COST Action FP1004

Final Meeting

15 April – 17 April 2015 – Lisbon, Portugal

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

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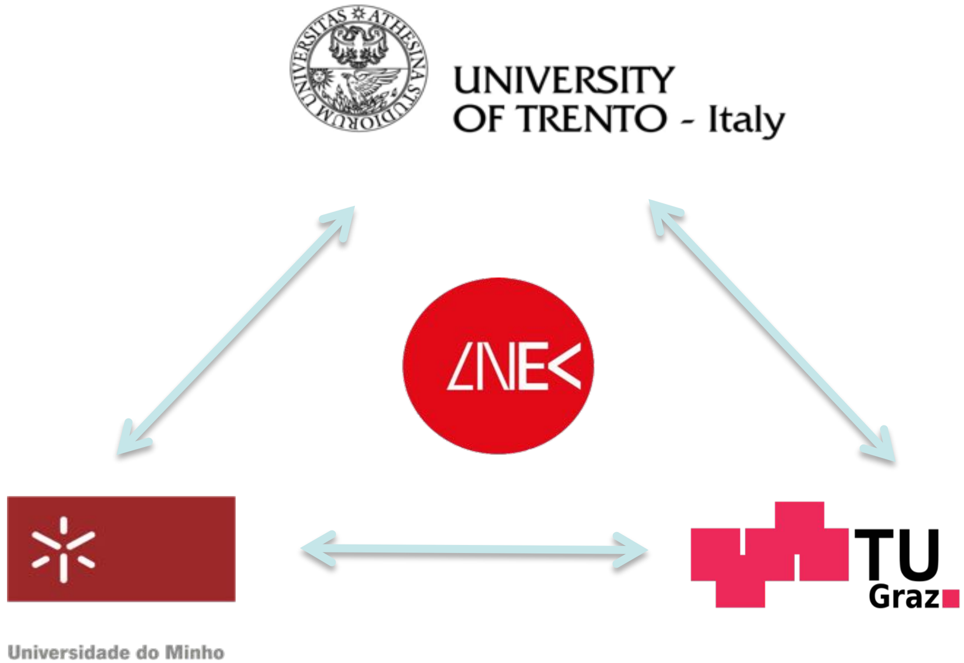
SERIES PROJECT (Seismic Engineering Research Infrastructures for European Synergies)

The research on timber buildings involves University of Trento, Italy as the lead institution, University of Minho, Portugal, University of Graz, Austria.



Shake table tests on a full-scale timber-frame building with gypsum fibre boards

University of Trento
Light framed walls system

Universidade do Minho

University of Minho
Log house system

University of Graz
CLT system

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

FACILITY:	NESDE shake table, LNEC, Lisbon (PT)
TA AGREEMENT :	January 2010 - Grant agreement n° 227887
STARTING DATE:	16th July 2011 kick-off meeting
END DATE:	21st February 2013
LEAD USER:	Maurizio Piazza & Roberto Tomasi, University of Trento (IT)
ADDITIONAL USERS:	Gerhard Schickhofer, TU Graz, AT Jorge Branco & Paulo B. Lourenço, University of Minho, PT

University of Trento	Daniele Casagrande, Paolo Grossi, Maurizio Piazza, Tiziano Sartori, Roberto Tomasi
TU Graz	Gerhard Schickhofer, Georg Flatscher
University of Minho	Jorge Branco, Paulo B. Lourenço
LNEC	Alfredo Campos Costa, Paulo Xavier Candeias

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

1

2

3

Connections

Walls

Buildings

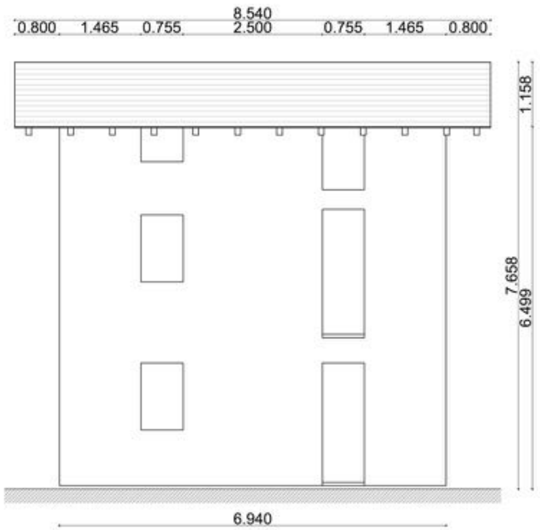
Shake table tests on a full-scale timber-frame building with gypsum fibre boards

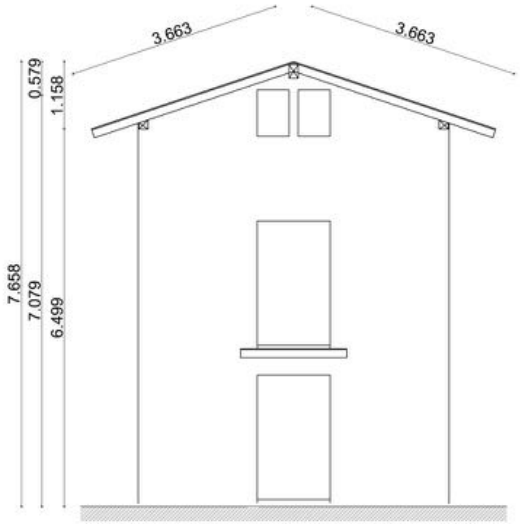
Specimens geometry

All specimens had the same geometry (squared 7 m x 5 m) and architectural layout.

- TF/CLT three storey to a maximum height to the peak of 7.65m
- LH two storey to a maximum height to the peak of 5.28m

All the four tested building were designed in accordance with EC 5/EC 8.





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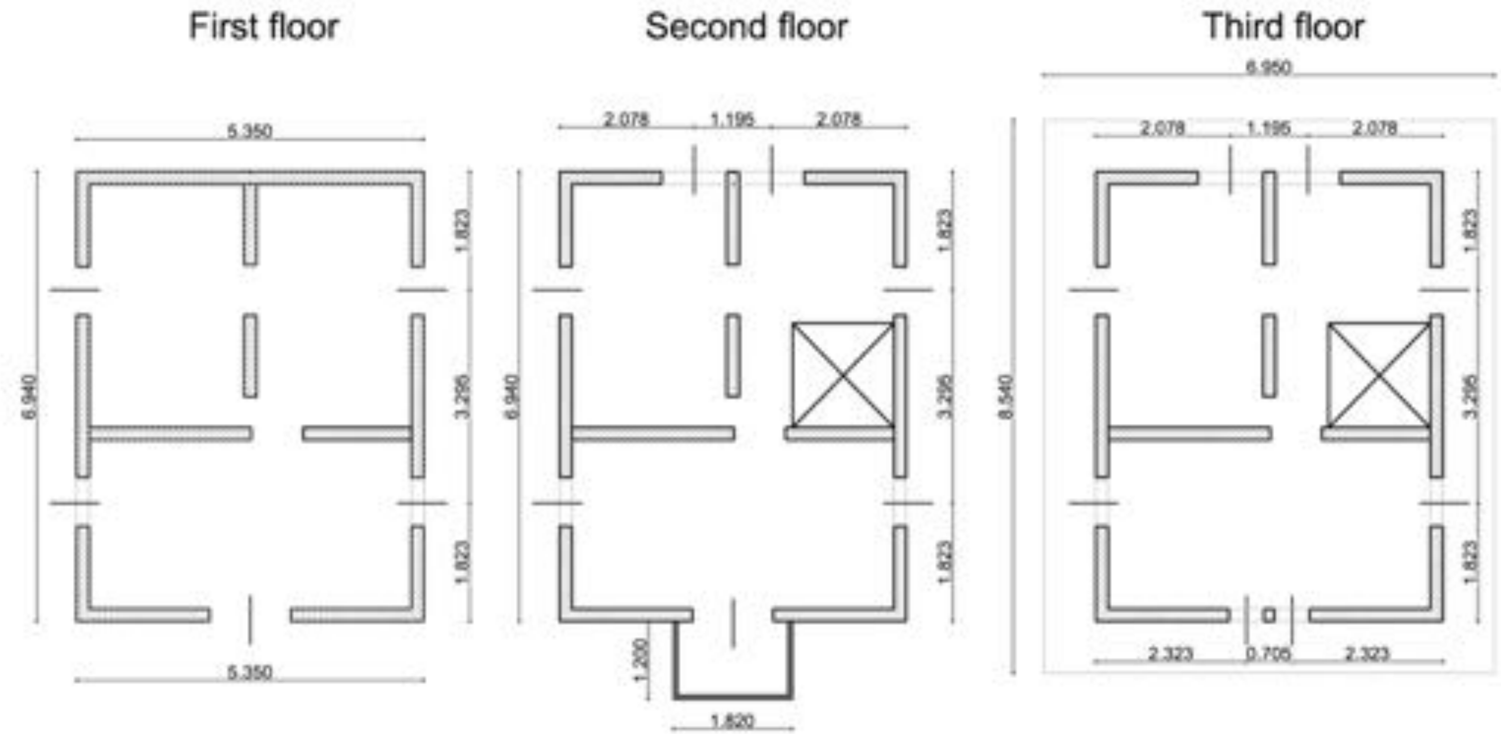
Plan and the opening distribution were designed to reproduce a real single-family home.



In order to guarantee the comparison between the different systems, permanent loads and variable loads were the same (permanent: 1.3 kN/m^2 - Variable load: 2 kN/m^2)

Log house specimen

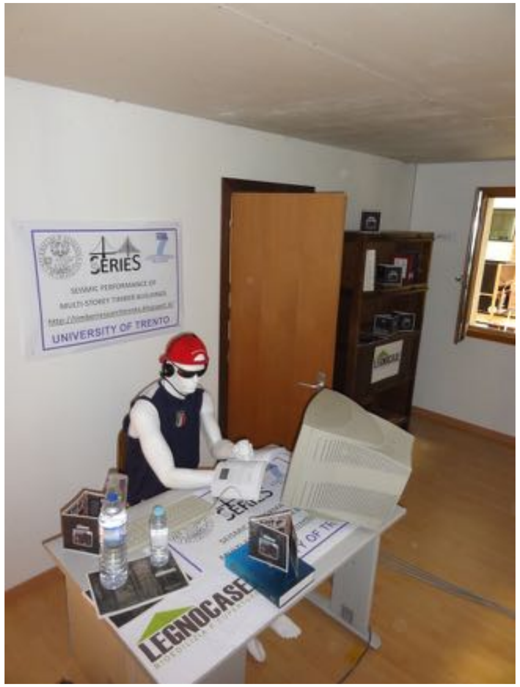
The **log house** specimen has been produced by the Portuguese company Rusticasa. According to the present production standard of the company only two storeys have been built, with a maximum height of 5.28 m at the ridge.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Walls	Inner walls logs 80x160 mm Outer walls logs 160x160 mm
Floor	Timber beams 90 x 165 mm + 15 mm OSB sheathing panels, ring nails (2.8 x 60 mm) Connection between walls and floors is obtained by means of dovetail joints
Roof	Solid wood rafters (70 mm x 190 mm), over which OSB panels are nailed The ridge board has a 120 mm x 200 mm cross-section
Connections	The sill logs are connected to the steel plate through M16 bolts, class 8.8

Light timber framed wall specimen 1

Two different timber frame specimens were tested. The first one, with **OSB structural sheathing panels**, has been produced by the Italian company Legnocase. The structure was completed with external and internal claddings and one room of the 2nd storey was also equipped with laminate floor - drywall and ceilings – doors - windows and furnitures.



Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Walls	light frame walls (60/100x160 mm studs and 60 mm top/bottom beams) OSB sheathing panels
Floor	600 mm x 140 mm modular Timber box elements (beams 78x31 mm upper and lower boards 31 mm) + 15 mm OSB sheathing panels nailed with ring nails 2.8x60 mm) Connection between walls and floors is obtained by means of screws
Roof	Solid wood beams rafter 100x140 mm/760 mm, ridge beam 160x240 mm, purlins 160x160 mm. Wooden plank (20 mm) reinforced with perforated metal strips
Connections	Shear connections: steel plate (anker nails 4x60 mm) Uplift connections: tie-downs (anker nails 4x60 mm)
	Base shear connections: screws 8x180 mm Base uplift connections: hold-downs (anker nails 4x60 mm)

Light timber framed wall specimen 2

The second TF building, produced by Italian company Rubner_haus, was built with **gypsum fibre structural sheathing panels** connected to the timber frame of the walls by means of steel staples (instead of using the system OSB + ring nails).

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Walls	light frame walls (80x120/160 mm studs and 60 mm top/bottom beams) Gypsum fiber sheathing panels
Floor	Timber beams 80x200 mm + 12 mm OSB lower panels and 22 mm OSB upper panels (all panels nailed with ring nails 2.8x60 mm) Connection between walls and floors is obtained by means of screws
Roof	Solid wood beams rafter 120x160 mm/840 mm , ridge beam 160x240 mm, purlins 160x240mm. Wood planks (20 mm) reinforced with perforated metal strips
Connections	Base shear connections: angle brackets (anker nails 4x60 mm) Base uplift connections: hold-downs (anker nails 4x60 mm)
	Shear connections: angle brackets (anker nails 4x60 mm) Uplift connections: tie-downs (anker nails 4x60 mm)

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Cross laminated timber specimen

The last test of Timber Building project within SERIES was carried out on **CLT** three storey building. In this case all the elements (walls, floors, roof) were built with cross laminated timber panels of different thickness.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Walls	3 layers CLT wall panel 100 mm (layup 30-40-30)
Floor	5 layers CLT floor panel 150mm (layup 30-30-30-30-30). Connection between walls and floors is obtained by means of screws
Roof	3 layers CLT floor panel 99mm (layup 33-33-33). Connection between walls and roof panels is obtained by means of screws
Connections	Base shear connections: angle brackets (anker nails 4x60 mm) Base uplift connections: hold-downs (anker nails 4x60 mm)
	Shear connections: angle brackets (anker nails 4x60 mm) Uplift connections: hold-downs (anker nails 4x60 mm)

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

LNEC Shaking table

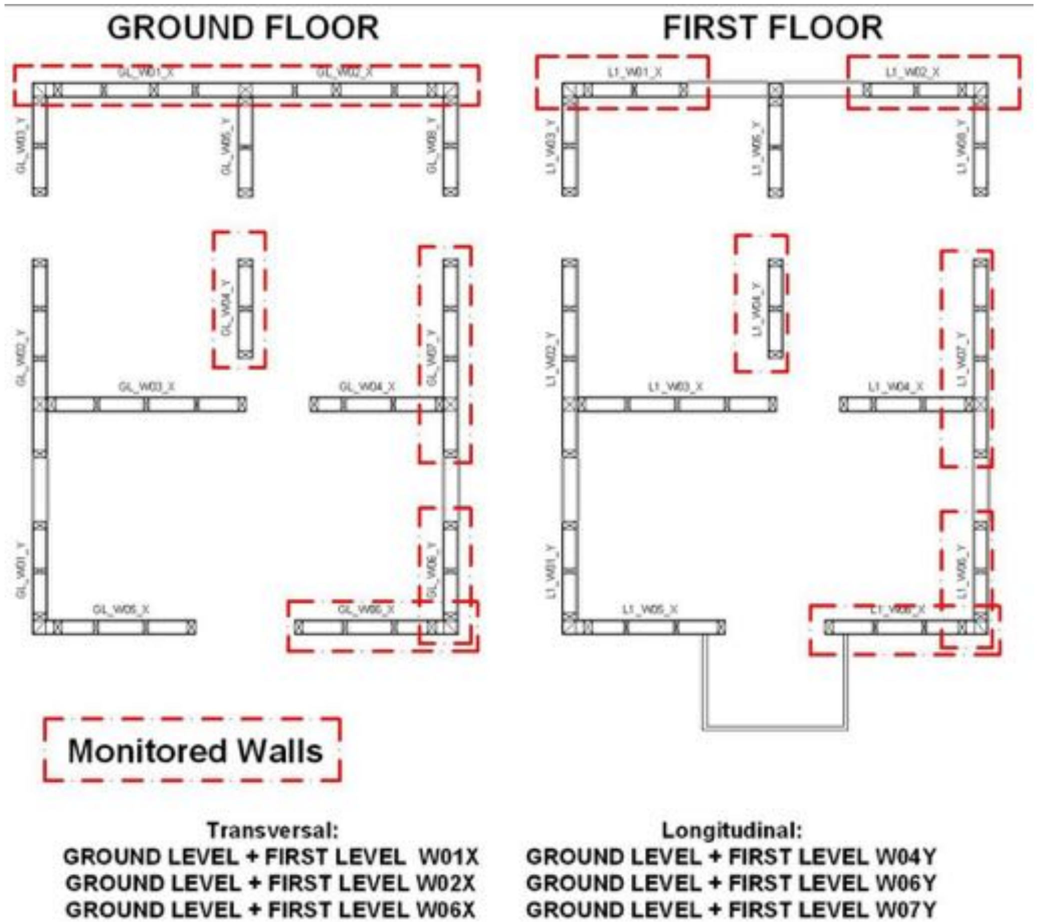
To test real scale lightweight timber structures the size of the table (5.6x4.6 m) was enlarged with a structural base frame (5x7m) made of steel beams bolted on the top plate.

Steel plates, anchored to the floor, reproduces the weight according the load combination for seismic load cases (self-weight of flooring and a fraction of variable load).

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Instrumentation

Type	Qty	Measure
LVDT	4	Inter-storey drift
LVDT	8	Wall sliding
LVDT	10	Wall uplift
Accelerometers on structure	39	Accelerations at different levels and
Accelerometers on steel basement	5	Accelerations at the shaking table level positions
Load cell	10	Forces on hold down anchoring elements
Optical displacement measurement system 1	5	Point absolute displacements (5 points x,y component)
Optical displacement measurement system 2	20	Point absolute displacements



Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Instrumentation

LVDT displacement transducers



Accelerometers

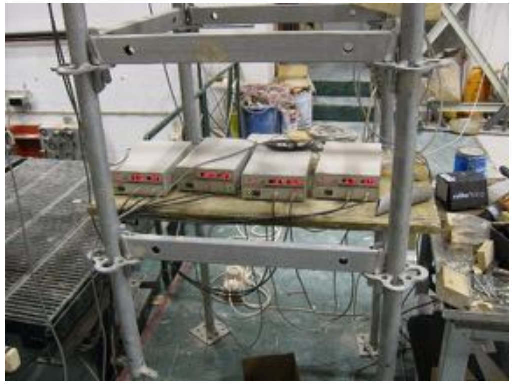


Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Load Cell

LNEC optical displacement measurement system



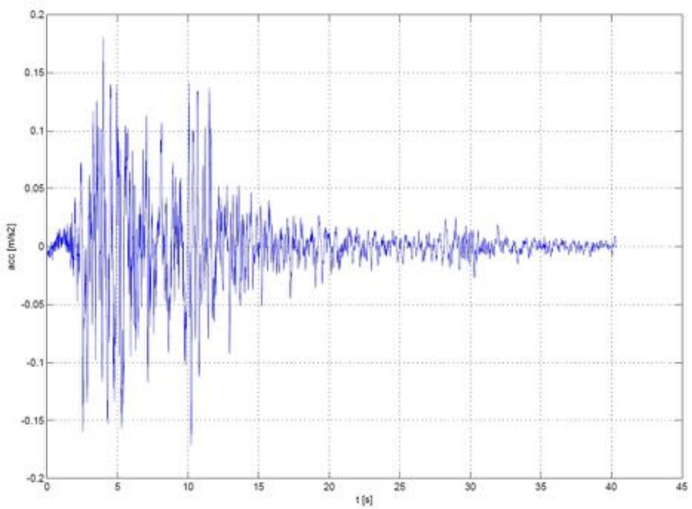




Shake table tests on a full-scale timber-frame building with gypsum fibre boards

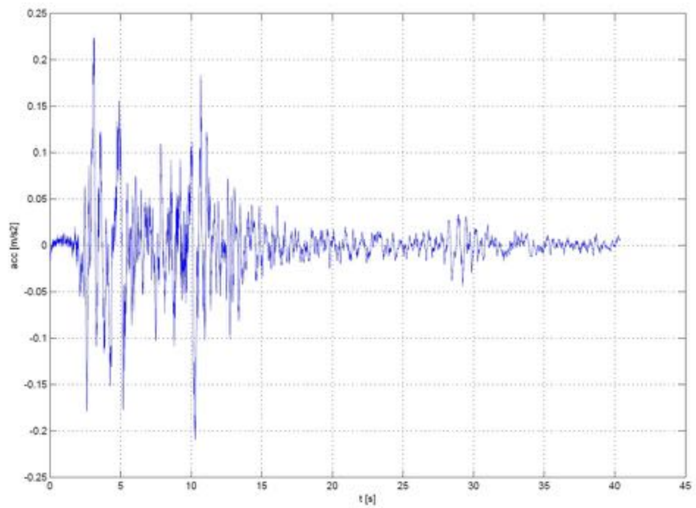
Input signal

The accelerograms were recorded at the station "Ulcinj - Hotel Albatros" located at an epicentral distance of 21 km during the Montenegro earthquake of 15/04/1979 (Mw 6.9).

