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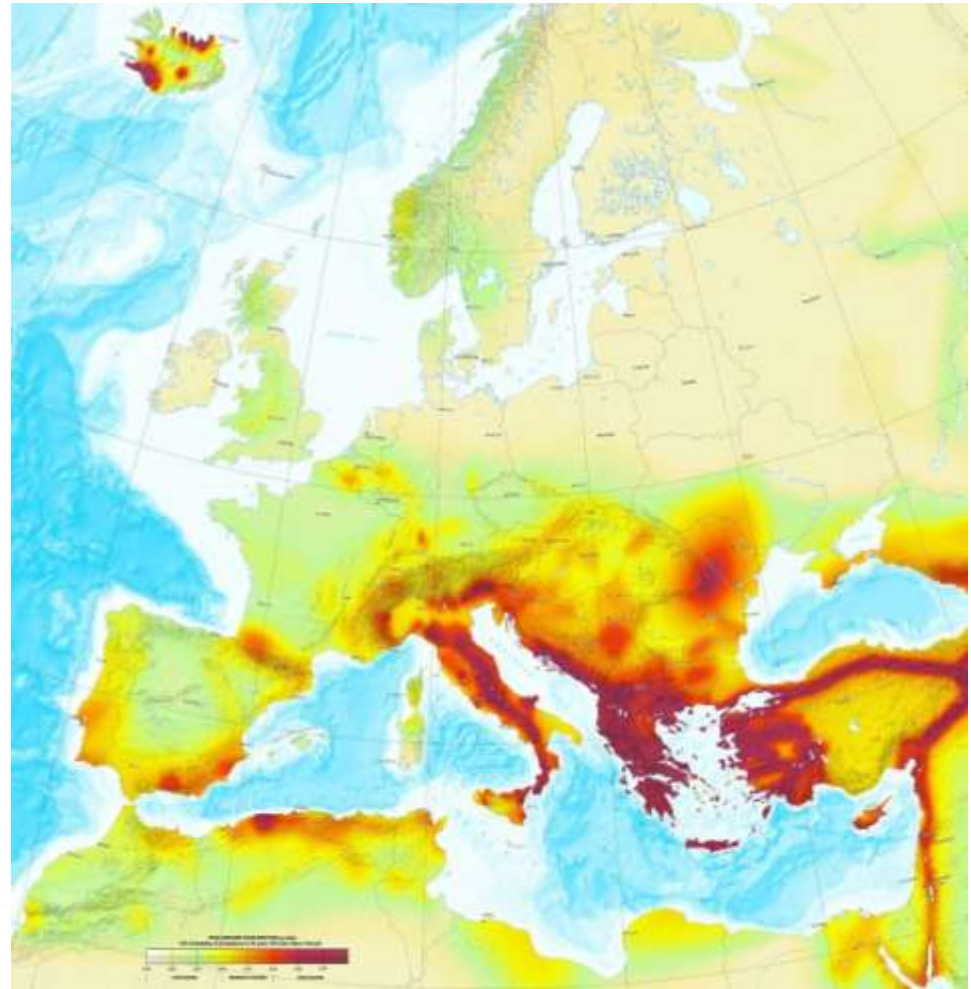
Cross Laminated Timber

Introduction to Seismic Performance

Ario Ceccotti, Univ.-Prof. Dr. P. Eng.
Trees and Timber Institute IVALSA-CNR
National Research Council, Italy

Seismic Performance of CLT Structures

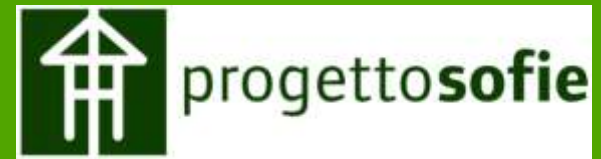
- Most structures built so far are in Central and Northern Europe, areas with low seismic activity
- Situation is different in Southern Europe where quakes strike heavily
- CLT is a **new** structural system without proven history of seismic performance during past earthquakes.....



