

Cross-lam construction as a resilient building technique in highly seismic zones

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National Research Council
Italy

Timber is a renewable resource



"using wood to save forests!"

1/3 of the entire earth surface is covered by forests and other wooded lands



PEFC (Programme for
Endorsement of Forest
Certification schemes)



FSC (Forest Stewardship
Council)

The general awareness of
the need to reduce environmental impact
supports
the use of timber for buildings

Earthquakes!

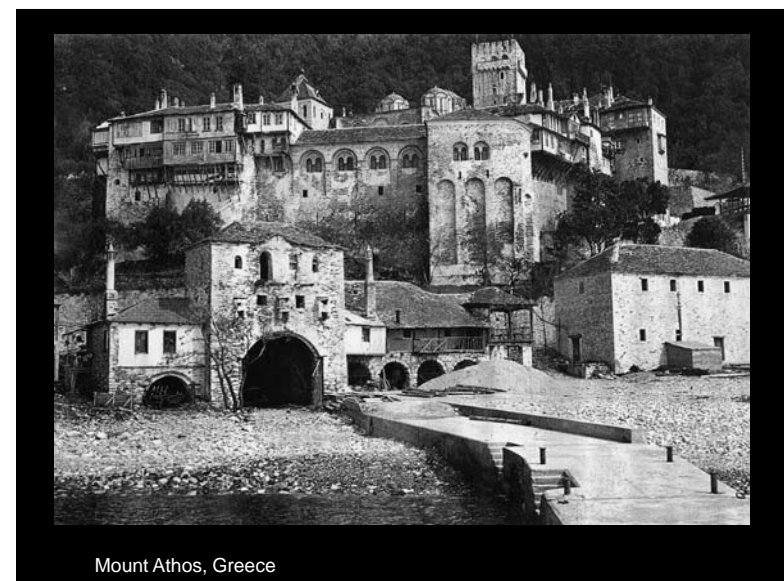
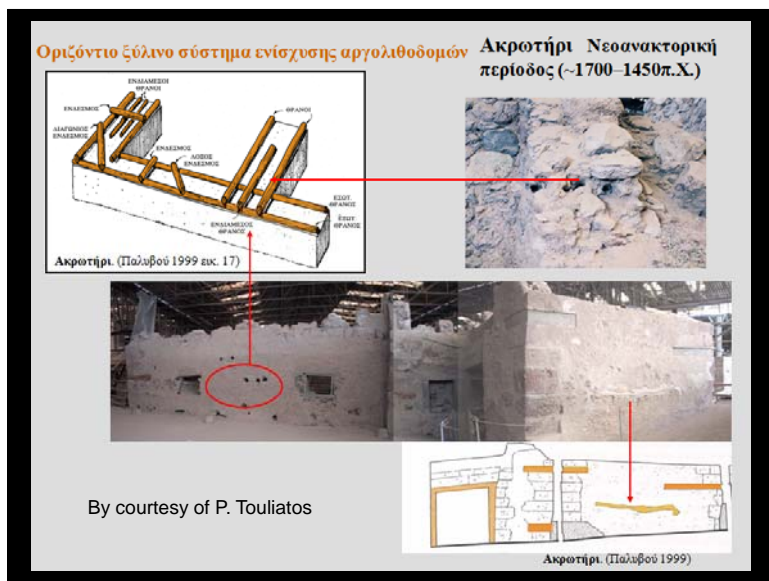
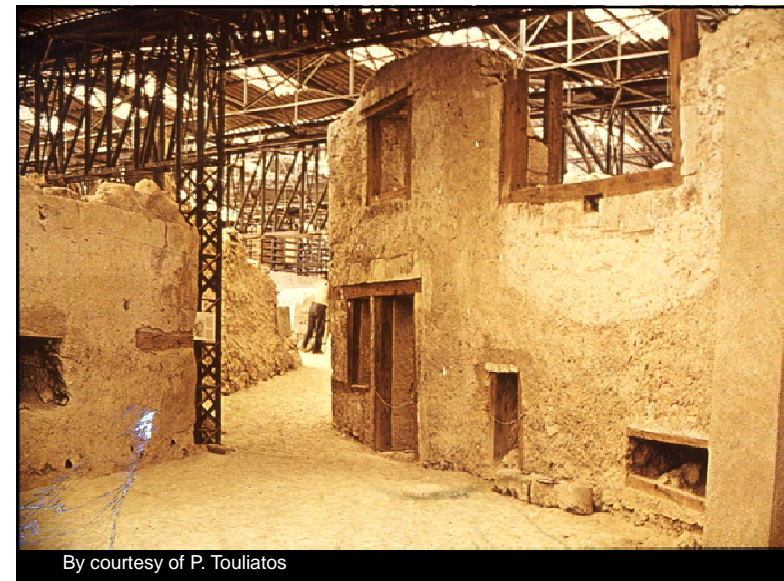
and the timber construction....

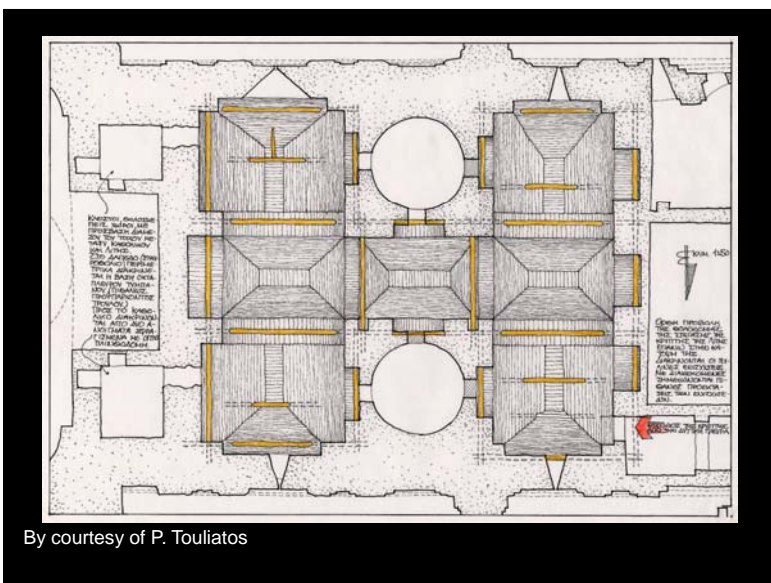
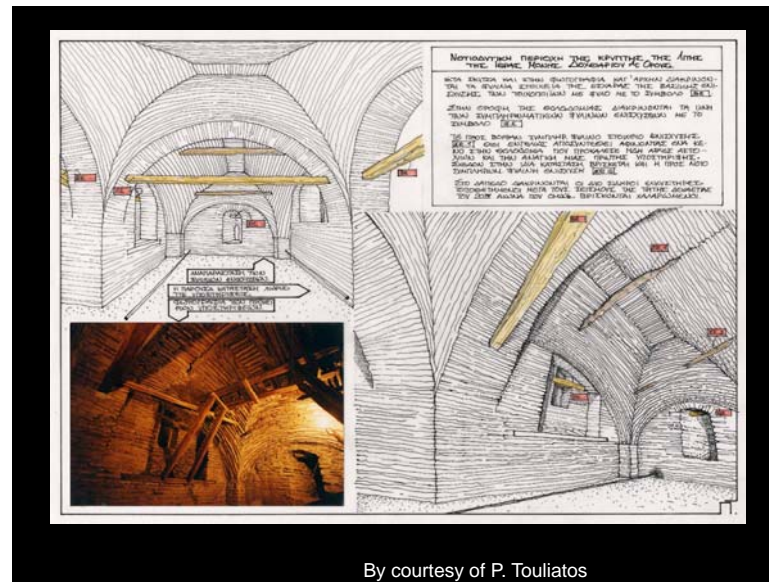


San Francisco Museum

...the experience from the past...