X-record



Y-record



The values of peak ground acceleration (PGA) at which the buildings were been tested, at different stages of tests, **ranged from 0.07g to 0.5g**.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

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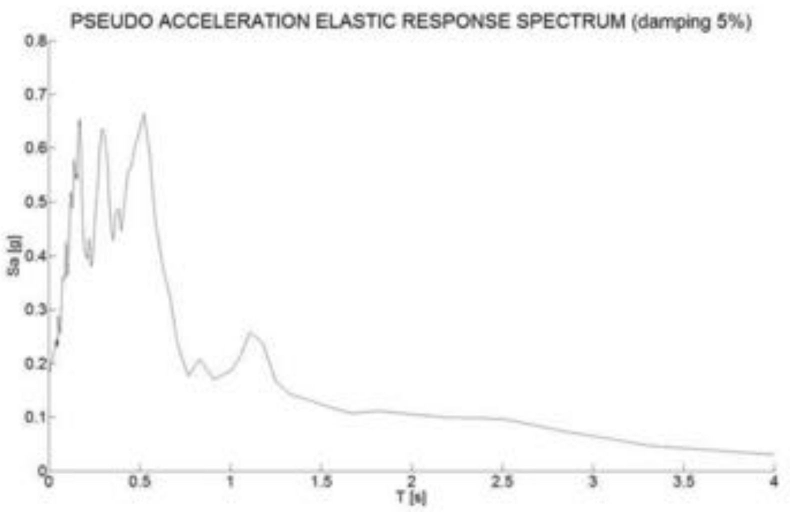
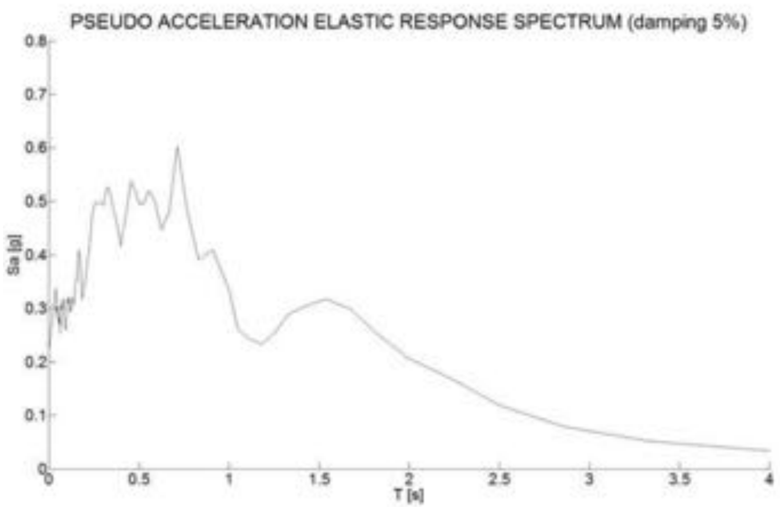


Y-record



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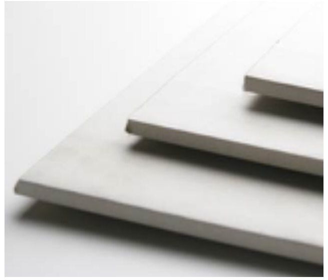
Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of experimental results of the 3rd specimen

Investigation of the seismic behaviour of a timber-frame building with gypsum fibre boards



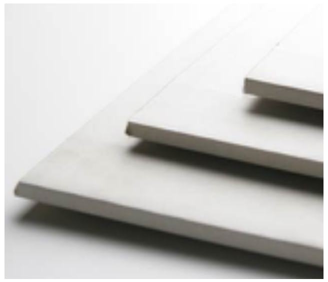
Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Gypsum fibre as material for sheathing panels

In the last twenty years gypsum fibreboard (GFB) has been demonstrated as an efficient solution both for **structural** and non-structural finishing of walls in light timber frame (LTF) buildings.

GFB demonstrate high performances in terms of sound insulation, vapour permeability and thermal inertia. Moreover GFB could be used to ensure an adequate fire protection of the walls.

Staples are usually adopted to connected the boards to the wood frame.



Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Gypsum Fibre boards vs Oriented Strand Boards

Properties		[°]	units	OSB	GFB
Thickness				15	15
Density	ρ_k		[kg/m³]	650	1150
Bending strength	$f_{m,k}$	0	[MPa]	16.4	4.0
		90	[MPa]	8.2	
Tensile strength	$f_{t,k}$	0	[MPa]	9.4	2.40
		90	[MPa]	7.0	
Compressive strength	$f_{c,k}$	0	[MPa]	15.4	8.50
		90	[MPa]	12.7	7.30
Shear strength	$f_{v,k}$		[MPa]	6.8	3.50
Modulus of elasticity in bending	E_m	0	[MPa]	4930	3800
		90	[MPa]	1980	
Modulus of elasticity in tension/compression	E_t	0	[MPa]	3800	3800
		90	[MPa]	3000	
Shear modulus	G		[MPa]	1080	1600
Thermal conductivity	λ		[W/mK]	0.13	0.32
Specific heat capacity c	c_p		[kJ/kgK]	1.7	1.1
Density	ρ_m		[kg/m3]	650	1150
Water vapour resistance factor	μ			30/50	13

Mechanical properties of GFB seem lower than OSB.

This does not mean that GFB is not adequate to be used as structural boards to bear lateral loads in LTF bindings during a seismic event!

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Background – Gypsum plaster boards GPB

Since the mid-90s different experimental campaigns have been carried out on LTF with gypsum plaster boards GPB.

Topics:

- ✓ Influence of GPB, used as finishing material, on the structural behaviour of shear walls sheathed with wood-based panels (OSB, PWD, Hardboard), *Van de Lindt (2004)*.
- ✓ Contribution of GPB in terms of dynamic proprieties changings (stiffening) and non-structural damages analysed by means of dynamic tests on shake table, *Fischer et al. (2001) - Christovasilis et al. (2007)*.
- ✓ Structural behaviour of shear walls sheathed with GPB, *Mc Mullin and Merrick (2007) – Dolan and Toothman (2003)*.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Background – Gypsum fibre boards GFB

On the contrary, **the mechanical behaviour of shear walls sheathed with GFB was not deeply studied, especially in the case of seismic loads**.

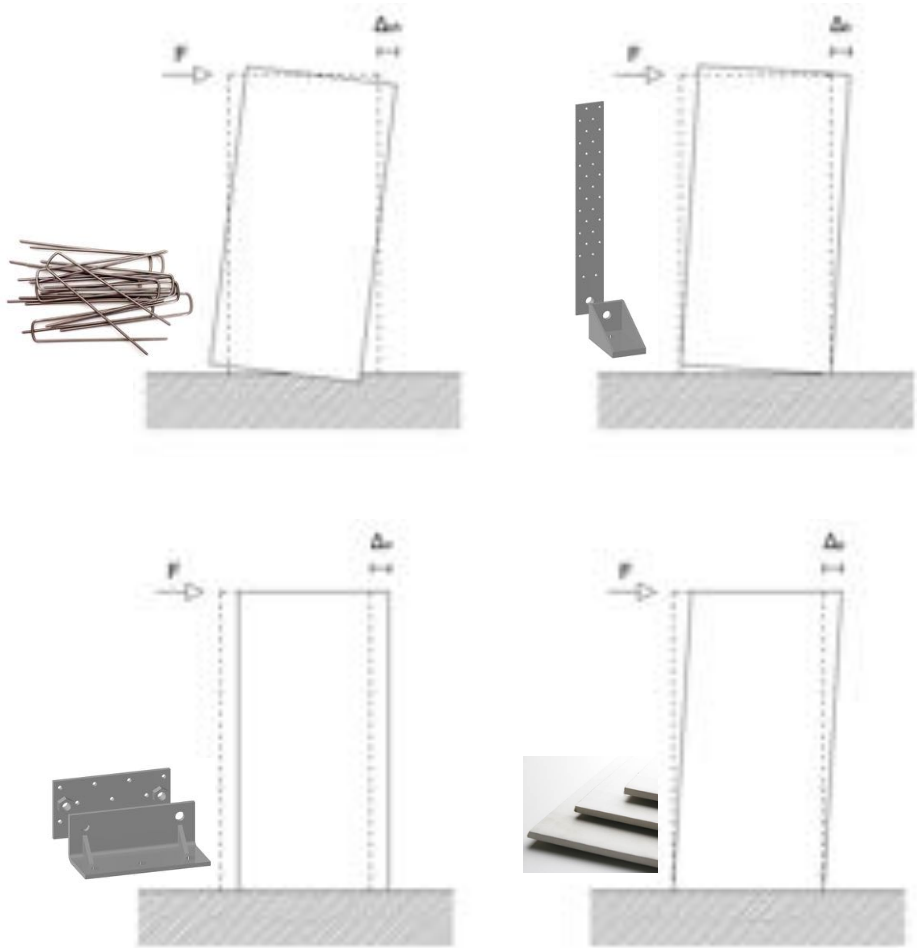
- ✓ *Grossi et al. (2014)* and *Vogt et al. (2014)*, compared the mechanical behaviour of walls sheathed with GFB, with OSB panels, or GFB-OSB mixed solution.
- ✓ Shake table tests, on wall segments were also carried out by *Finn (2006)* to investigate the load bearing capacity under a seismic dynamic input.

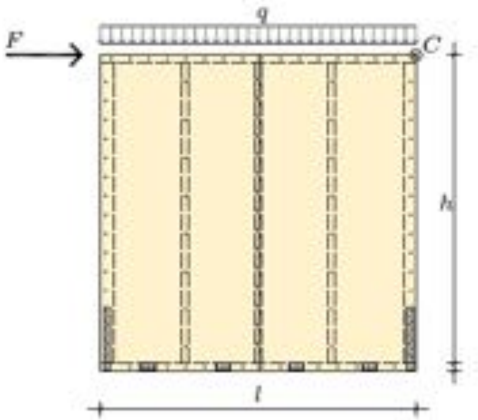
Next Step → Investigation of a LTF building completely sheathed by GFBs by means of a full-scale shaking table test. *Casagrande,Grossi and Tomasi. (2015)*

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Preliminary tests

The mechanical behaviour under lateral loads of the walls in LTF buildings can be related to four main contributions, *Casagrande et al. (2015),* namely the sheathing-to-framing connection (SH), the sheathing panel (P), the mechanical devices used to prevent the wall rotation (H) and sliding (A)