Research Projects on Seismic Performance

- Since CLT is not yet accepted as a structural system in building codes, the designer has to guarantee the performance of every structure
- Codification related to the seismic performance and force modification factors is needed
- Consequently, **research projects** on **seismic** performance were undertaken mainly at:
 - University of Ljubljana in Slovenia
 - The SOFIE Project by IVALSA-CNR in Italy
 - University of Graz in Austria
 - University of Karlsruhe in Germany
 - FPInnovations in Canada

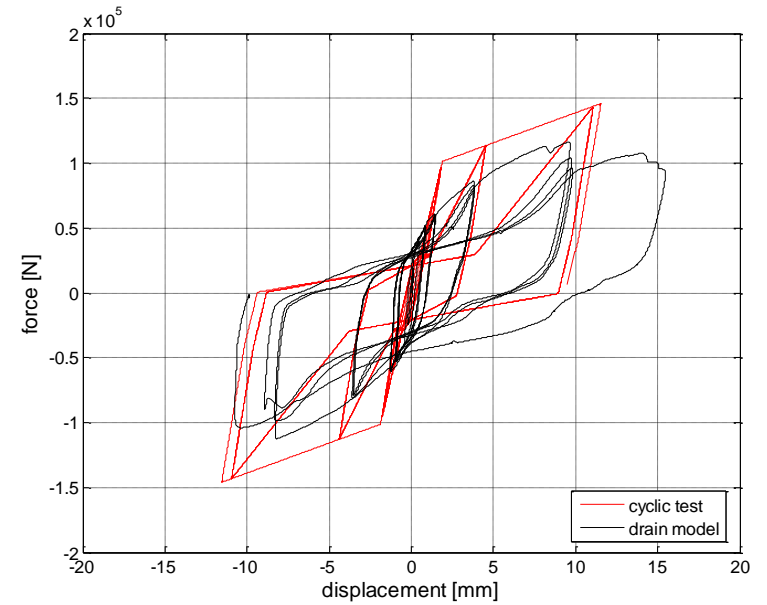
The SOFIE Project



- Monotonic and cyclic tests on 3x3m CLT **walls** at IVALSA, Trento, Italy
- Pseudo-dynamic tests on full-scale **1-storey** box-type specimen at University of Trento
- Full-scale shaking table tests on **3-storey** CLT building at NIED, Tsukuba, Japan
- Full-scale shaking table tests on **7-storey** CLT building at E-Defense, Miki, Japan