Lisboa, Portugal



France, maisons à colombage





Turkey
By courtesy of R. Langenbach



By courtesy of R. Langenbach



Japan



China



Vancouver, Canada



Anchorage, Alaska, 1964



Kobe, Japan, 1995



By courtesy of M.Yasumura

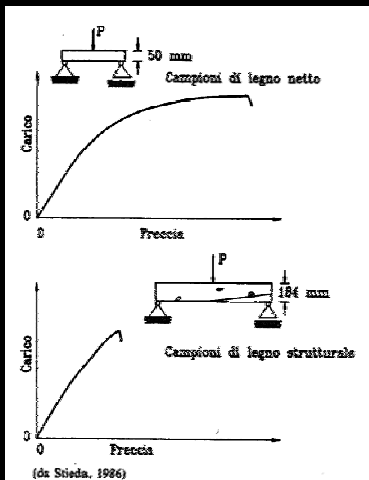




San Francisco, 1906

negative aspects

brittleness



Courtesy of H. Prion

positive aspects

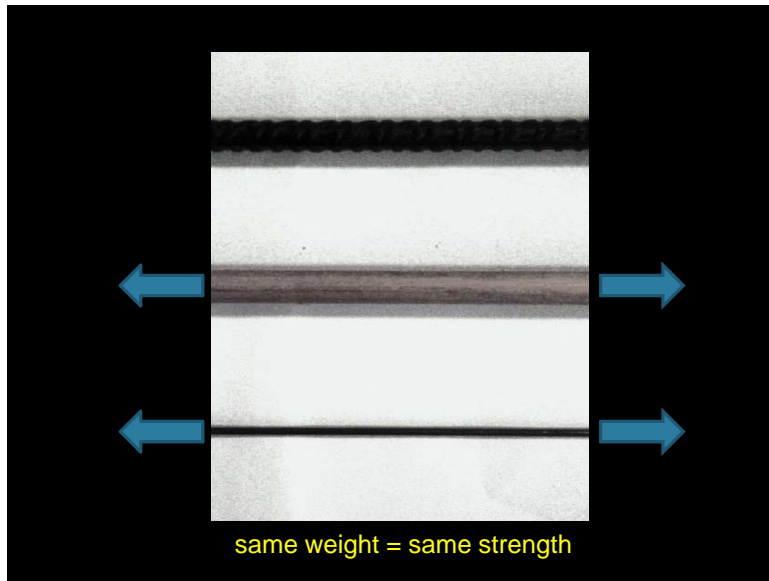
lightness



Shrinagar, Kashmir

positive aspects

strength/density





South Tirol, Italy



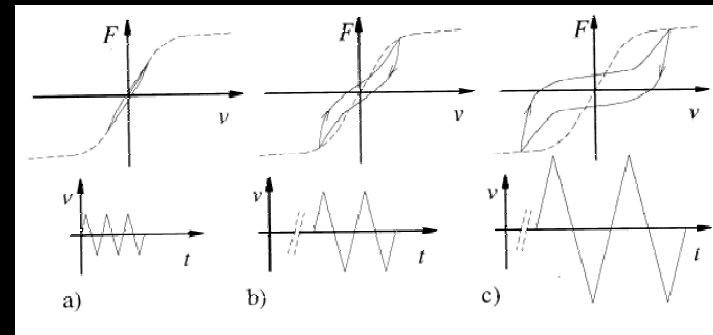
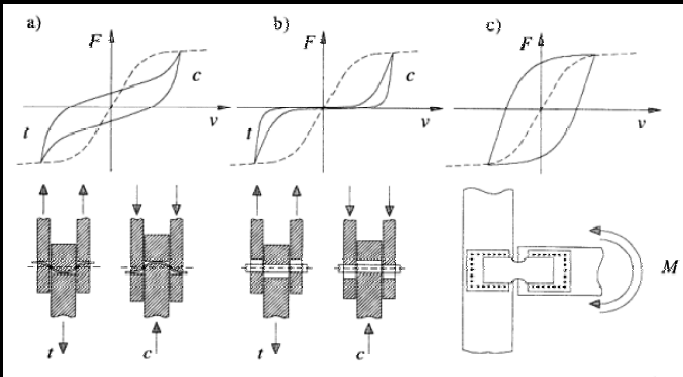
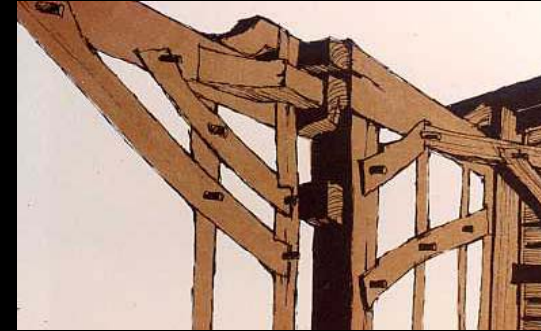
Himachal Pradesh, India