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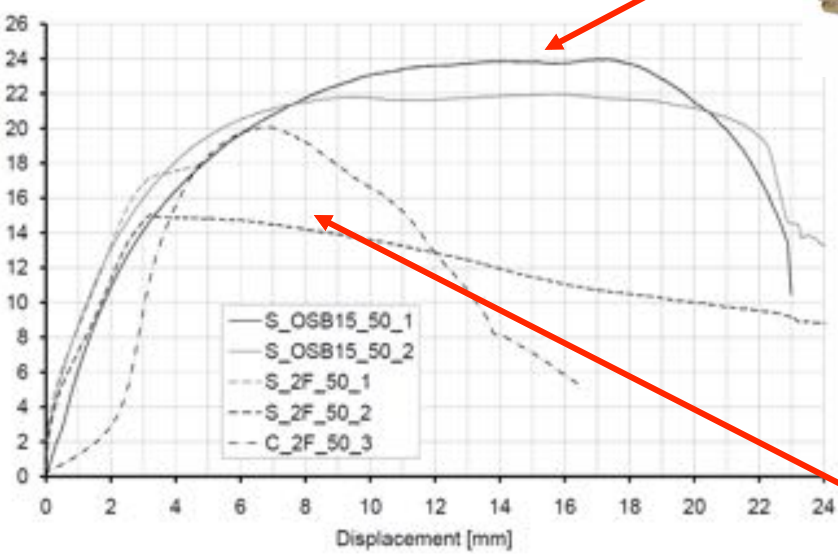
Sheathing-to-framing connection

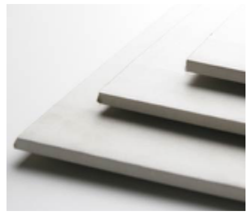
Tomasi and Sartori (2013)



OSB
(Oriented strand boards)

Ring nails
(2.8x60mm)

GFB
(Gypsum fibre boards)



Staples
(1.4x1.6x55mm)

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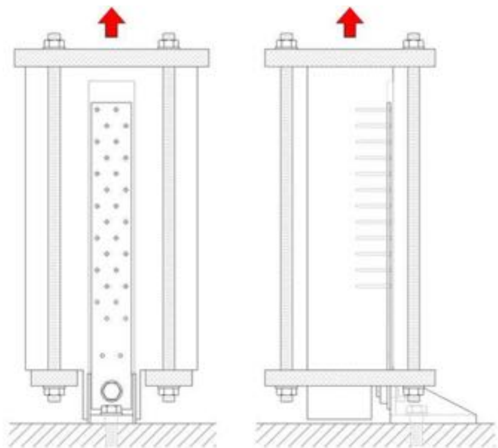
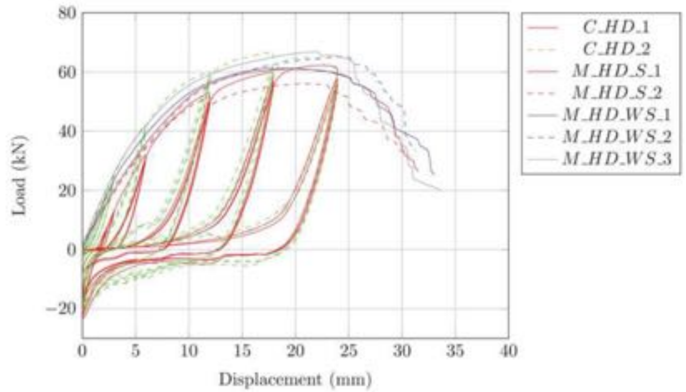
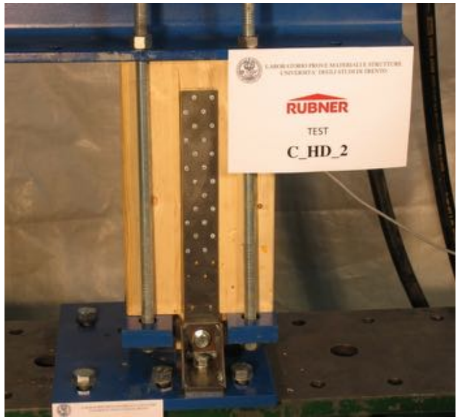
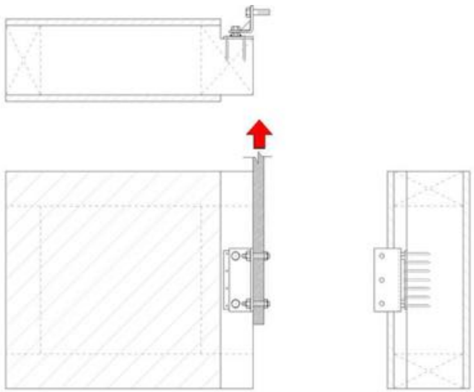
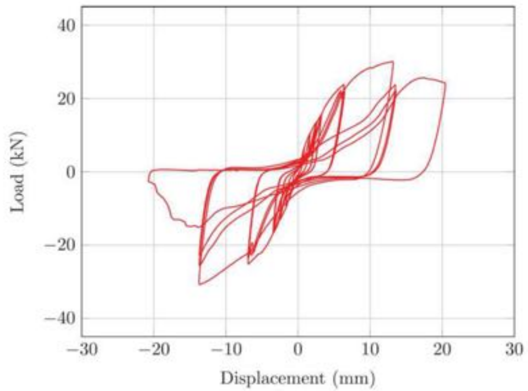
Hold-down and angle-brackets











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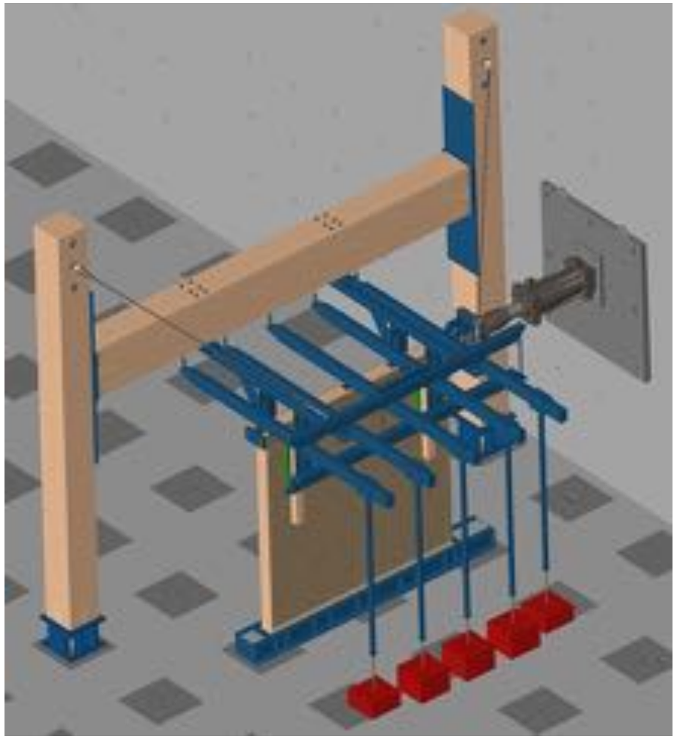
Preliminary tests on full-scale walls



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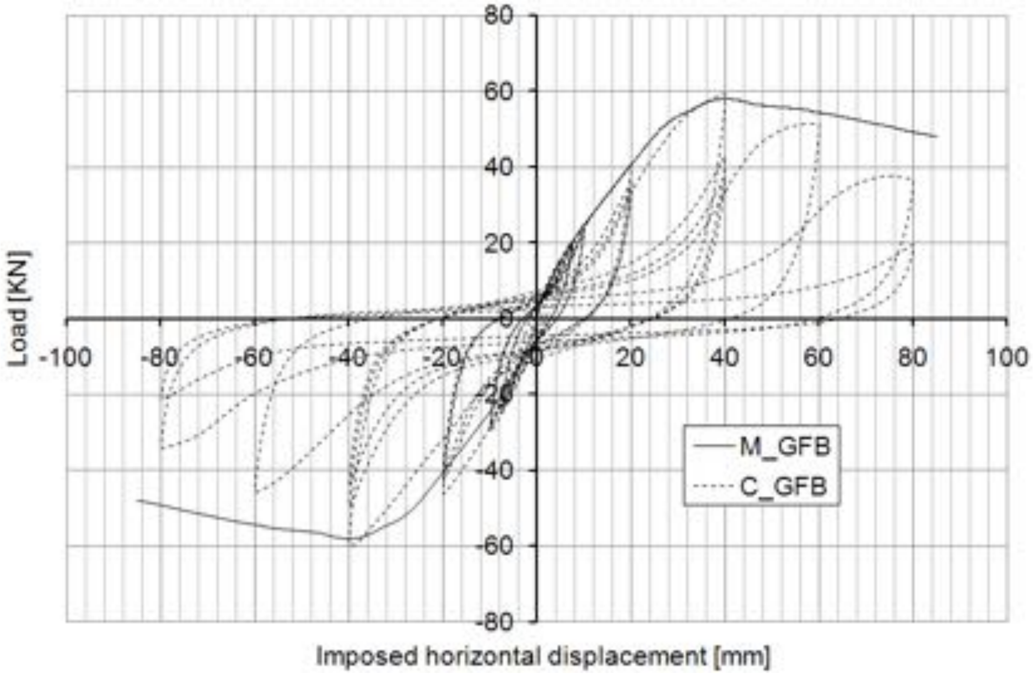
Preliminary tests on full-scale walls

The mechanism failure of the wall was related to the oligo-cyclic fatigue failure of the staple legs.



Therefore, in tested wall, the sheathing-to-framing connection represents the weakest component of the structural system.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Shake table test: two different stages

UN-WEAKENED BUILDING

Un-weakened building (stage 1)			
Labe	Typology	Targ-x	Targ-y
I0	Dynamic id.	-	-
D1	Seismic test		
D2	Seismic test	0.06g	0.07g
T1	Seismic test		
I1	Dynamic id.	-	-
D3	Seismic test		
D4	Seismic test	0.12g	0.15g
T2	Seismic test		
I2	Dynamic id.	-	-
D5	Seismic test		
D6	Seismic test	0.23g	0.28g
T3	Seismic test		
I3	Dynamic id.	-	-
D7	Seismic test		
D8	Seismic test	0.40g	0.50g
T4	Seismic test		
I4	Dynamic id.	-	-

The input signals was scaled from 0.07 g to 0.50 g along the longitudinal direction (Y) of the specimen

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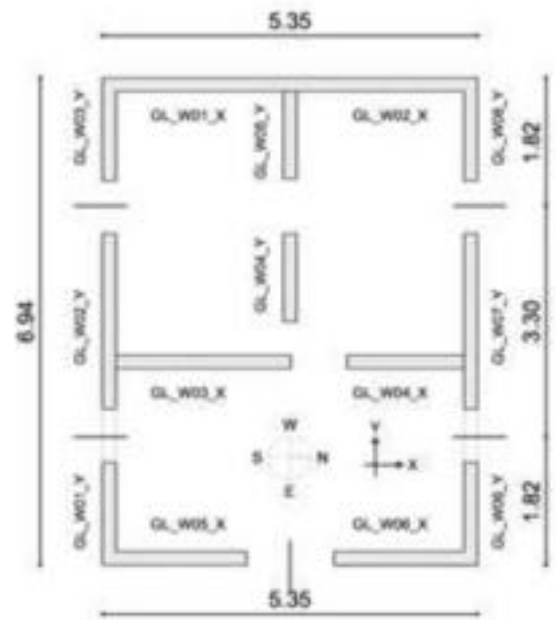
Shake table test: two different stages

