Erdbebensicherheit im 7-Geschosser – der Praxisversuch

Seismic safety in seven-storey buildings – a practical test

Sicurezza sismica di un edificio di 7 piani – un esperimento nella pratica

Sécurité contre les tremblements de terre sur 7 étages – la recherche pratique

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Seismic safety in seven-storey buildings – a practical test.

1. Aka: the SOFIE Project, i.e. how a 7 storey wooden building can resist 7 destructive quakes in a row.

On October 19 and 23, 2007, in Miki town, near Kobe, Japan, at the Laboratory of the National Institute for Earth science and Disaster prevention (NIED), i.e. on the world most powerful shaking table, a 7 storey wooden building (7.5x15x23 m), 120 tons self weight plus 150 tons overload, (Figures 1 and 2) has been shaken by a series of destructive earthquakes in a row.

Given quakes have been the following (look at Table 1):

- *1995 Kobe earthquake* at JMA station (max peak ground acceleration 0,82g)
- *2007 Niigata-Ken Chuetsu-oki earthquake* at Kashiwazaki station (max peak ground acceleration 0,68g)
- *1997 Umbria-Marche earthquake* at Nocera Umbra station (max peak ground acceleration 0,50g).

The final result can be simply summarized by Figure 5, where the picture of the building after <u>all</u> the shakes is shown.
Building is still standing perfectly vertical, without important damages and with no need of strengthening and/or repair, but a simple retightening of the bolted connections between floors.

In Figure 4 the building structural deformed shape under 3D (three dimensional) 100% JMA Kobe quake is shown.

Where is the secret?
The constructive system based on the use of X-Lam, cross-laminated timber, also known as BSP (Brettsperrholz) in German speaking Countries.
X-Lam is made by gluing wooden boards in a 90 degrees crossed way (i.e. like a plywood panel but with plies thick as much as 2 cm). It has been invented 12 years ago in Germany and soon developed in Austria. Compensating the physical-mechanical behavior of wood on two cross dimensions it is possible to obtain wooden panels almost indestructible, with an excellent and suitable mechanical behavior. Simply genial.

In fact X-LAM panels are extremely strong and stiff, considering their low density; they are also quite easy to process and to assembly with ordinary tools; the quick erection of solid and durable structures - even in seismic areas - is possible even for non-highly-skilled manpower. The good thermal insulation, and a fairly good behaviour in case of fire are added benefits deriving from the massive wood structure.
Hence, X-LAM opens a growing market for residential and non-residential constructions based on a local, renewable natural resource, with a positive impact on the socio-economical situation of large European areas where Spruce forests are spread, but "traditional" timber buildings are considered only for cottages, temporary housing, and similar small, "lightweight" constructions.

CNR-IVALSA researchers – thanks to the support of the Italian Province of Trento, very rich of *Picea abies* trees – have concentrated their main work in evaluating the seismic behavior of X-Lam , up to now not yet studied enough. Their research project has been called SOFIE, i.e. Sistema cOstruttivo FIemme.

In fact, until now, design of X-LAM system buildings is not yet considered by European standards. E.g. in Eurocode 8 – the European code for seismic design of buildings, this constructive system is not yet included and no recommendations are given regarding its seismic behaviour. Especially regarding the value of the seismic behaviour factor ***q*** to be used in seismic design of this new typology of wooden buildings, no provisions are given.

In [Ceccotti, 2008], the outcomes of a previous experimental test performed on a full-scale three-floor X-LAM building are reported. The experimental results are compared with the outcomes of a numerical analysis with the aim to derive the behaviour factor ***q*** to be used in a simplified elastic design, according to Eurocode 8 requirements. Readers are invited to consult this paper for more technical information.

The 7-storey test building X-Lam panels for walls and floors have been pre-cut, with openings for windows, doors and stairs passages, according to the architectural design, with the use of CNC machines.

At NIED Laboratory in Miki, Japan, the X-LAM panels have been assembled all together with mechanical fasteners like annular ringed nails, new generation screws - self-drilling and self tapping screws- and steel hangers for hold down connections, some of them especially and purposely designed by IVALSA researchers (Figure 3).

The building behavior can be considered as a whole compound of panels that under the seismic action deform elastically – very little indeed - and rock in a self-centering way due to the almost non-deformable nature of the panels and thanks to the mechanical connections system.

The lightness of the buildings plays a major role indeed. In fact dissipation of energy comes from mechanical connections, but their damage has resulted very limited, so that it has been possible to withstand a so impressive series of destructive quakes in a row, with the necessity of a simple retightening of hold downs bolts only.

2. Conclusions

Test results have confirmed that X-LAM building is a self-centering construction system that can be safely and easily designed against earthquakes to avoid not only loss of lives but also loss of property, according to the rules anticipated by CNR-IVALSA [1].

Recently, in Italy, a **SOFIE**VERITAS Consortium has been set up to provide a quality label based on a voluntary-based certification for those buildings that will be erected according to the CNR-IVALSA SOFIE protocol (global building performance in terms of acoustical behavior, thermal behavior, hydro-thermal comfort, fire and seismic safety).

Some general data

- Wall thickess at ground and first floor: 14,2 cm
  - at second and third floor: 12,2 cm
  - at upper three floors: 8,5 cm
- Used Trentino *Picea abies* wood volume: 250 m^3
- Wood weight: 120 tons
- Overload on floors: 150 tons in total
- Growing time of 250 m^3 of wood in Trentino forest: 2 hours
  Picea abies seeds necessary for this volume of wood, in 70 years growing time: less than 250.