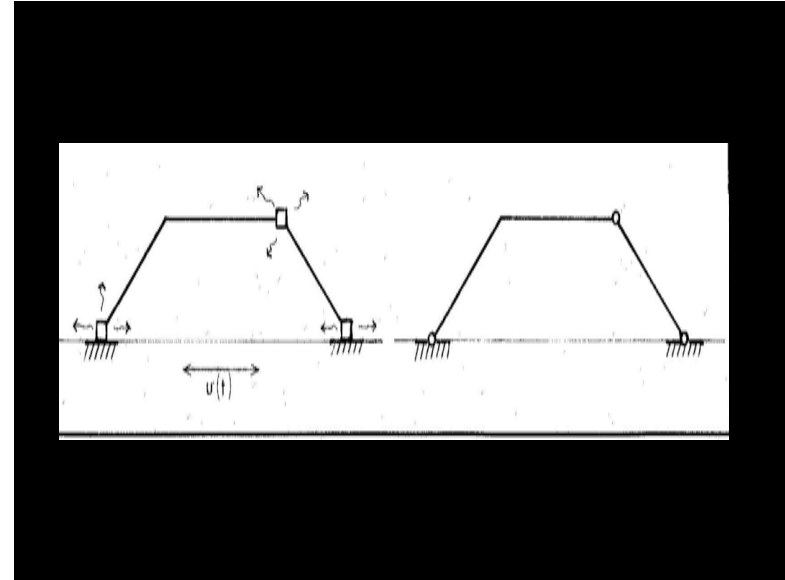
positive aspects

energy dissipation



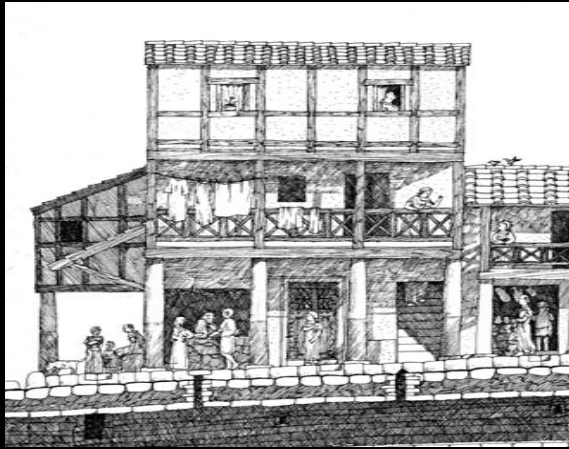
Germany, Europe



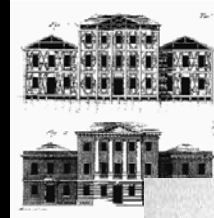


Courtesy of A. Lejten

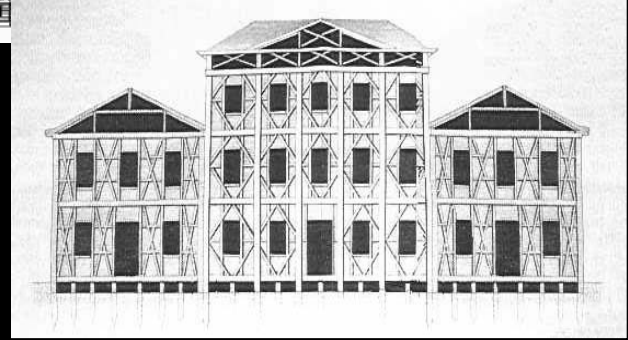




Rome, Italy

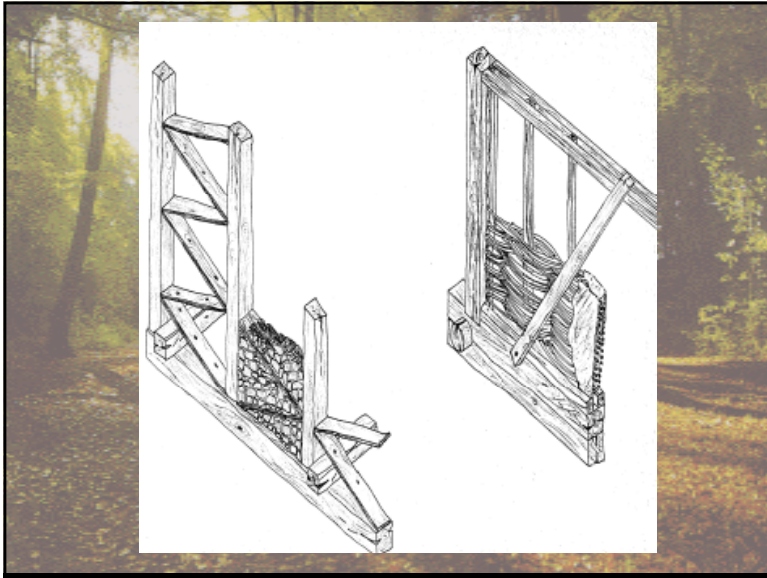


Calabria, Italy



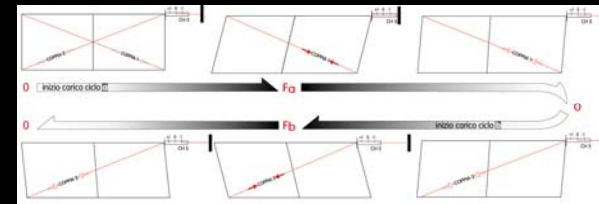
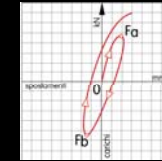
Cadore, Italy





Environnement et Patrimoine: Les nouvelles donnees GC' 2003 Paris - 26 et 27 mai 2003

Experimentation



Istituto Universitario di Architettura di Venezia - DCA - A. Ceccotti P. Faccio M. Nart P. Simeone



Environnement et Patrimoine: Les nouvelles donnees GC' 2003 Paris - 26 et 27 mai 2003

Experimentation



M2

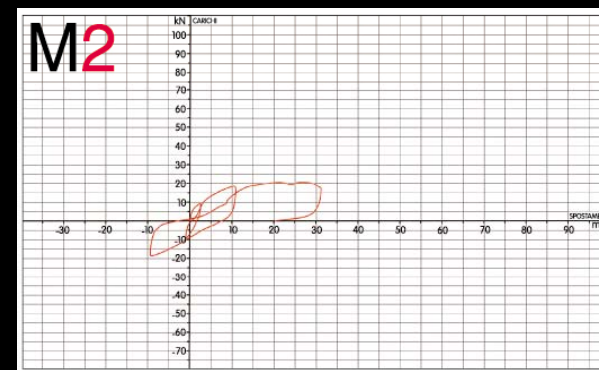


Istituto Universitario di Architettura di Venezia - DCA - A. Ceccotti P. Faccio M. Nart P. Simeone



Environnement et Patrimoine: Les nouvelles donnees GC' 2003 Paris - 26 et 27 mai 2003

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Experimentation

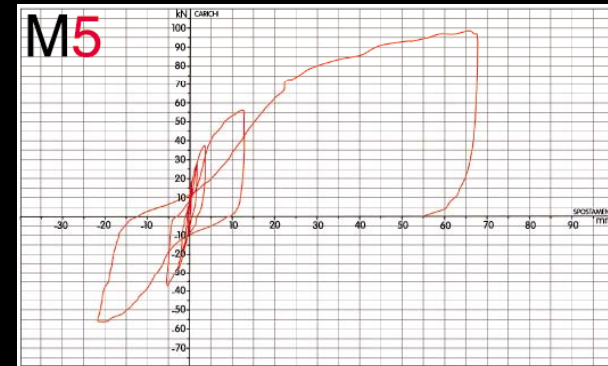


M5

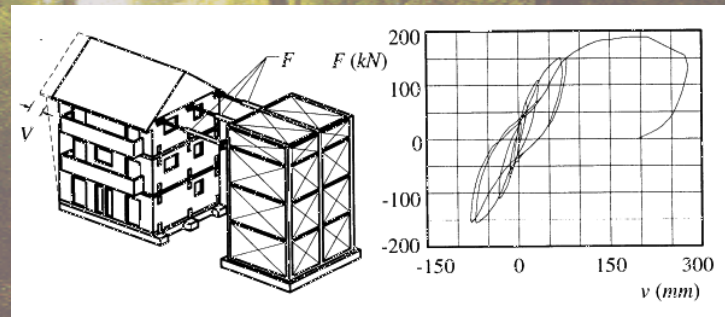


Istituto Universitario di Architettura di Venezia - DCA - A. Ceccotti P. Faccio M. Nart P. Simeone

Experimentation



Istituto Universitario di Architettura di Venezia - DCA - A. Ceccotti P. Faccio M. Nart P. Simeone

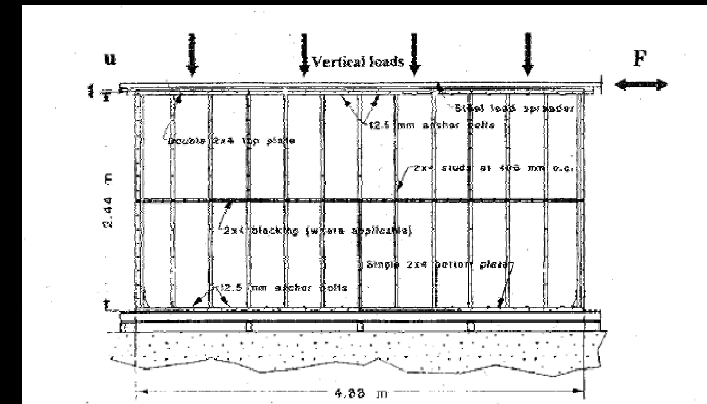


Japan

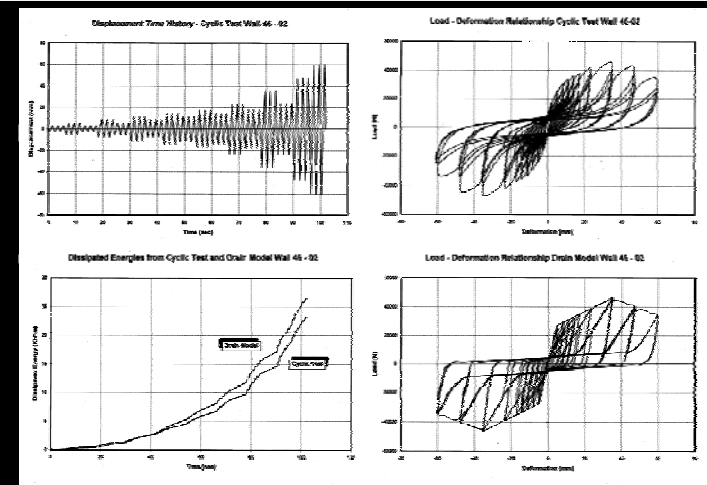
2x4 construction



Vancouver, Canada



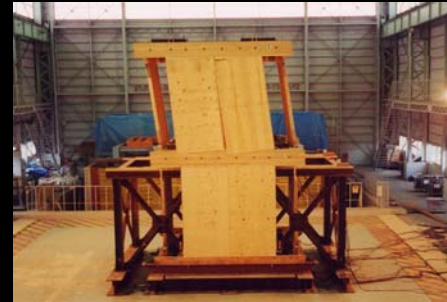
Forintek Lab, Vancouver, Canada





Tsukuba, NIED Lab.