Tests on single walls

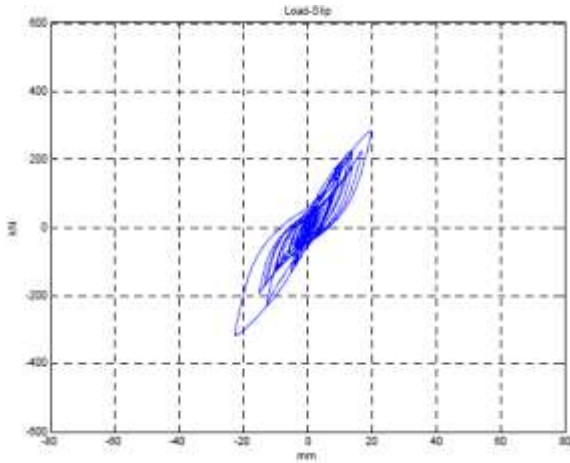


Pseudo-Dynamic Tests on Single Storey Specimens

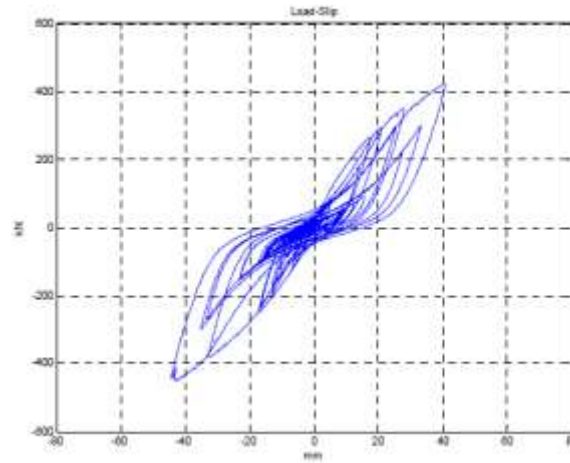
- 7m x 7m in plan and 3m high
- 3 specimens with different wall configurations
- 2 earthquakes (Kobe and El Centro), 2 intensities (0.15 and 0.5g)



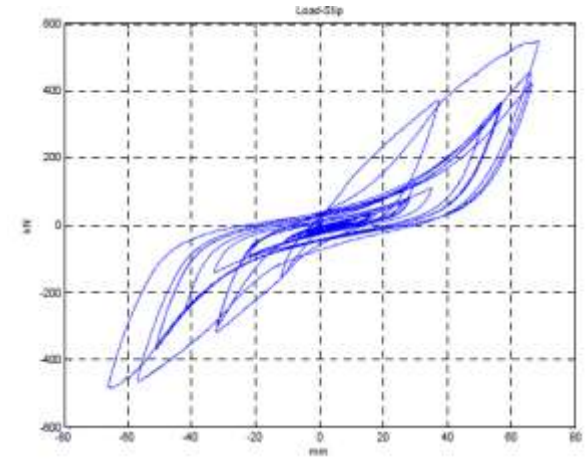
Load-Displacement Curves for Kobe 0.5g



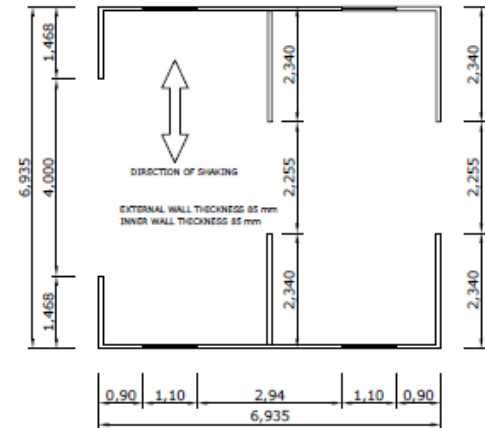
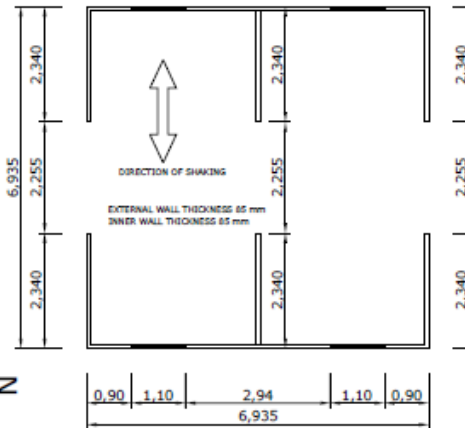
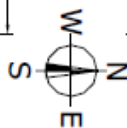
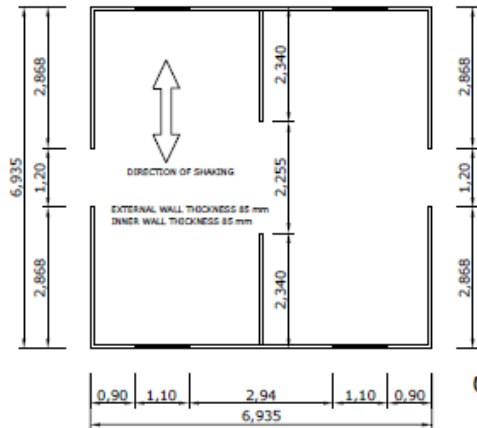
Configuration 1