- Panels fabrication made at Finnforest-Merck in Aichach, Germany
- Used mechanical fasteners:
- hold-down 800,
  hangers 2200,
  screws 52000,
  nails 32000.
- Mechanical fasteners provided by Rothoblaas, Egna, Italy

3. References

[1] Ceccotti: "New Technologies for Construction of Medium-Rise Buildings in Seismic Regions: The XLAM Case". Structural Engineering International, Journal of the International Association for Bridge and Structural Engineering (IABSE), May 2008, volume 18, number 2 pgg. 156-165.

[2] www.progettosofie.it

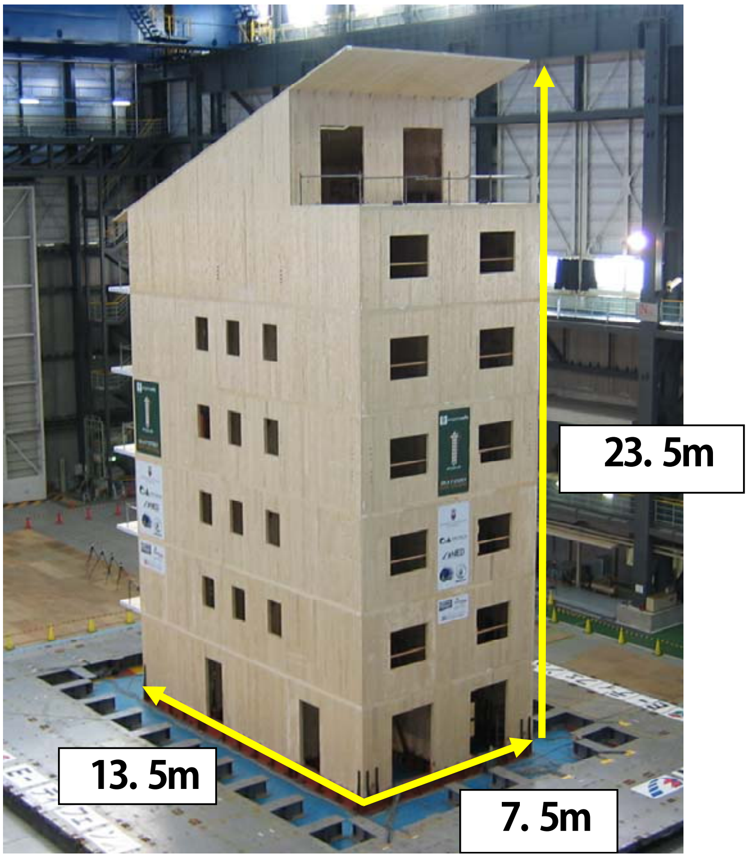

Figure 1: North and Est view of the test building

Figure 2: South and Est view of the test building

Figure 3: overload steel plates – foreground-, hold-downs and hanger connectors - background.

Table 1: earthquake input loading

No.	earthquake	direction(s)	Given peak acceleration, g (% of the actual historical acceleration)		
			X direction (short)	Y direction (longitudinal)	Z direction (vertical)
1	Nocera Umbra E-W	1D Y	----	0,35 (70%)	----
2	Nocera Umbra E-W	1D Y	----	0,50 (100%)	----
3	JMA KOBE N-S	1D Y	----	0,50 (60%)	----
4	JMA KOBE E-W	1D X	0,30(50%)	----	----
5	JMA KOBE N-S	1D Y	----	0,82 (100%)	----
6	JMA KOBE E-W	1D X	0,60(100%)	----	----
7	JMA-KOBE	3D X,Y,Z	0,60(100%)	0,82 (100%)	0,34 (100%)
8	Kashiwasaki R1	3D X,Y,Z	0,16(50%)	0,340(50%)	0,204(50%)
9	JMA-KOBE	3D X,Y,Z	0,60(100%)	0,820(100%)	0,340(100%)
10	Kashiwasaki R1	3D X,Y,Z	0,31(100%)	0,680(100%)	0,408(100%)

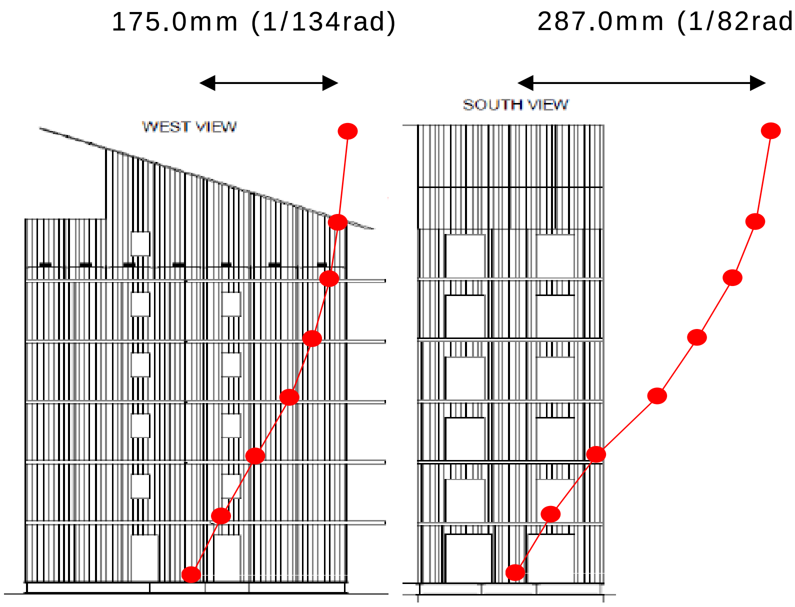

Figure 4: amplified maximum deformation under JMA Kobe 3D 100%

Figure 5: the X-LAM building at the end of all tests.

4. Acknowledgements

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