New developments in Europe...



FOWL - Forest and Other Wooded Land



Italy

Italy land 29.4 M ha

Italy FOWL 11.1 M ha

FOWL - Forest and Other Wooded Land

Trentino



Trentino land 0.62 M ha

Trentino FOWL 0.34 M ha

Share of FOWL 55 %

Capacity of sustainable exploitation 500 000 m³



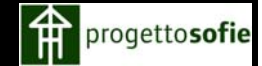
PROVINCIA AUTONOMA DI TRENTO

The SOFIE Project





The SOFIE Project



The scope of the project was 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 or CLT**) through testing analysis and study of every single aspect :
(**seismic, fire, building physics, durability**).

The project was funded by the **Autonomous Province of Trento**

SYSTEME XLAM

XLAM

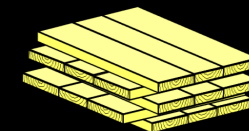
(cross-laminated solid timber, a.k.a. **CLT**) has been invented in Germany around 14 years ago and has been spread rapidly across the most part of European Countries like Austria, Italy, Switzerland and Scandinavian Countries...



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 : Production

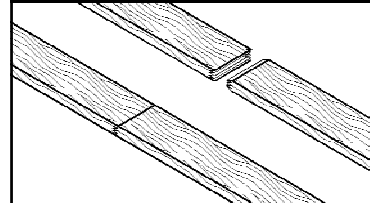


Spruce boards of thicknesses varying from 17 to 27 mm and width from 160 to 200 are machine dried up to 10-12 % of moisture content and planed...



Photo: courtesy of Finnforest-Merk

XLAM : Production



... machine graded, checked for defects and finger jointed in length...



Photo: courtesy of Finnforest-Merk

XLAM : Production

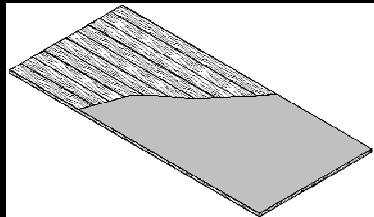


Photo: courtesy of Finnforest-Merk

then assembled in layers...



XLAM : Production

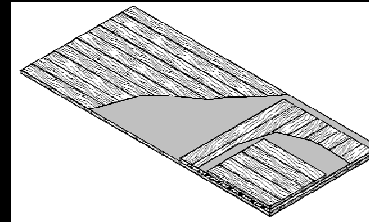


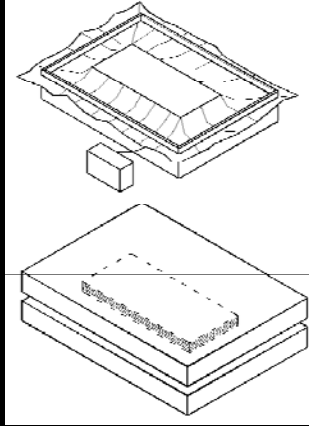
Photo: courtesy of Finnforest-Merk

and cross glued with poliurethane glue (from a minimum of 3 layers up to a maximum of 11 layers) and...



XLAM : Production

Vacuum suction: pressure max 1 Kg/cm²



...finally vacuum or clamp pressed and assembled in big size panels (up to 4.8x20 m with thicknesses between 50 and 400 mm) which are then cut with CNC machines to the desired sizes and delivered



Mechanically pressed: up to 10 kg/cm²



Photo: courtesy of Spanevello



Photo: courtesy of Spanevello

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 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

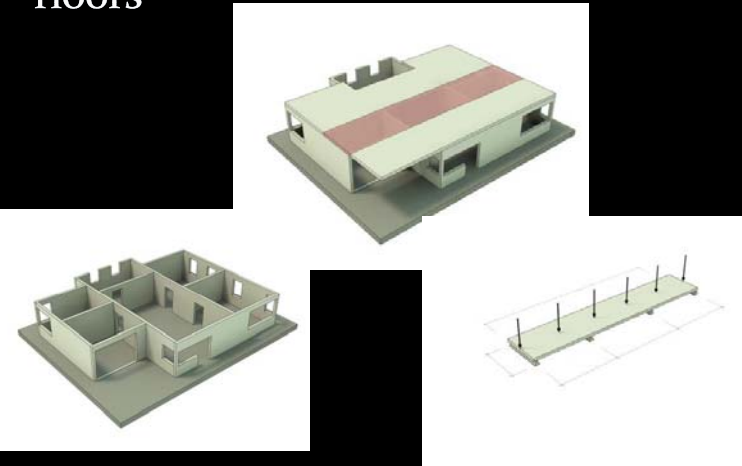
- XLAM panels are extremely strong and stiff whatever is the timber quality, therefore they allow the use of medium-low grades of home-grown sawn wood



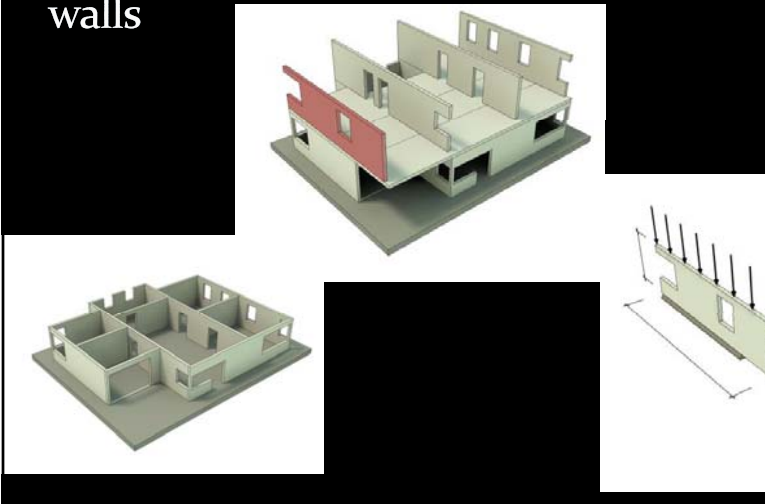
XLAM SYSTEM : Advantages

- But most of all, the XLAM System is more attractive to a large part of European public, unfavourable to “lightweight” timber buildings systems which are often considered only for cottages or temporary housing

floors



walls



connections

Points where design of connections must be undertaken:

screws

- 1 wall-wall
- 2 floor-floor
- 3 wall-corner wall
- 4 floor-wall

hold-downs

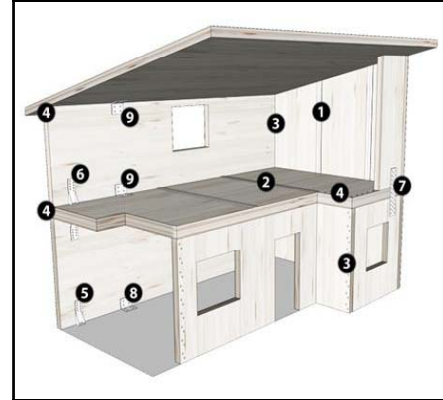
- 5 wall-foundation
- 6 wall-floor/floor-wall

steel straps

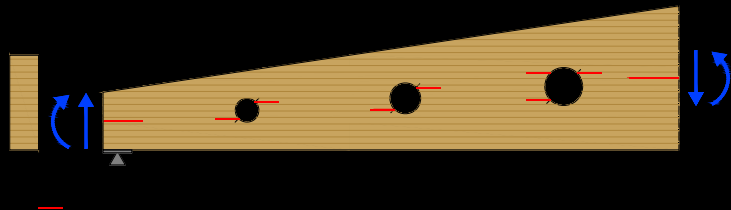
- 7 wall-wall

steel angles

- 8 wall-foundations
- 9 wall-floor/ wall-wall (in vertical)