Configuration 2



Configuration 3



Shaking Table Tests on 3-storey Buildings

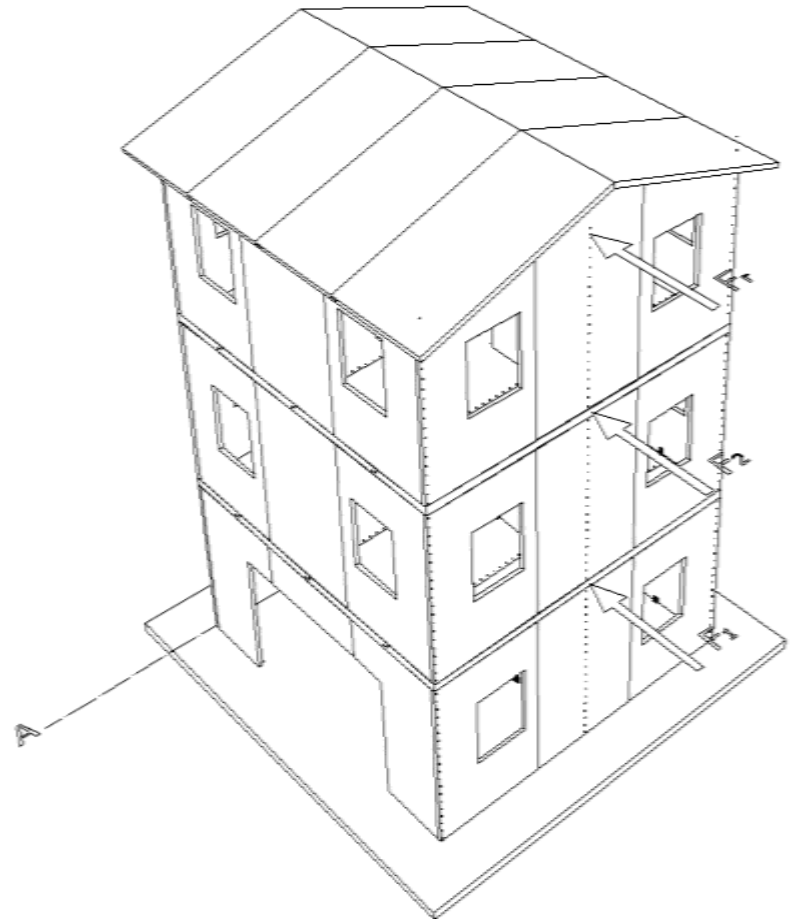
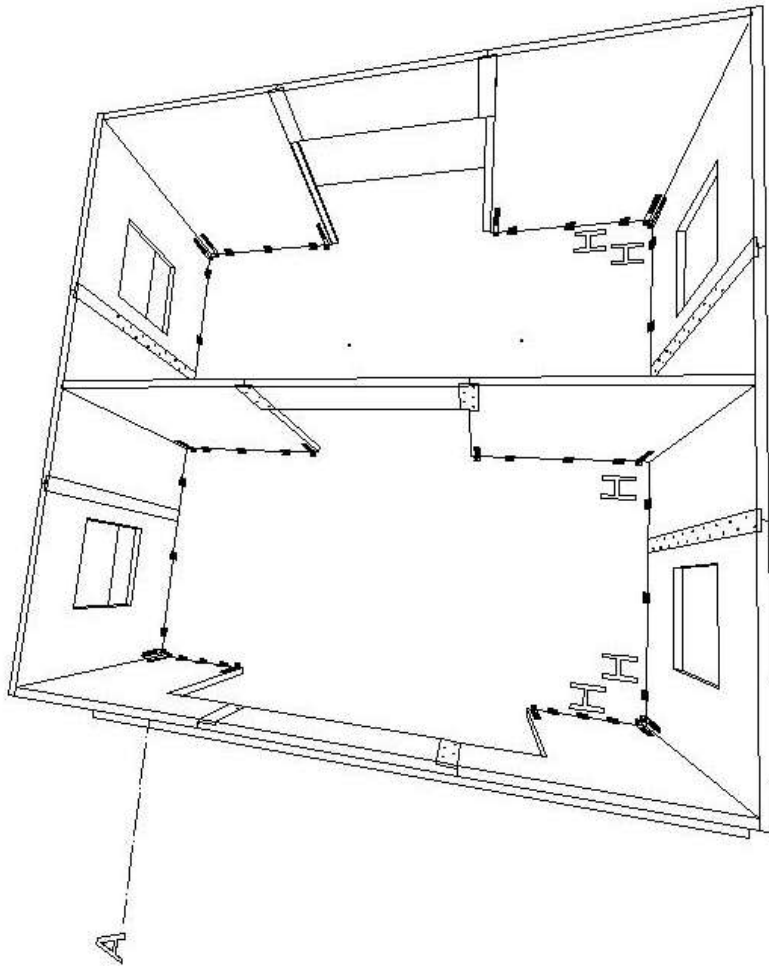
- Conducted at NIED Tsukuba
- Building was 7 x 7 m in plan and 10 m high
 - Weight 50t (20t +30t)
 - Walls 85 mm
 - Floors 142 mm
- Designed with $q = 1$
- 3 Earthquakes (0.15 - 1.2g)
 - El Centro
 - Kobe
 - Nocera Umbra
- **Total of 26 tests**
 - 14 tests were $\geq 0.5g$