WEAKENED BUILDING

First floor



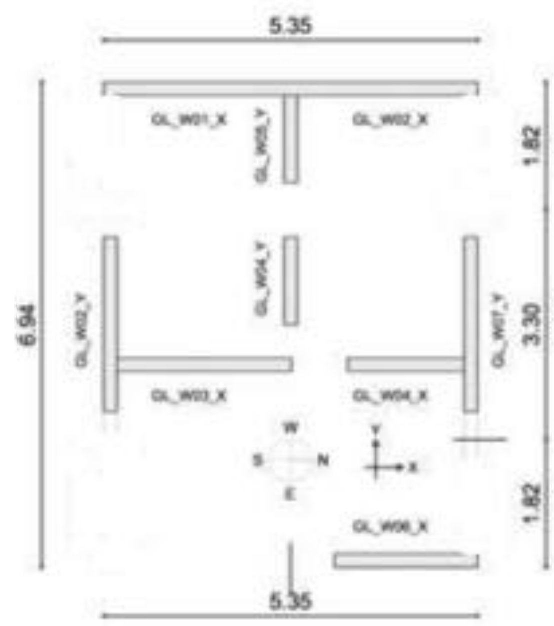
This operation leads to a “new structure” where the lateral load bearing system of the ground floor is reduced keeping the same capacity for vertical loading.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Shake table test: two different stages

WEAKENED BUILDING

First floor



Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Shake table test: two different stages

WEAKENED BUILDING

Weakened building (stage 2)

Label	Typology	Targ-x	Targ-y
I5	Dynamic id.	-	
D9	Seismic test		
D10	Seismic test	0.06g	0.07g
D11	Seismic test		
T5	Seismic test		
I6	Dynamic id.	-	
D13	Seismic test		
D12	Seismic test	0.12g	0.15g
T6	Seismic test		
I7	Dynamic id.	-	
D14	Seismic test		
D15	Seismic test	0.23g	0.28g
D16	Seismic test		
T7	Seismic test		
I8	Dynamic id.	-	
D17	Seismic test		
D18	Seismic test	0.40g	0.50g
D19	Seismic test		
I9	Dynamic id.	-	
T8	Seismic test	0.40g	0.50g
I10	Dynamic id.		
T9	Seismic test	0.53g	0.66g
I11	Dynamic id.	-	

The input signals was scaled from 0.07 g to 0.66 g along the longitudinal direction (Y) of the specimen

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Shake table test

0.50g

0.66g

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Shake table test

0.50g

0.66g

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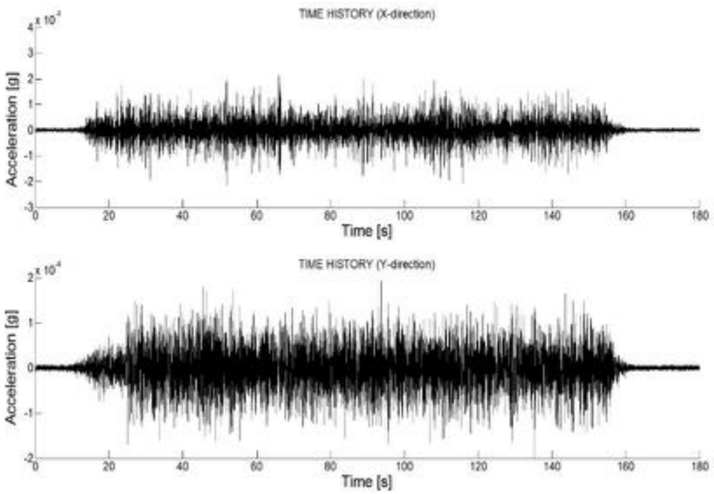
Dynamic identification

After each step of the test a dynamic identification of the model was performed (noise signal with a RMS of 0.05g and a frequency range between 0.1 and 30hz in order to get **natural frequencies and mode shapes**.



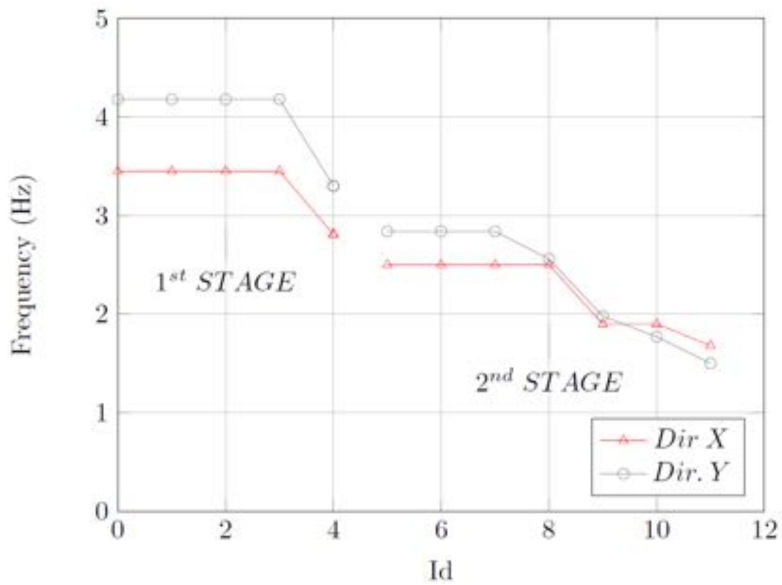
Un-weakened building (stage 1)			
Labe	Typology	Targ-x	Targ-y
I0	Dynamic id.	-	-
D1	Seismic test	0.06g	0.07g
D2	Seismic test		
T1	Seismic test		
I1	Dynamic id.	-	-
D3	Seismic test	0.12g	0.15g
D4	Seismic test		
T2	Seismic test		
I2	Dynamic id.	-	-
D5	Seismic test	0.23g	0.28g
D6	Seismic test		
T3	Seismic test		
I3	Dynamic id.	-	-
D7	Seismic test	0.40g	0.50g
D8	Seismic test		
T4	Seismic test		
I4	Dynamic id.	-	-

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – natural frequencies

With the aim of detecting any damage of the structure a dynamic identification test was carried out after every target T seismic test.

Since a variation of modal properties was observed after the seismic tests of the stage (test I4), we can assume that the dynamic behaviour of the building in the stage 2 had been influenced by the stage 1 seismic tests. For this reason **the un-weakened building, despite of no visible damage was detected by visual inspection, cannot be considered as a "new" building**



frequencies [Hz]

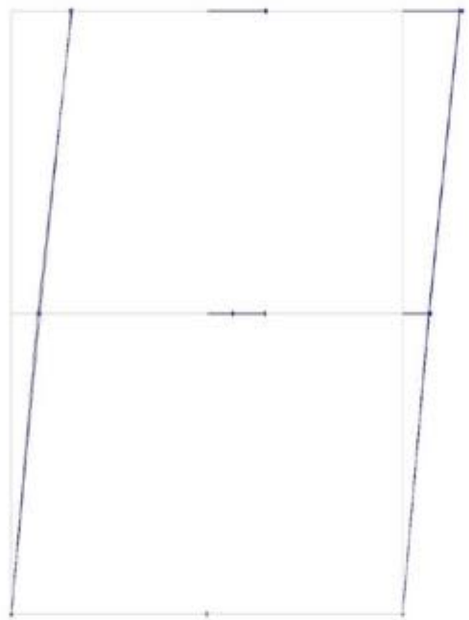
	I0	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11
1st x	3.45	3.45	3.45	3.45	2.81	2.50	2.50	2.50	2.50	1.90	1.90	1.68
1st y	4.18	4.18	4.18	4.18	3.30	2.84	2.84	2.84	2.56	1.98	1.77	1.50