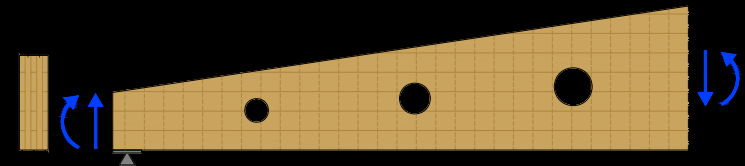


Holes in glulam

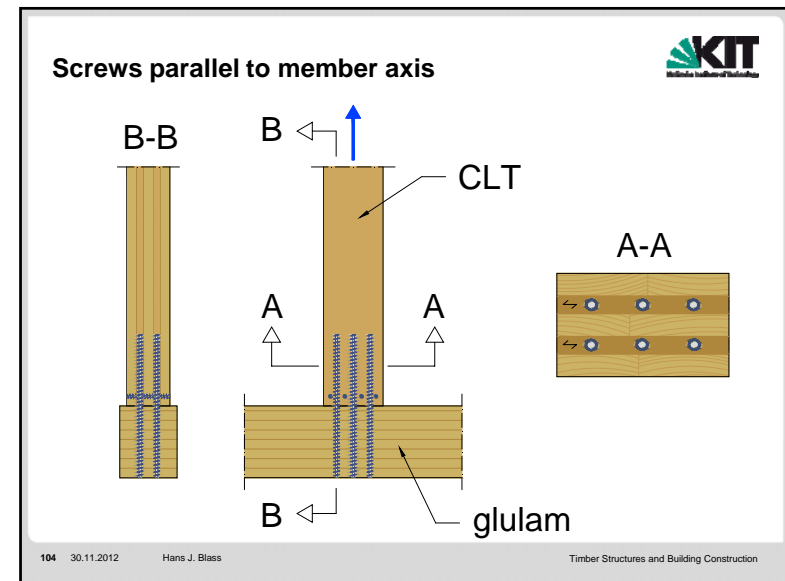
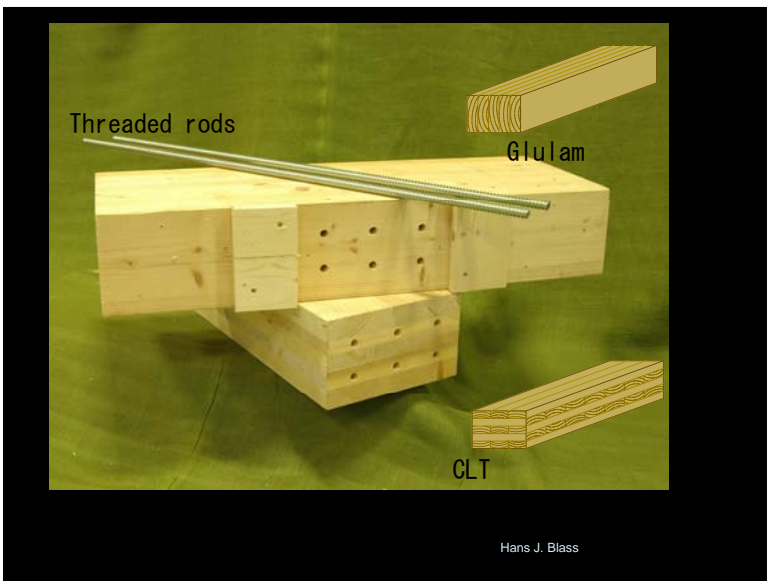
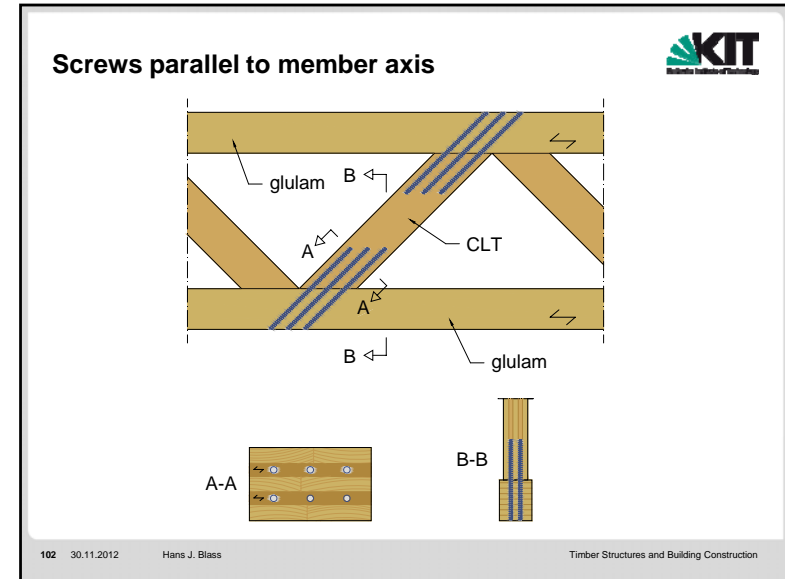