Connecting elements



Design



Test Video - Configuration C with Kobe 0.8g



Record	PGA [g]	Restoring intervention (before the test)	Observed damage (after the test)
Nocera Umbra	0.35	Tightening of holdown anchor bolts	None
El Centro	0.50	Tightening of holdown anchor bolts. Replacing of screws in vertical joints between panel	None
Kobe	0.50	Idem	None
Kobe	0.80	Idem	Slight deformation of screws in vertical joints between panels
Kobe	0.50	Idem	None
Kobe	0.50	Tightening of holdown anchor bolts	None
Kobe	0.80	Replacing of holdown anchors and tightening of bolts. Replacing of screws in vertical joints between panel	Slight deformation of screws in vertical joints between panels
Nocera Umbra	1.20	Tightening of holdown anchor bolts. Replacing of screws in vertical joints between panel	Holdown failure and deformation of screws in vertical joints between panels

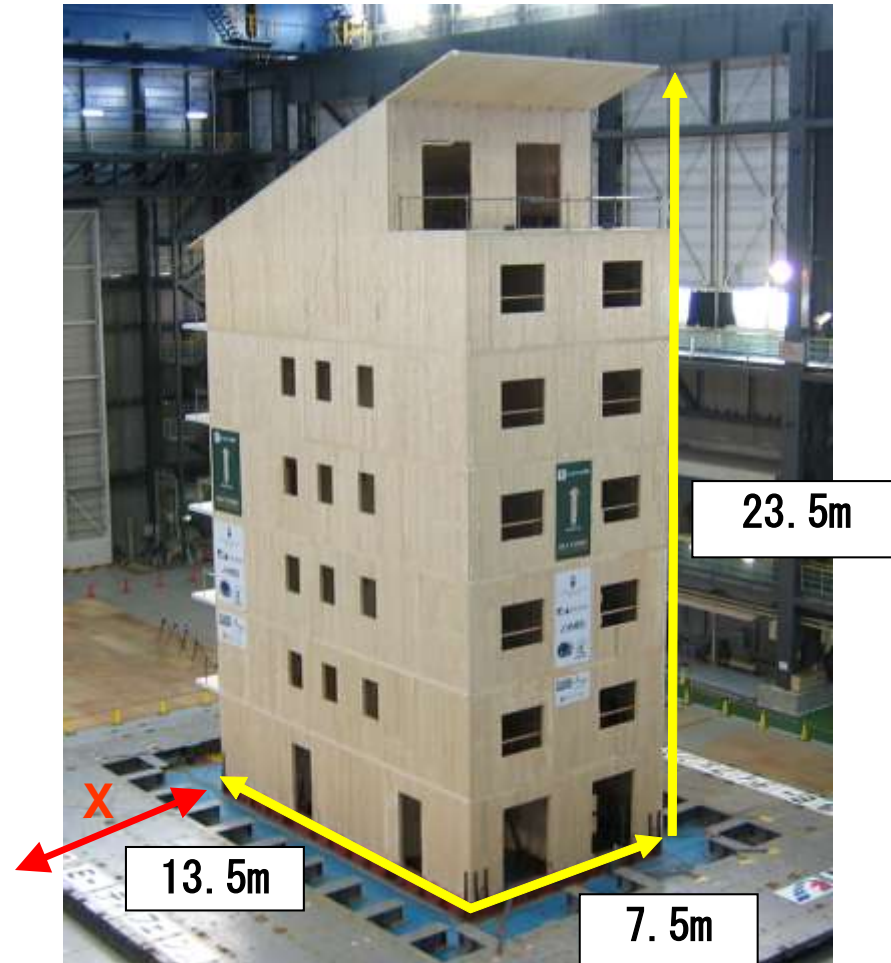