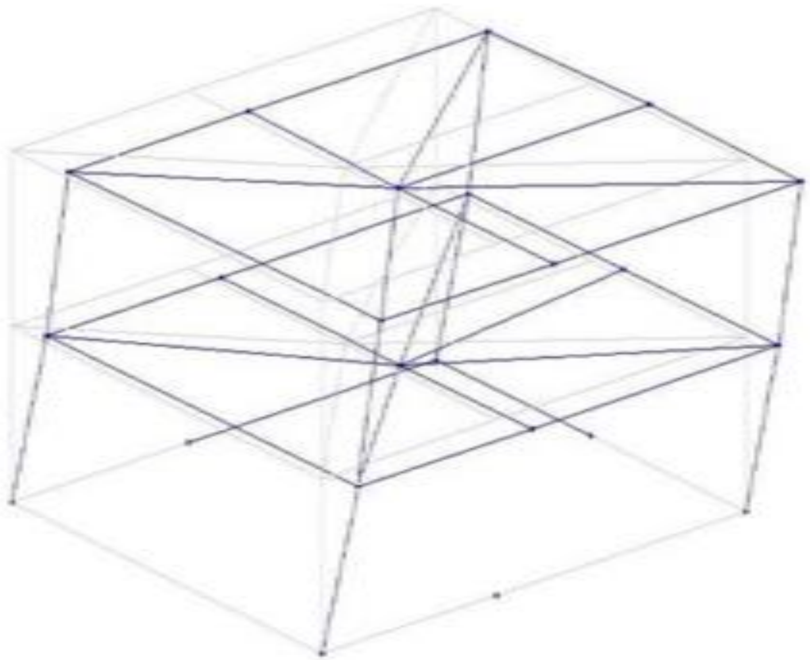
Un-weakened Weakened

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – mode shapes

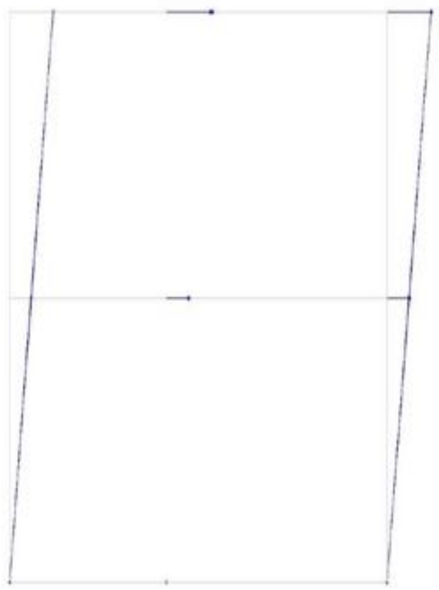
Un-weakened
TRANSVERSAL X
3.45 Hz

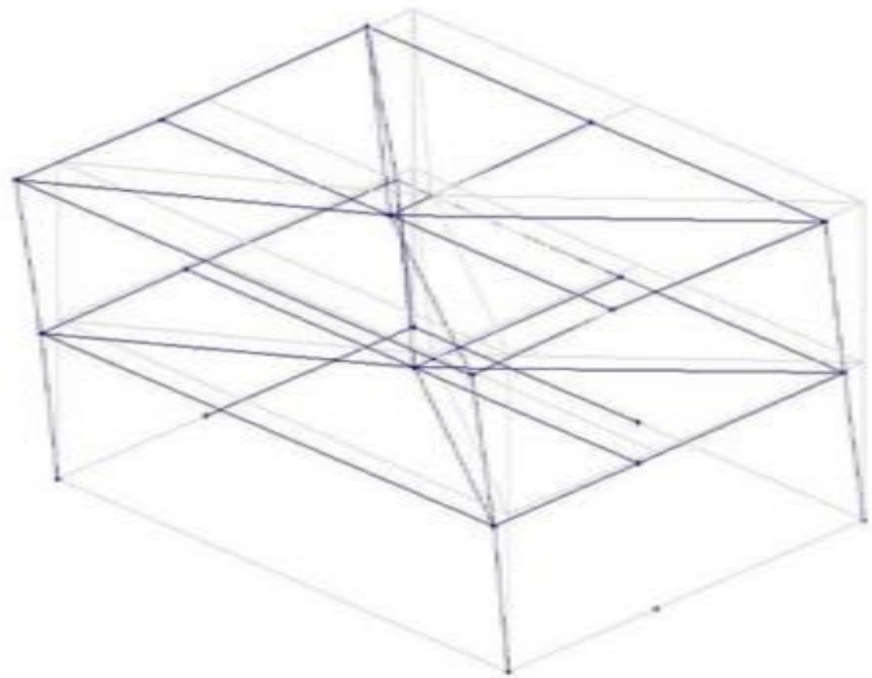




Analysis of results – mode shapes

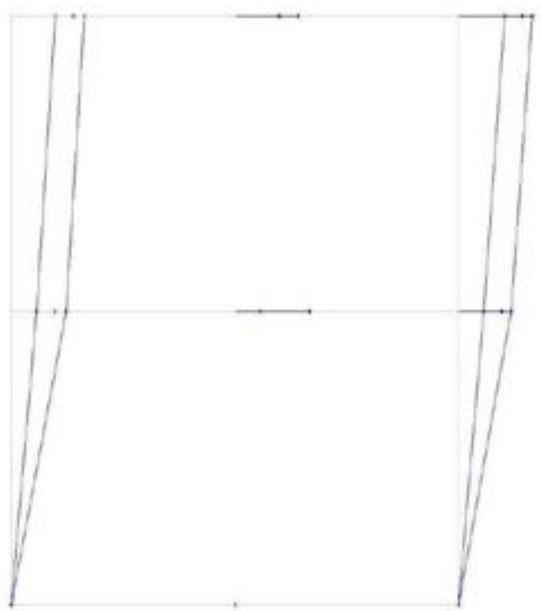
Un-weakened
LONGITUDINAL Y
4.18 Hz

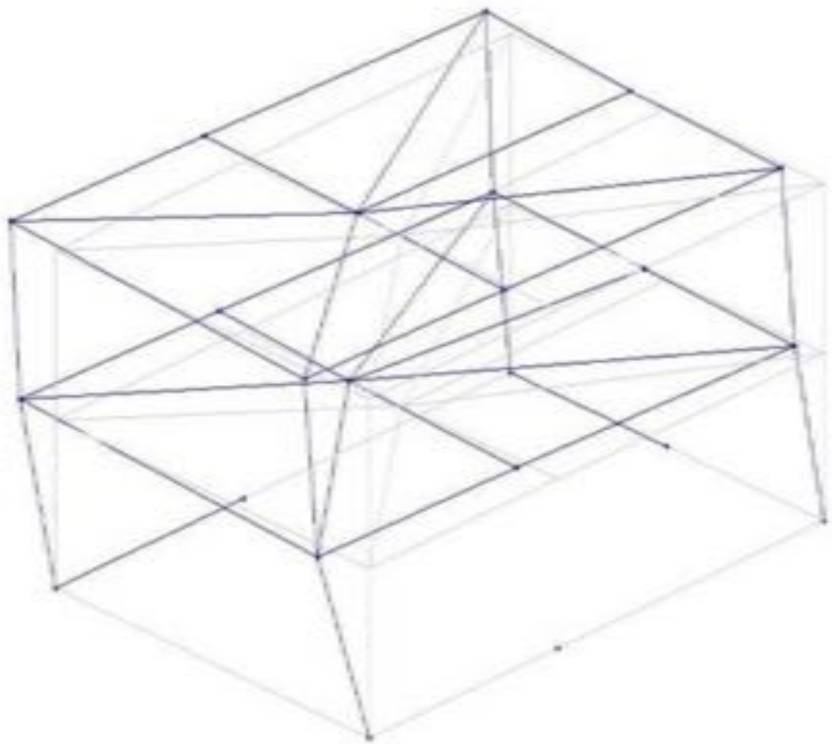




Analysis of results – mode shapes

Weakened
TRANSVERSAL X
2.50 Hz

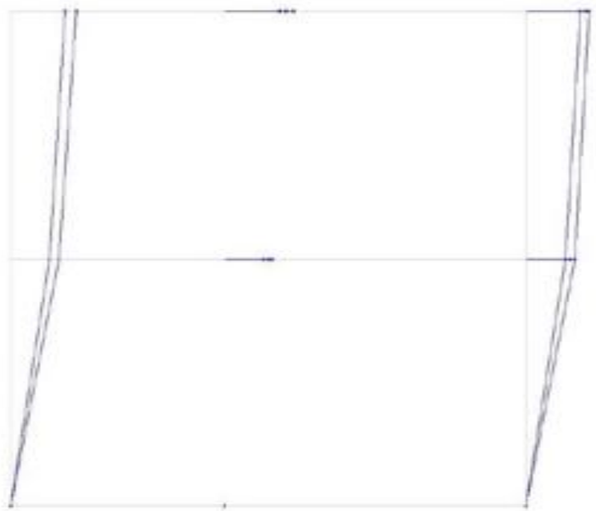


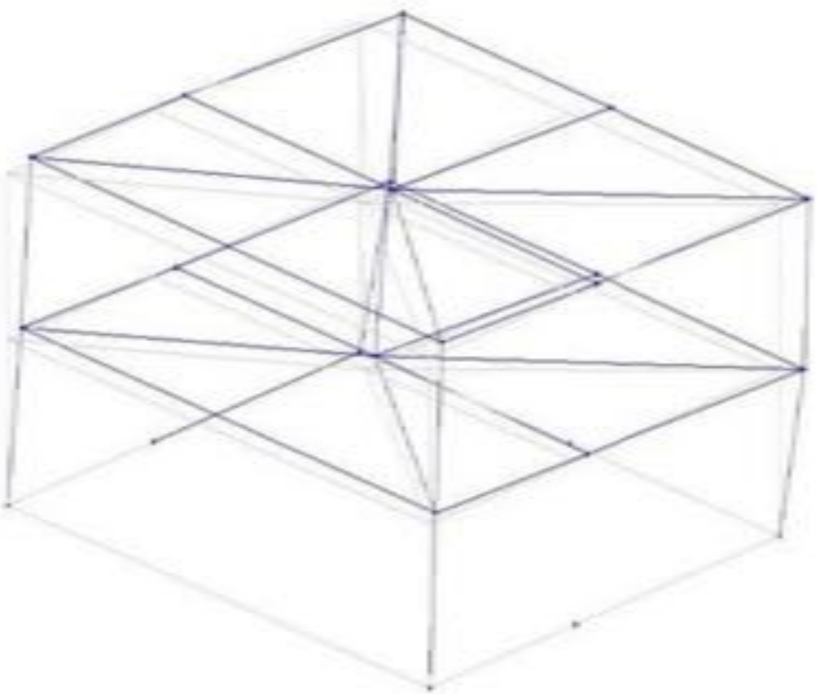


Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – mode shapes

Weakened
LONGITUDINAL Y
2.84 Hz



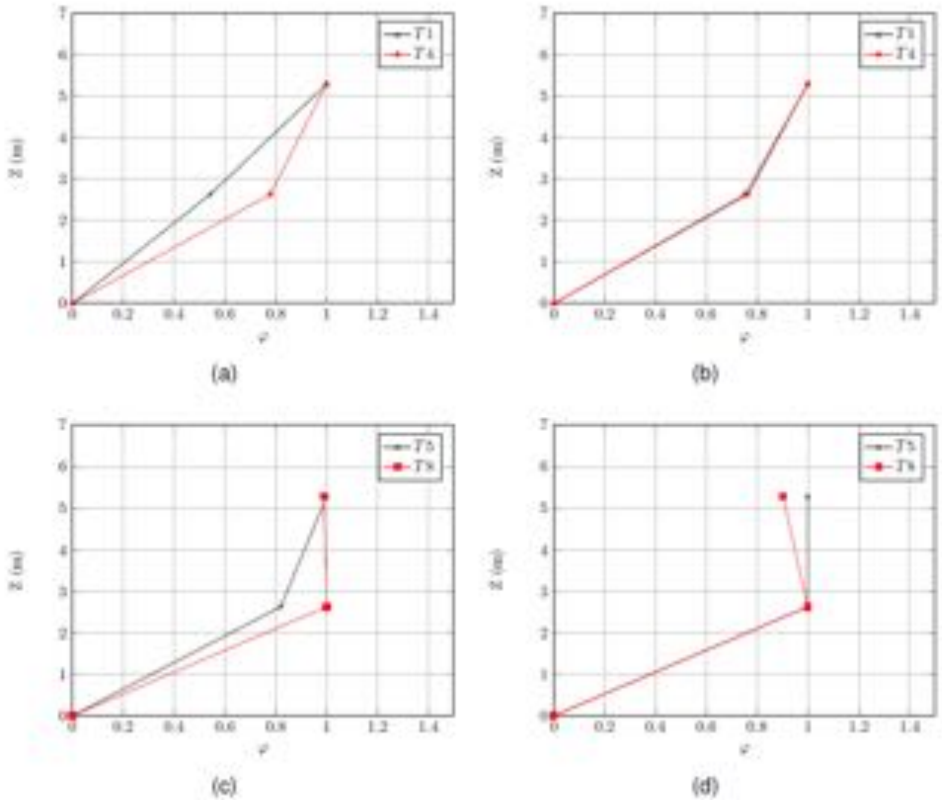


Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – peak accelerations (g)

Dir.	Test / Pos.	Un-weakened (stage 1) T1	T2	T3	T4
X	Ref.acc.				
	Table	0.06	0.12	0.22	0.57
	1st floor	0.1	0.17	0.35	0.69
	2nd floor	0.19	0.3	0.49	0.89
Y	Ref.acc.				
	Table	0.07	0.13	0.28	0.51
	1st floor	0.1	0.18	0.39	0.62
	2nd floor	0.13	0.25	0.44	0.82