Hans J. Blass

Holes in CLT



Hans J. Blass



London



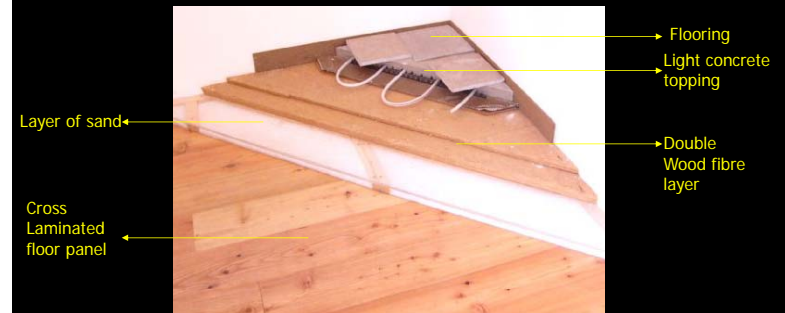
Appartment complex Murray Grove London



XLAM SYSTEM : Construction and details



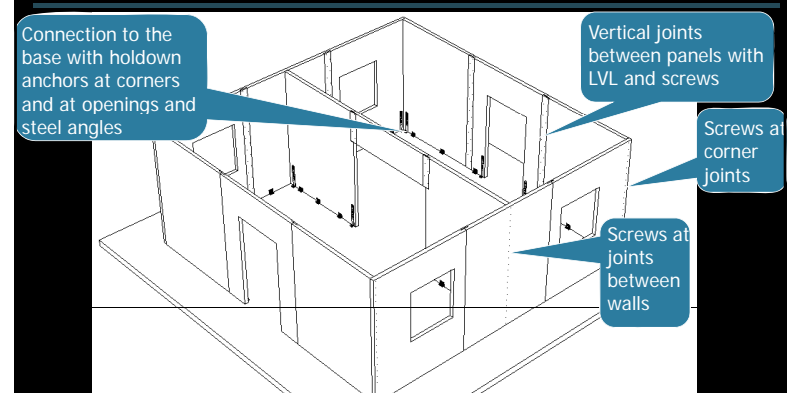
XLAM SYSTEM : Construction and details



XLAM SYSTEM : construction details



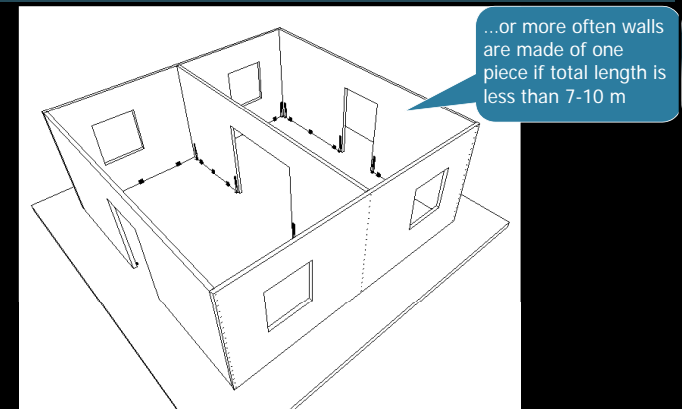
SYSTEM XLAM : Construction and details



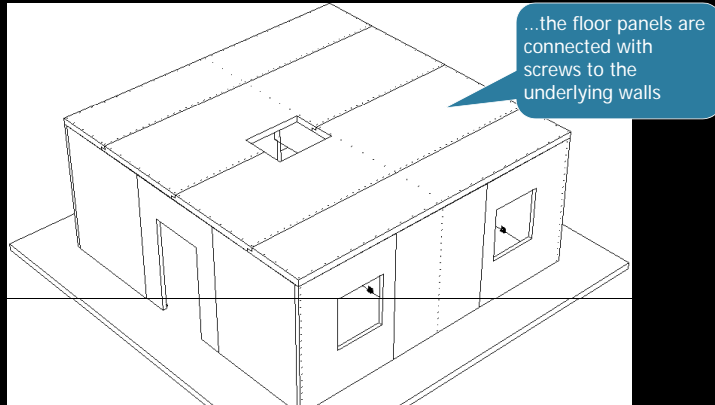
SYSTEM XLAM : Construction and details



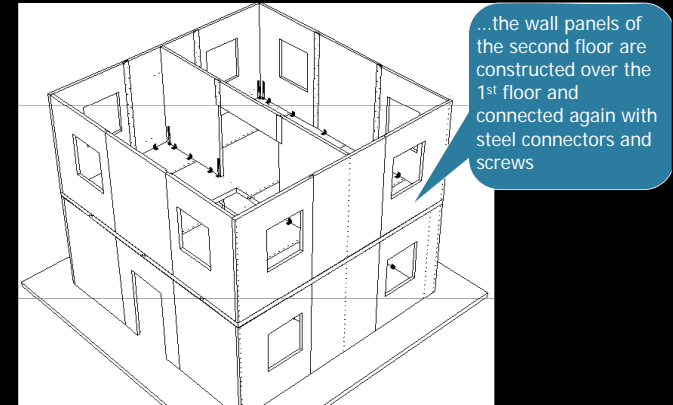
SYSTEM XLAM : Construction and details



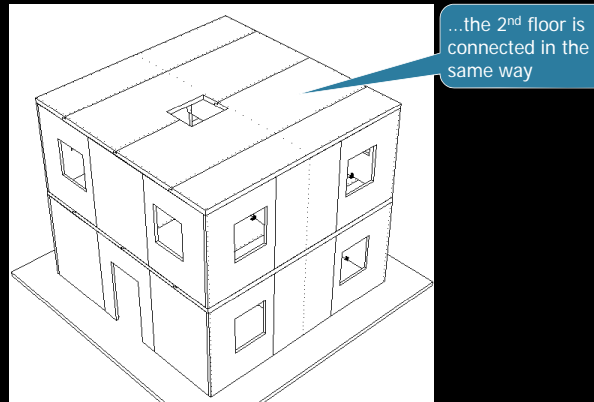
SYSTEM XLAM : Construction and details



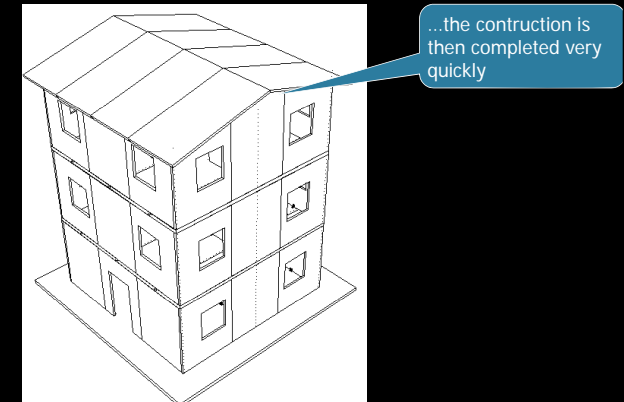
SYSTEM XLAM : Construction and details

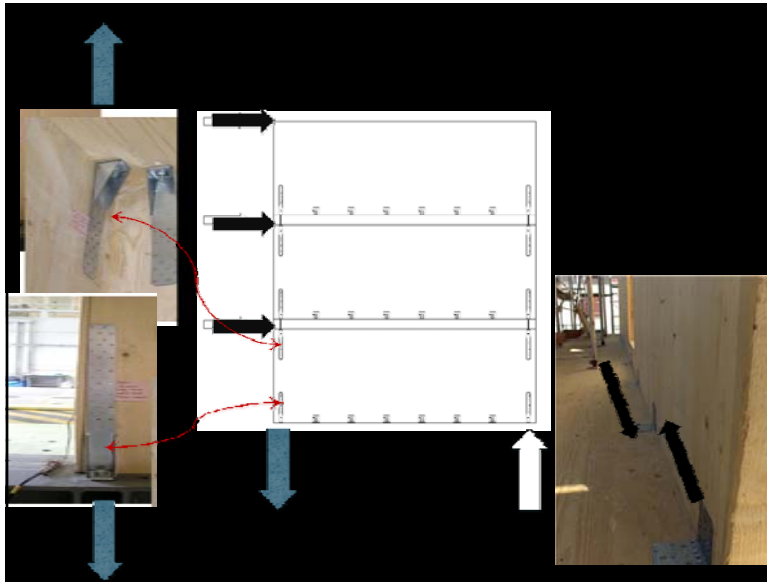


SYSTEM XLAM : Construction and details



SYSTEM XLAM : Construction and details





SYSTEM XLAM : Construction and details



SYSTEM XLAM : Construction and details



SYSTEM XLAM : Construction and details



SYSTEM XLAM : Construction and details



Hotel LAMM
Castelrotto (BZ)
North-East of Italy
(Trentino-Alto Adige)

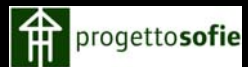


7 STOREY BUILDING

First 7 storey wooden building
ever built in Italy



Seismic tests

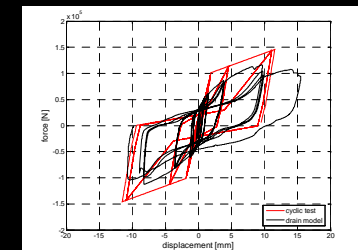
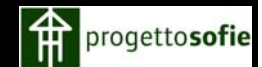


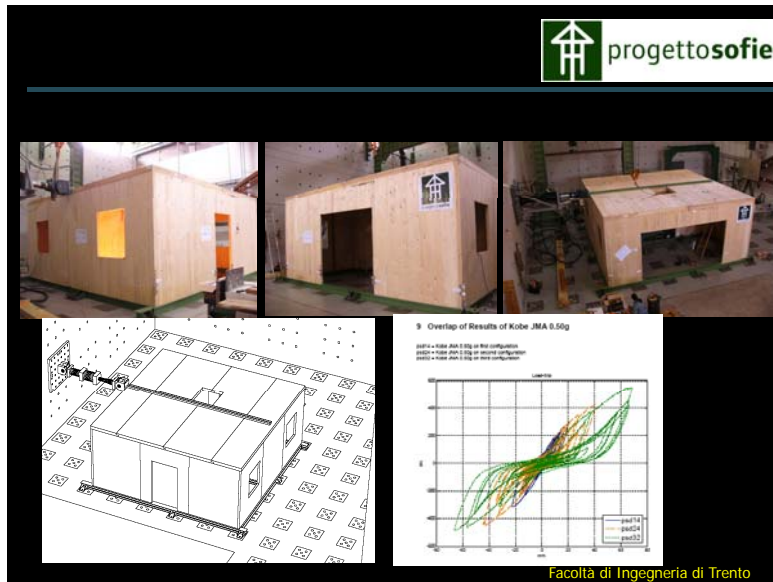
In plane
Cyclic Tests
on walls and
connections

