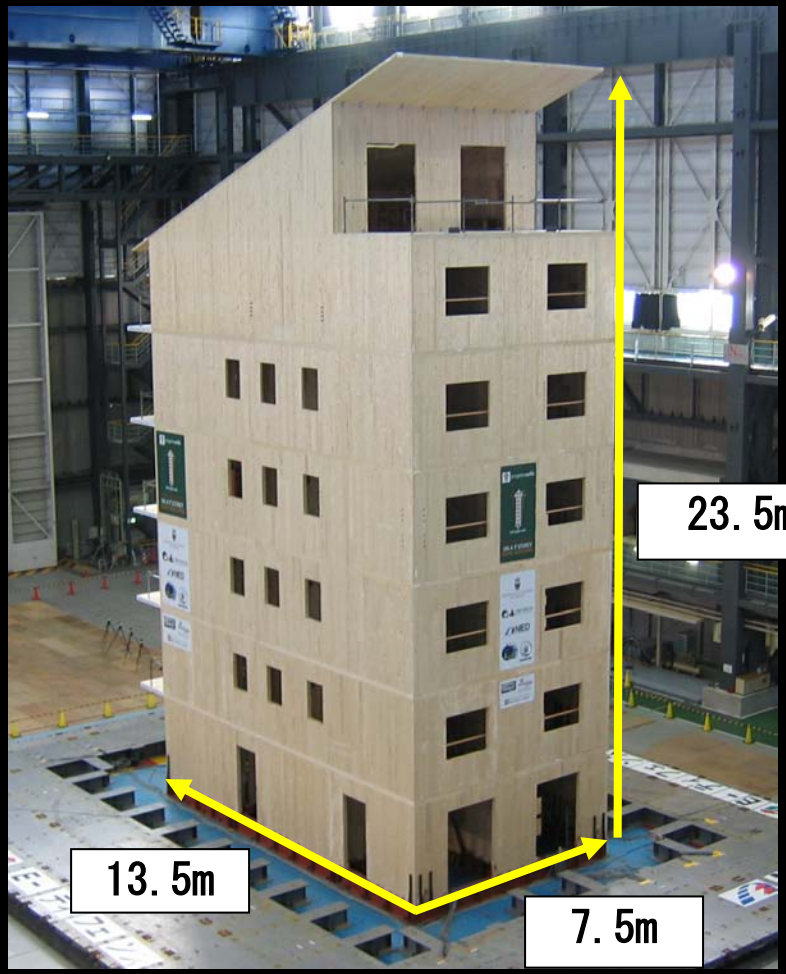


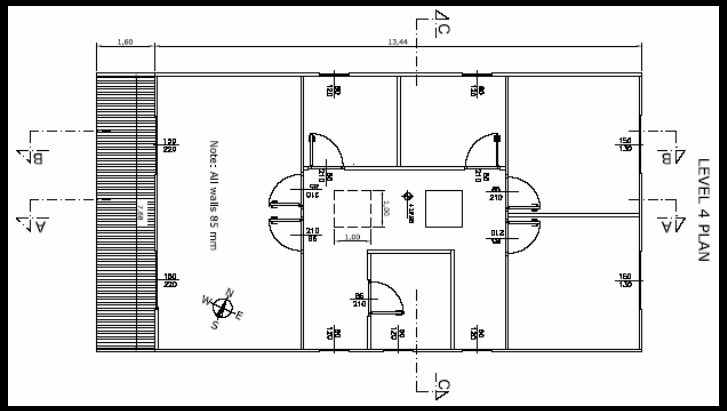




Full-Scale Tests of Wooden Houses on E-Defense

BUILDING SELF WEIGHT 120 t
ADDITIONAL LOAD ON FLOORS 150 t





Input :

JMA Kobe 3D x,y,z 0.60, 0.82, 0.34 g

Building Working

(at E-defense in MIKI)