Failure Modes



Shaking Table Tests on 7-storey Building

- Conducted at E-Defense in Japan
- Building weight 270t (120t + 150t)
- Wall panel thickness
 - 140 mm floors 1 and 2
 - 125 mm floors 3 and 4
 - 85 mm top 3 floors
 - All floor panels 142 mm
- Wall panels length 2.5 m
- Two 3-axial records used
 - Kashiwazaki Kariwa Quake
 - X (0.3g) Y (0.68g) Z (0.4g)
 - Kobe JMA Quake
 - X (0.6g) Y (0.82g) Z (0.34g)
- **Total of 14 tests**
 - 10 tests were $\geq 0.3g$



Connecting Devices

- Connectors included steel brackets with screws and custom made hold-downs with screws



Building Response - Kobe Earthquake 0.82g

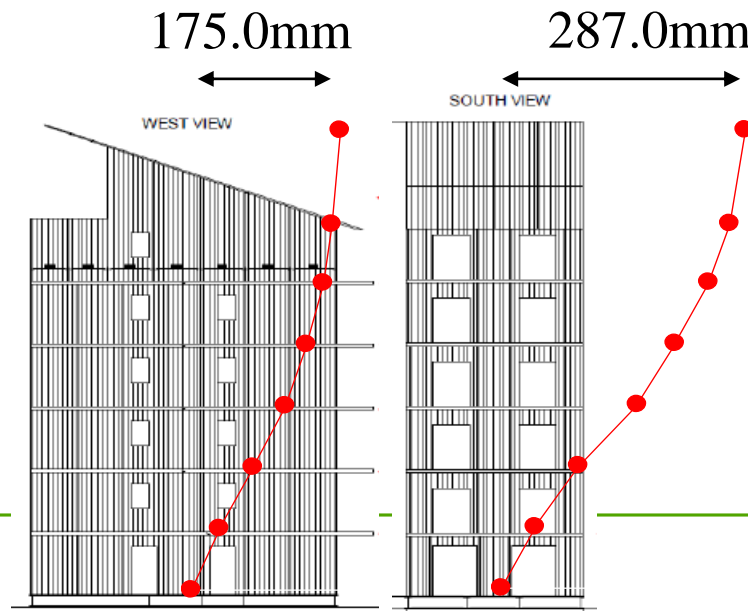


Test Observations



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**



Low Residual Deformations



Conclusions:

New trend
for building design in seismic regions:

no loss of lives
but also
no loss of property