Pseudo-
dynamic
tests on
one storey
specimen






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





XLAM SYSTEM : Comparison with 2by4

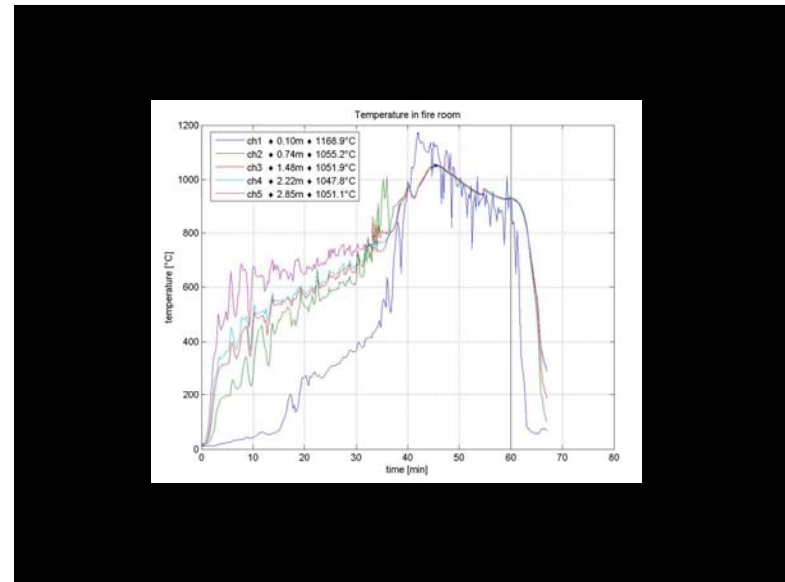
3storey house 7x7x10m		3storey house 7x7x10m
Total weight XLAM: 20 ton (3 rd grade timber)		Total weight 2by4: 7 ton (1 st grade timber)
Ultimate Lateral Load carrying capacity		Ultimate Lateral Load carrying capacity
XLAM: 35 kN/m		2by4: 7 kN/m
Lateral Stiffness		Lateral Stiffness
XLAM: 2.5 kN/mm/m		2by4: 1 kN/mm/m





FIRE TEST AT BRI TSUKUBA MARCH 2007





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

2008-2009 Schedule of E-Defense

Table Size	20m x 15m	2008	2009
Payload	12MN(1200ton)		
Shaking Direction	X, Y - Horizontal	Z - Vertical	
Max. Acceleration	900cm/s ²	1500cm/s ²	
(at Max. Loading)			
Max. Velocity	200cm/s	70cm/s	
Max. Displacement	4000mm	4000mm	

Full-Scale Tests of Wooden Houses on E-Defense

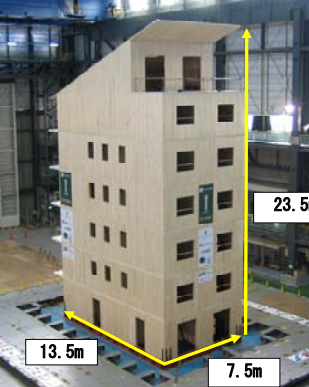
New Type I **Conventional Type II**

Traditional Type III **Protective Platform**

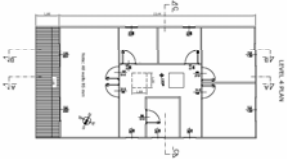

Input: JMA Kobe

Type I: W8m x L10m x H1m 30ton
 Type II: W10m x L12m x H1m 30ton
 Type III: W10m x L12m x H1m 30ton
 Date: Oct - Nov 2008
 Input: JMA Kobe

SEISMIC TEST IN MIKI 2007 OCT 23



23.5m
13.5m
7.5m

Input:
 JMA Kobe 3D x,y,z 0.60, 0.82, 0.34 g
 BUILDING SELF WEIGHT 120 t
 ADDITIONAL LOAD ON FLOORS 150 t





Building Working
(at E-defense in MIKI)

Courtesy of M. Okabe

progettosofie

2007/09/12

2007/09/19

2007/09/27

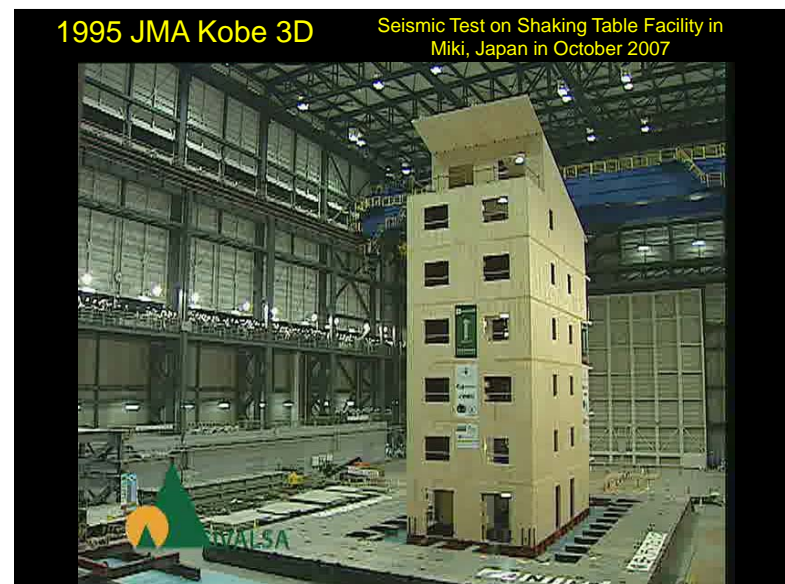
2007/10/02

2007/10/08

2007/10/13

2007/10/15

2007/10/19,23
Test



2007 Kashivasaki 3D

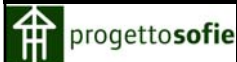


Table 1. Test sequence of seven-storey building

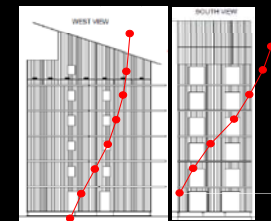
test number	input	direction	dimension	intensity	PGA	
					in x	in y
1	step	X, Y	2D		0.3g	0.3g
2	Nocera Umbra E-W	Y	1D	70%	-	0.35g
3	Nocera Umbra E-W	Y	1D	100%	-	0.5g
4	JMA Kobe N-S	Y	1D	60%	-	0.5g
5	JMA Kobe E-W	X	1D	50%	0.3g	-
6	step	X, Y	2D	-	0.3g	0.3g
7	JMA Kobe N-S	Y	1D	100%	-	0.82g
8	step	X, Y	2D	-	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 $PGA \geq 0.3g$ in all power



Test Observations

- The building showed very good seismic behaviour under all severe earthquake motions
- Max top displacement of 287 mm (X) and 175 mm (Y)
 - Max storey drifts
 - approx 2.4% (X)
 - and 1.6% (Y)
- The damage after all tests was negligible



Conclusions:

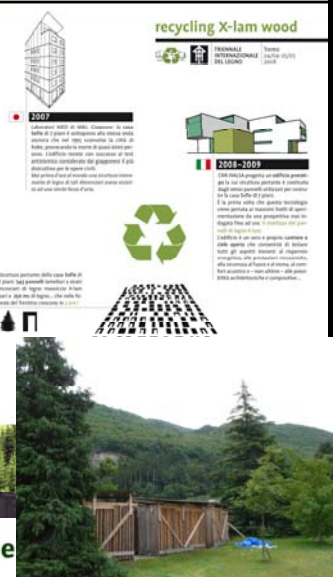
new possibility
for building design in seismic regions:

no loss of lives
but also
no loss of property
at almost no extra cost



www.progettosofie.it

Recyclable...