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2007/10/19,23
Test

2007/10/13

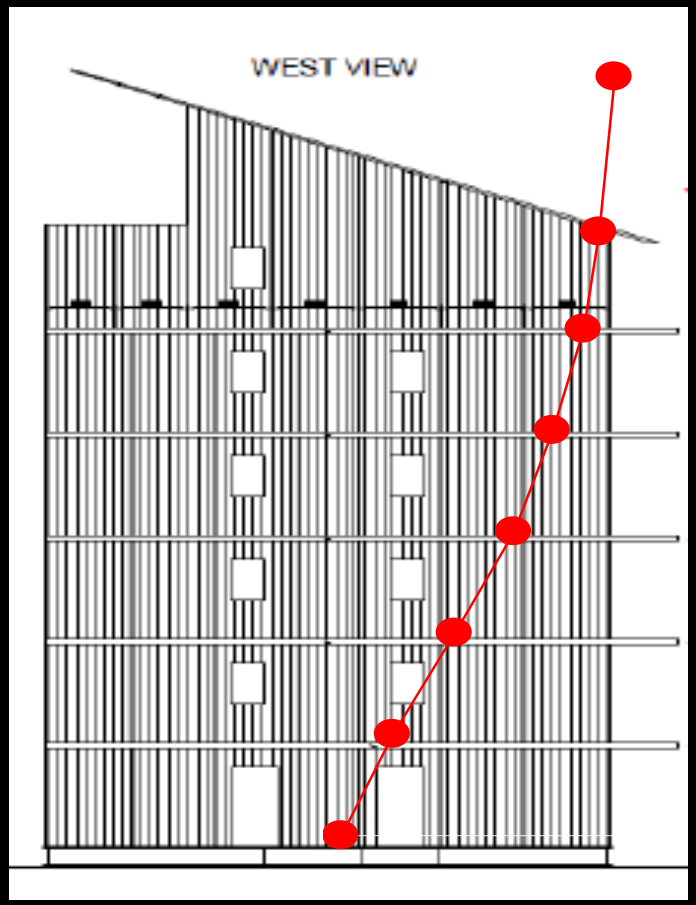
2007/10/15

1995 JMA Kobe 3D

Seismic Test on Shaking Table Facility in Miki, Japan in October 2007

175.0mm (1/134rad)

287.0mm (1/82rad)



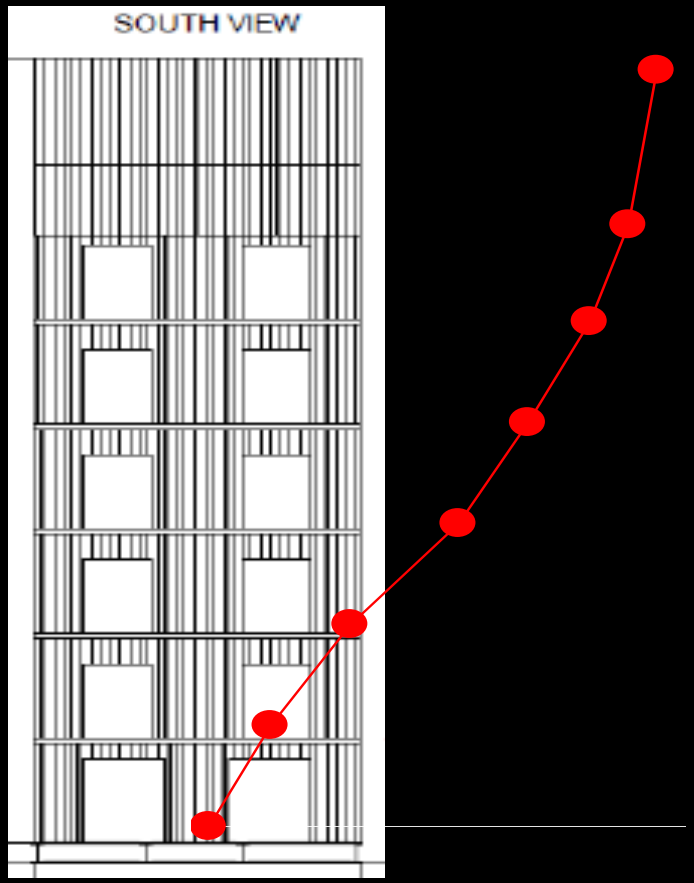


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Table 1. Test sequence of seven-storey building