Dir.	Test / Pos.	Weakened (stage 2) T5	T6	T7	D19	T8	T9
X	Ref.acc.						
	Table	0.06	0.1	0.22	0.42	0.43	0.44
	1st floor	0.08	0.2	0.57	1.01	0.97	0.84
	2nd floor	0.1	0.24	0.57	0.99	0.96	0.93
Y	Ref.acc.						
	Table	0.07	0.14	0.29	0.47	0.73	0.73
	1st floor	0.13	0.25	0.52	0.89	1.03	1.1
	2nd floor	0.13	0.23	0.45	0.87	0.93	0.96



Analysis of results – inter-storey displacement and drift

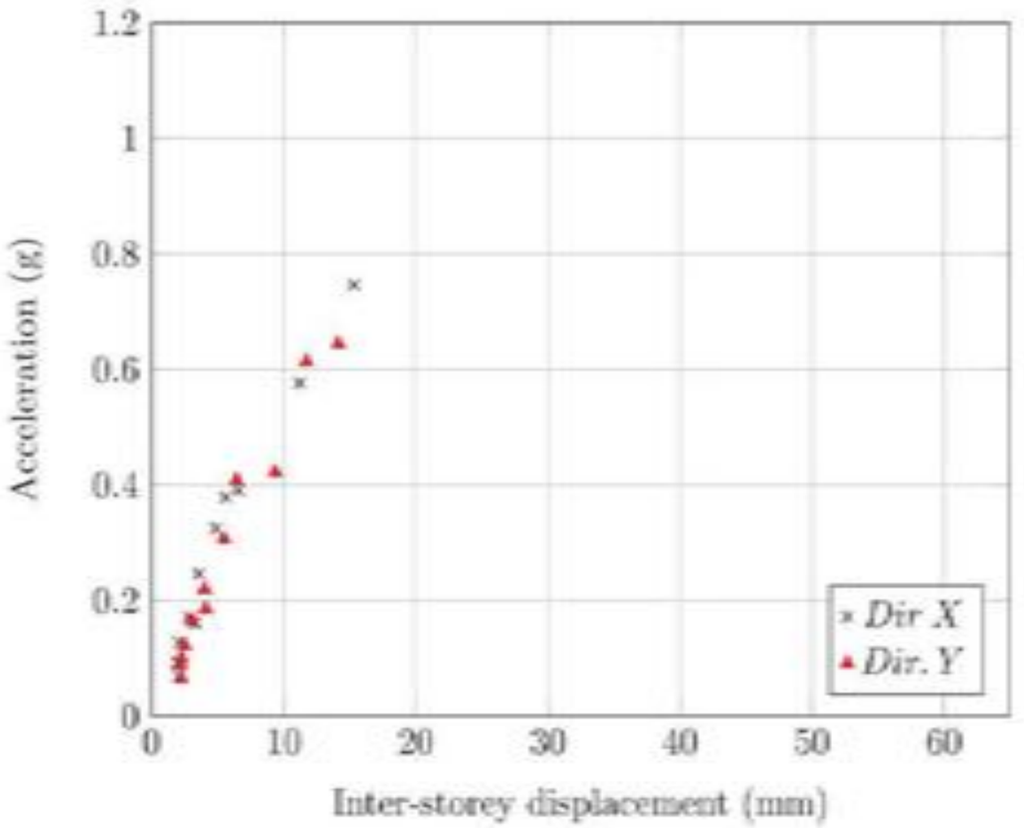
The inter-storey displacement and the **inter-storey drift** , defined as the ratio between and the inter-storey height of the building (in this case equal to 2560 mm), are **key factors for understanding the mechanical behaviour of a structure under a seismic event**. The damage-level and the seismic capacity of the structure are in fact strongly related to these two parameters, *Fischer et al. (2001) - Van de Lindt et al. (2006) – Tomasi et al. (2014)*.

	Ground-first dir. X				Ground-first dir. Y			
	Lvdt		opt.		Lvdt		opt.	
	Δ [mm]	ϑ [%]	Δ [mm]	ϑ [%]	Δ [mm]	ϑ [%]	Δ [mm]	ϑ [%]
T1	0.5	0.02	1.9	0.08	0.9	0.04	2.2	0.09
T2	1	0.04	2.8	0.11	2.2	0.09	4.1	0.16
T3	2.6	0.1	5.6	0.22	7.1	0.28	6.4	0.25
T4	6.6	0.26	15.3	0.6	19.6	0.77	14.1	0.55
T5	1.1	0.04	2.6	0.1	3.5	0.14	4.5	0.18
T6	2.5	0.1	5.5	0.22	7.9	0.31	7.1	0.28
T7	5.6	0.22	10.8	0.42	16.7	0.65	15.3	0.6
D19	11	0.43	16.7	0.65	34.1	1.33	30	1.17
T8	12	0.47	15.3	0.6	40.8	1.6	38.6	1.51
T9	12.5	0.49	16	0.62	60	2.35	62.9	2.46

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

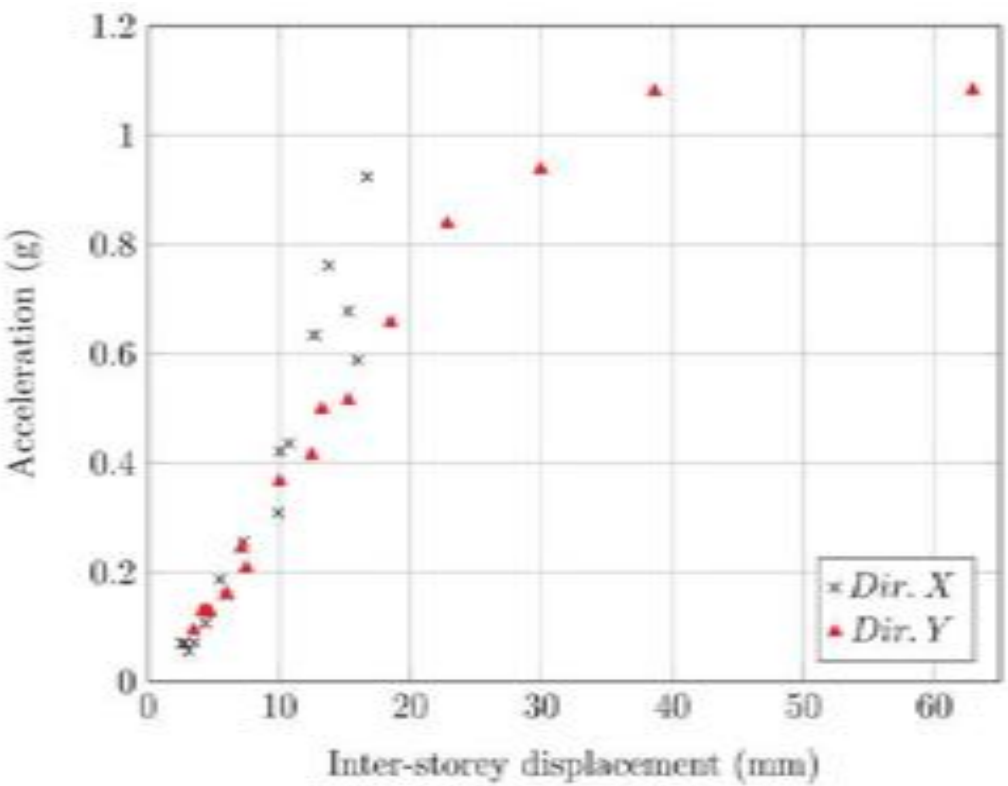
Analysis of results – peak acceleration vs inter-storey drift

Un-Weakened



Analysis of results – peak acceleration vs inter-storey drift

Weakened



a significant reduction of the curve slope shown for displacement greater than 30 mm, confirming a strong non-linear behaviour of the structure in the last tests.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – visual inspection

D19
0.50 g

T9
0.66g

list of visual damages for stage 2

Test	Detected damage
D19	Cracking of GFB in the proximity of the hold down anchor (W06_X, north east bottom corner), cracking on gypsum wallboards at corners of openings at the ground level (W01_Y, south east - W02_Y, south - W06_X, north east), cracking on the GFB at the ground level (W_06_X, north), spalling of the bottom edge of the GFB (W07_Y, north) at the ground level.
T8	Cracking on the GFB at the ground level (W_07_Y, north – W04_X, central), cracking of the bottom corner of the GFB (W07_Y, north) at the ground level.
T9	Spalling at the corner of the window (W_06_Y, north), staples pull through (W_07_Y, north),cracking of GFB in the proximity of the hold down anchor (W04_X, north east bottom corner), cracking on the GFB at the ground level (W_07_Y, north)

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – Tensile Forces in Hold-downs

Peak values [kN]

peak tensile force values [kN]

	Un-weakened (stage 1)				Weakened (stage 2)					
	T1	T2	T3	T4	T5	T6	T7	D19	T8	T9
GLW06X_L	0.2	0.2	0.2	5.3	0.1	0.2	0.2	3.6	4.1	4.9
GLW06X_R	0.1	0.2	0.3	13.4	0.2	1.0	13.5	37.2	**39.3**	32.0
GLW07Y_L	0.2	0.3	0.6	5.9	0.2	0.5	1.1	6.5	8.4	8.1
GLW07Y_R	0.8	1.3	1.8	19.2	0.6	0.9	13.4	43.4	32.0	16.9
GLW01X_L	0.2	0.2	0.2	1.2	0.2	0.2	0.2	2.2	4.8	10.7
GLW01X_R	0.1	0.1	0.4	5.6	0.1	0.2	0.3	8.0	7.8	2.2
GLW04Y_L	0.2	0.4	1.1	2.1	0.3	0.6	1.2	5.8	11.9	21.3
GLW04Y_R	1.2	1.0	1.4	6.1	0.5	0.4	1.8	14.3	18.5	24.2
GLW02X_L	0.1	0.2	5.0	**25.1**	0.2	0.4	8.7	25.6	21.8	10.3
GLW02X_R	0.1	0.2	0.4	3.3	0.1	0.1	0.2	0.7	0.9	1.0