Opera Universitaria Trento



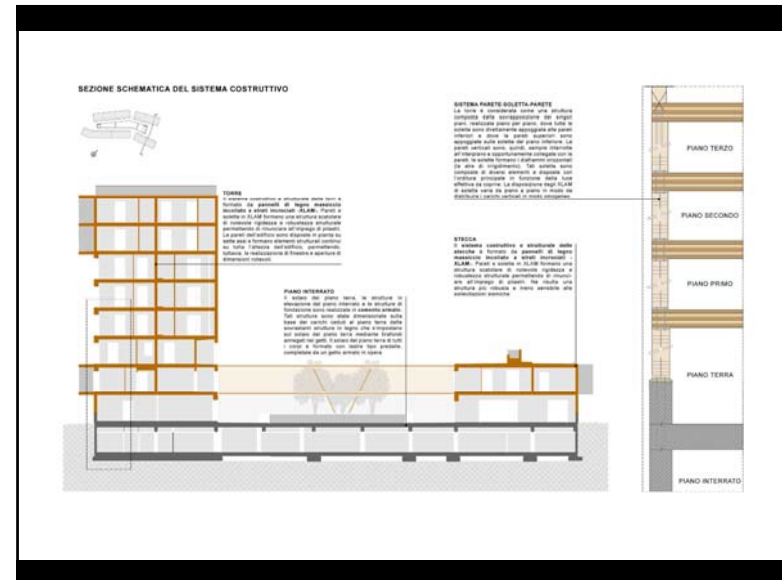
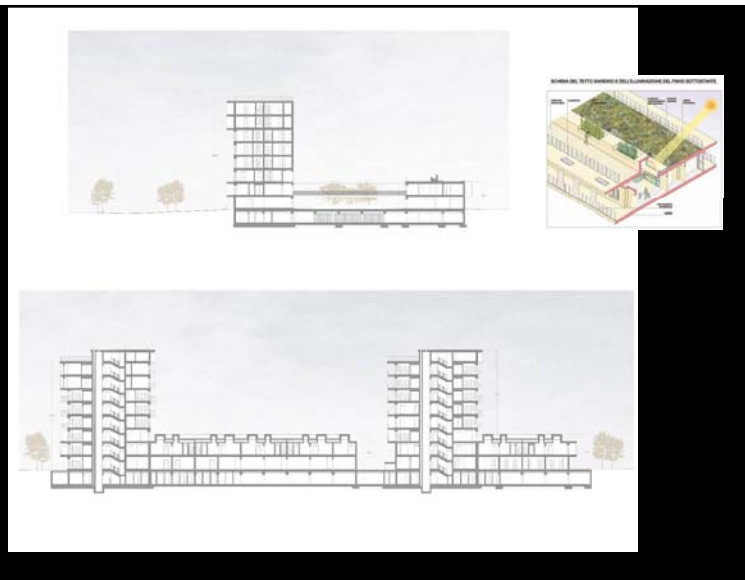
Viale Giannotti in Firenze

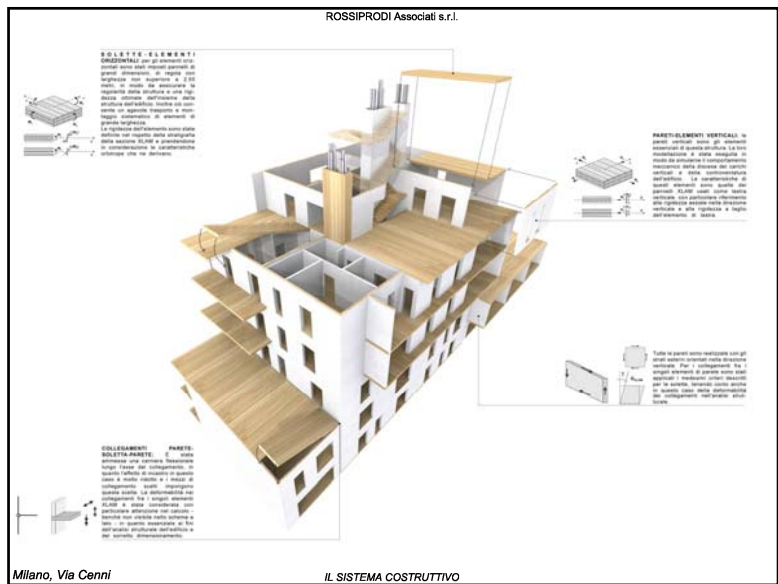
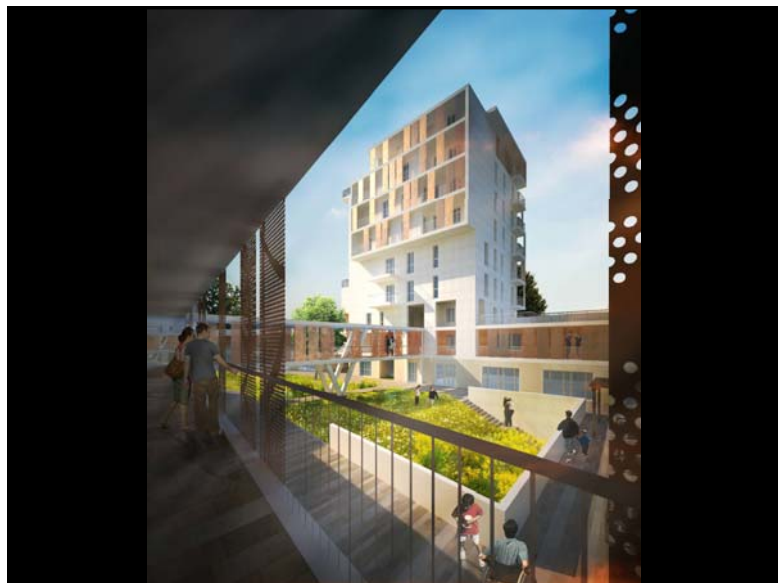


Via Cenni, in Milano



RPA







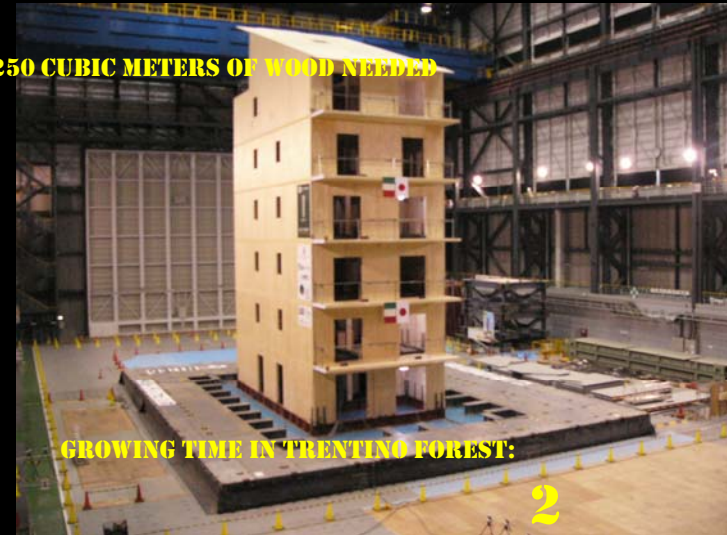


Next: SMS building in Milano



Dante O. Benini & Partners Architects

250 CUBIC METERS OF WOOD NEEDED



GROWING TIME IN TRENTINO FOREST:

2

YEAR

THE BEGINNING...



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• Thank you for your attention!