test number	input	direction	dimension	intensity	PGA	
					in x	in y
1	step	X, Y	2D		0.3g	0.3g
2	Nocera Umbra E-W	Y	1D	70%	-	0.35g
3	Nocera Umbra E-W	Y	1D	100%	-	0.5g
4	JMA Kobe N-S	Y	1D	60%	-	0.5g
5	JMA Kobe E-W	X	1D	50%	0.3g	-
6	step	X, Y	2D	-	0.3g	0.3g
7	JMA Kobe N-S	Y	1D	100%	-	0.82g
8	step	X, Y	2D	-	0.3g	0.3g
9	JMA Kobe E-W	X	1D	100%	0.6g	
10	step	X, Y	2D	-	0.3g	0.3g
11	step	X, Y	2D	-	0.3g	0.3g
12	JMA Kobe interrupted	X, Y, Z	3D	100%	0.6g	0.82g
13	step	X, Y	2D	-	0.3g	0.3g
14	step	X, Y	2D		0.3g	0.3g
15	Kashiwazaki R1	X, Y, Z	3D	50%	0.155g	0.34g
16	step	X, Y	2D		0.3g	0.3g
17	step	X, Y	2D		0.3g	0.3g
18	JMA Kobe	X, Y, Z	3D	100%	0.6g	0.82g
19	step	X, Y	2D		0.3g	0.3g
20	step	X, Y	2D		0.3g	0.3g
21	Kashiwazaki R1	X, Y, Z	3D	100%	0.311g	0.68g
22	step	X, Y	2D		0.3g	0.3g

Before the shaking

After 10 quakes PGA≥0,3g in a row!

Conclusions

XLAM technology can provide

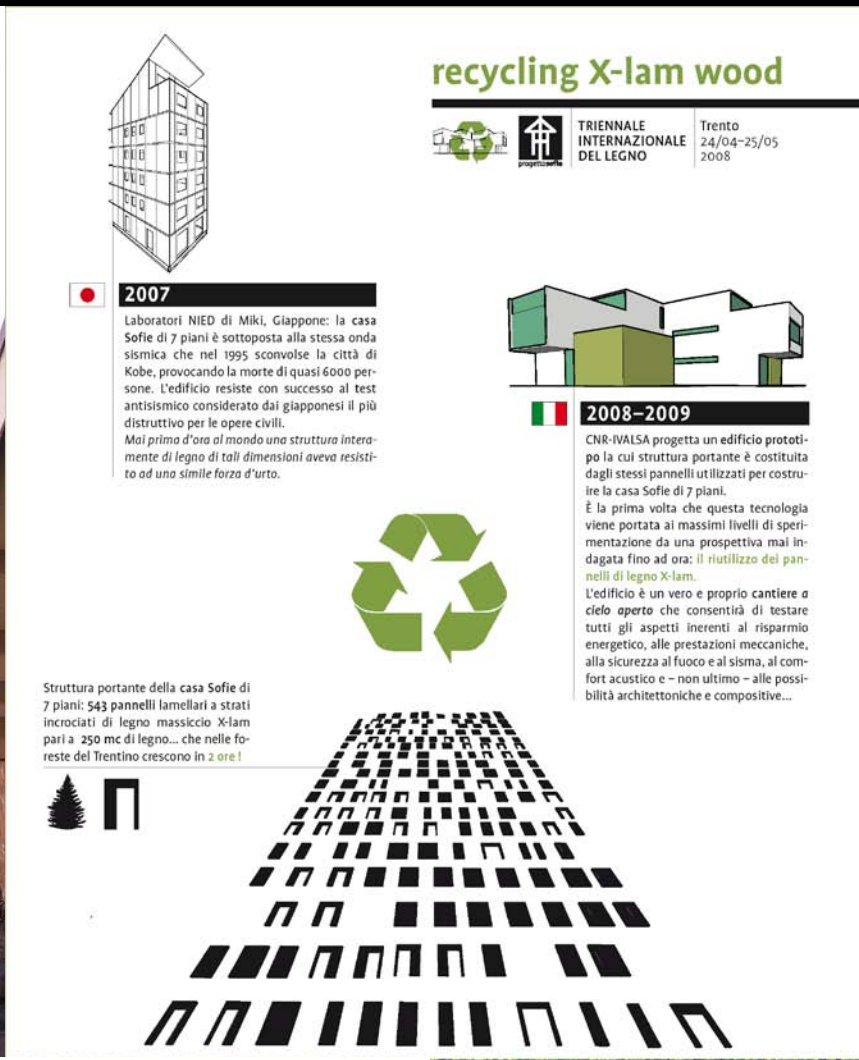
self-centering rocking resilient structures opening for new possibilities

for building design in seismic regions:

No loss of lives
No loss of property

at almost no extra cost

Recyclable...



recycling X-lam wood

TRIENNALE INTERNAZIONALE DEL LEGNO
Trento
24/04–25/05
2008

2007

Laboratori NIED di Miki, Giappone: la **casa Sofie** di 7 piani è sottoposta alla stessa onda sismica che nel 1995 sconvolse la città di Kobe, provocando la morte di quasi 6000 persone. L'edificio resiste con successo al test antisismico considerato dai giapponesi il più distruttivo per le opere civili.
Mai prima d'ora al mondo una struttura interamente di legno di tali dimensioni aveva resistito ad una simile forza d'urto.

2008–2009

CNR-IVALSA progetta un **edificio prototipo** la cui struttura portante è costituita dagli stessi pannelli utilizzati per costruire la casa Sofie di 7 piani.
È la prima volta che questa tecnologia viene portata ai massimi livelli di sperimentazione da una prospettiva mai indagata fino ad ora: il riutilizzo dei pannelli di legno X-lam.
L'edificio è un vero e proprio **cantiere** *a cielo aperto* che consentirà di testare tutti gli aspetti inerenti al risparmio energetico, alle prestazioni meccaniche, alla sicurezza al fuoco e al sisma, al comfort acustico e – non ultimo – alle possibilità architettoniche e compositive...

Struttura portante della **casa Sofie** di 7 piani: **543 pannelli** lamellari a strati incrociati di legno massiccio X-lam pari a **250 mc** di legno... che nelle foreste del Trentino crescono in 2 ore!

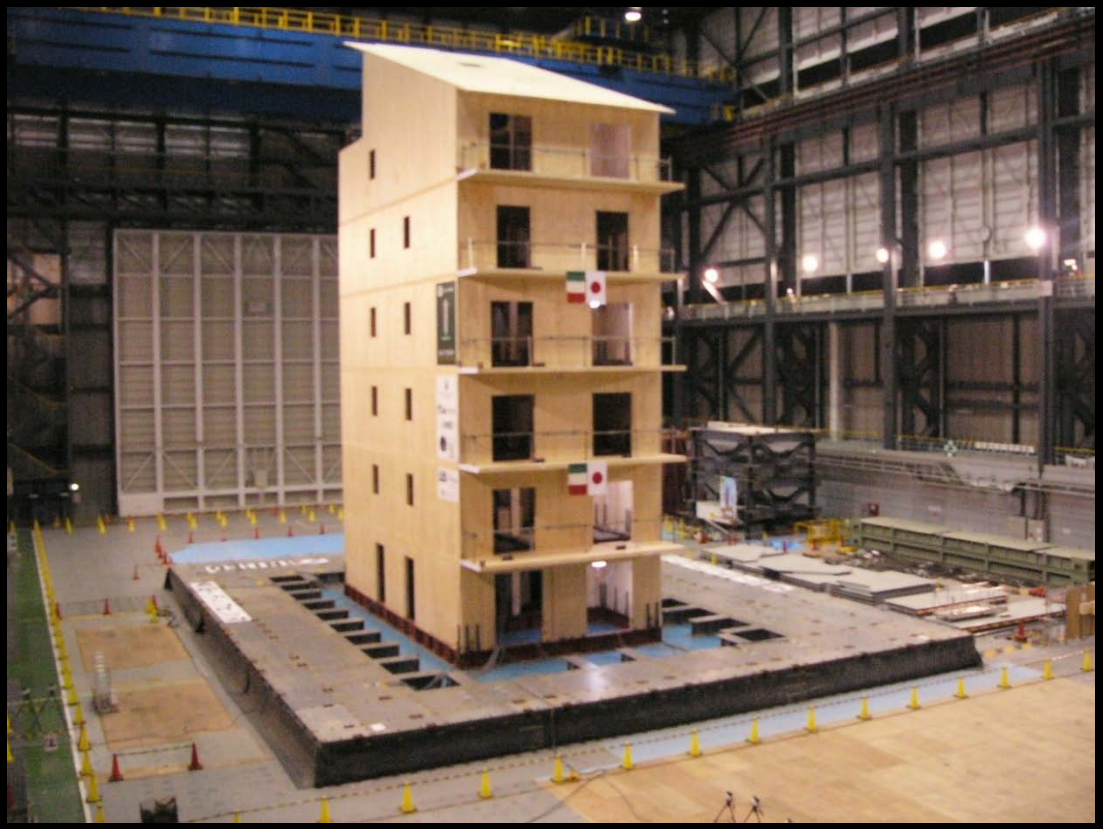
progettosofie

Next: SMS building in Milano

Dante O. Benini & Partners Architects

"using wood to save forests!"

250 CUBIC METERS OF WOOD NEEDED



GROWING TIME IN TRENTINO FOREST:

2 HOURS


THE BEGINNING…