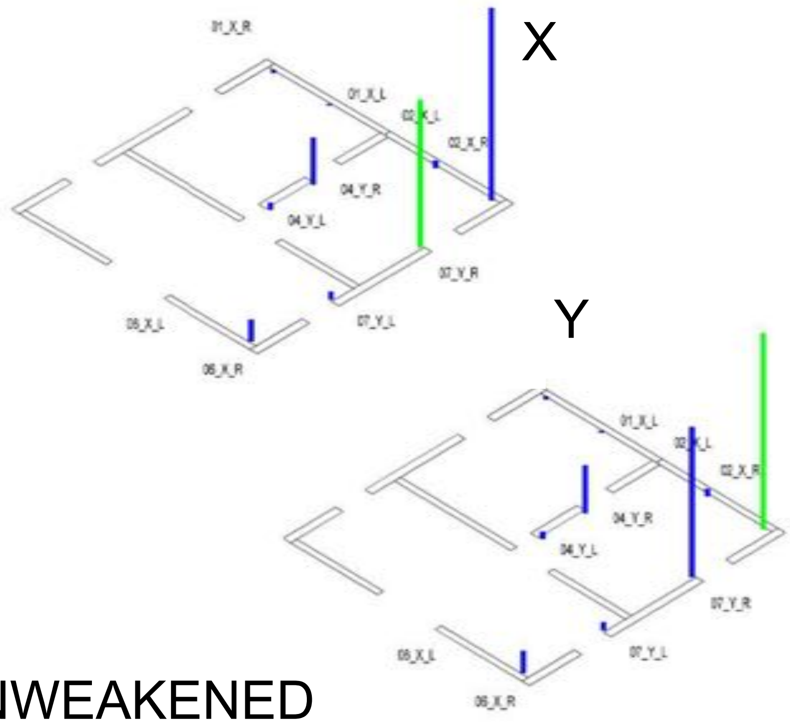
These values are quite lower than the strength obtained from laboratory test (equal to 62 kN), confirming that the structural damage was related to the sheathing-to-framing connections and GFB.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

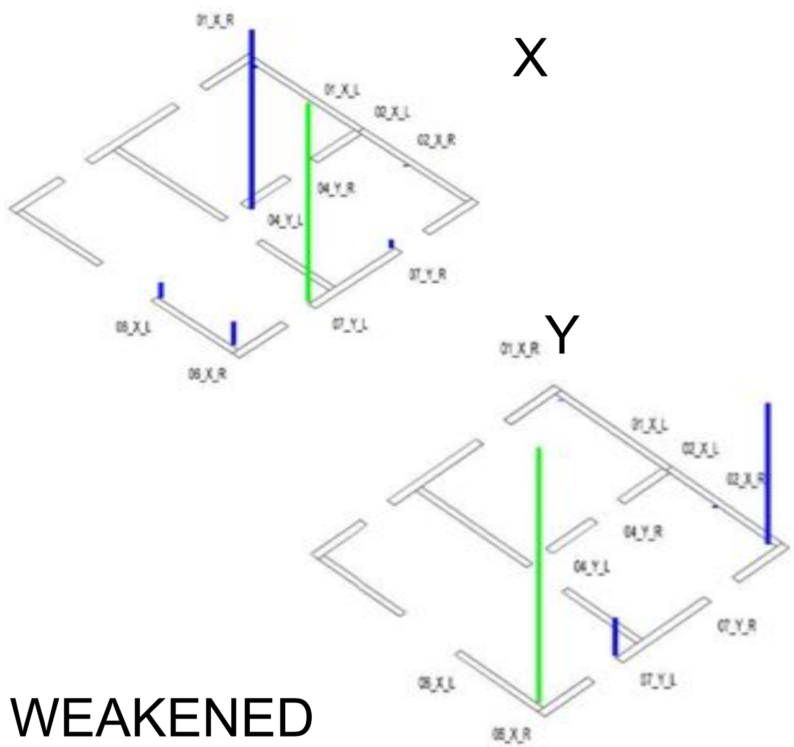
Action FP1004

Analysis of results – Tensile Forces in Hold-downs

0.50g - Simultaneous values [kN]



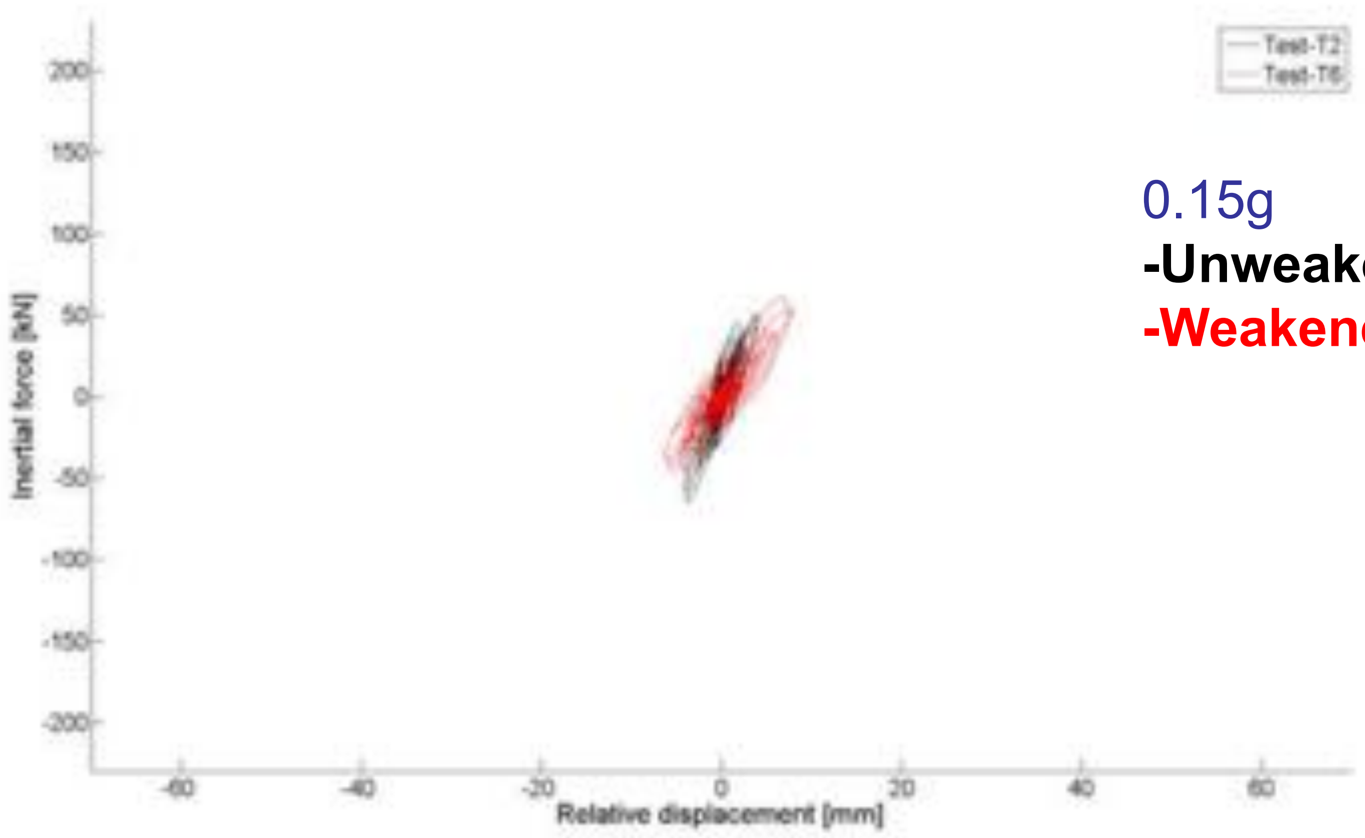
UNWEAKENED



WEAKENED

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – Global hysteresis behaviour along Y-direction



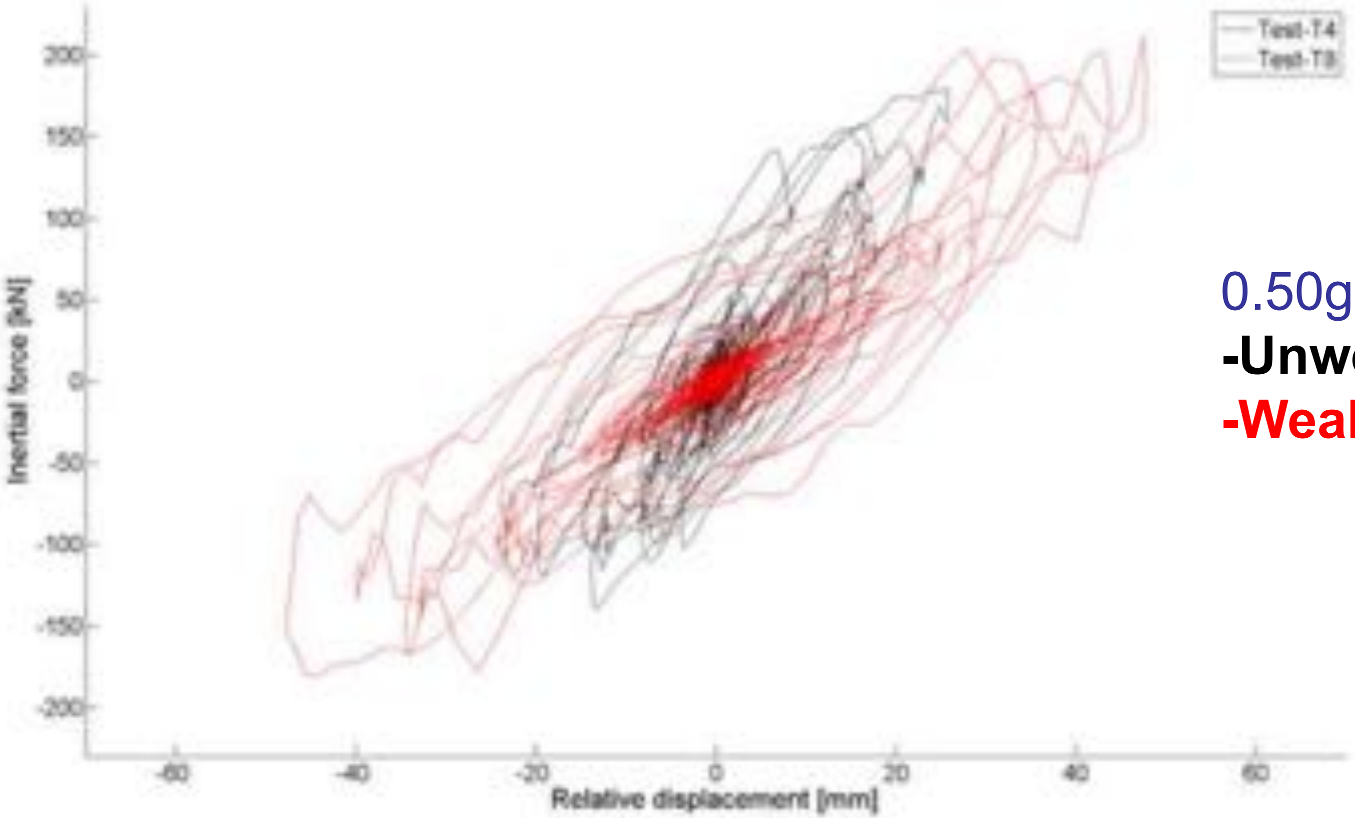
0.15g

-Unweakened

-Weakened

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – Global hysteresis behaviour along Y-direction



0.50g

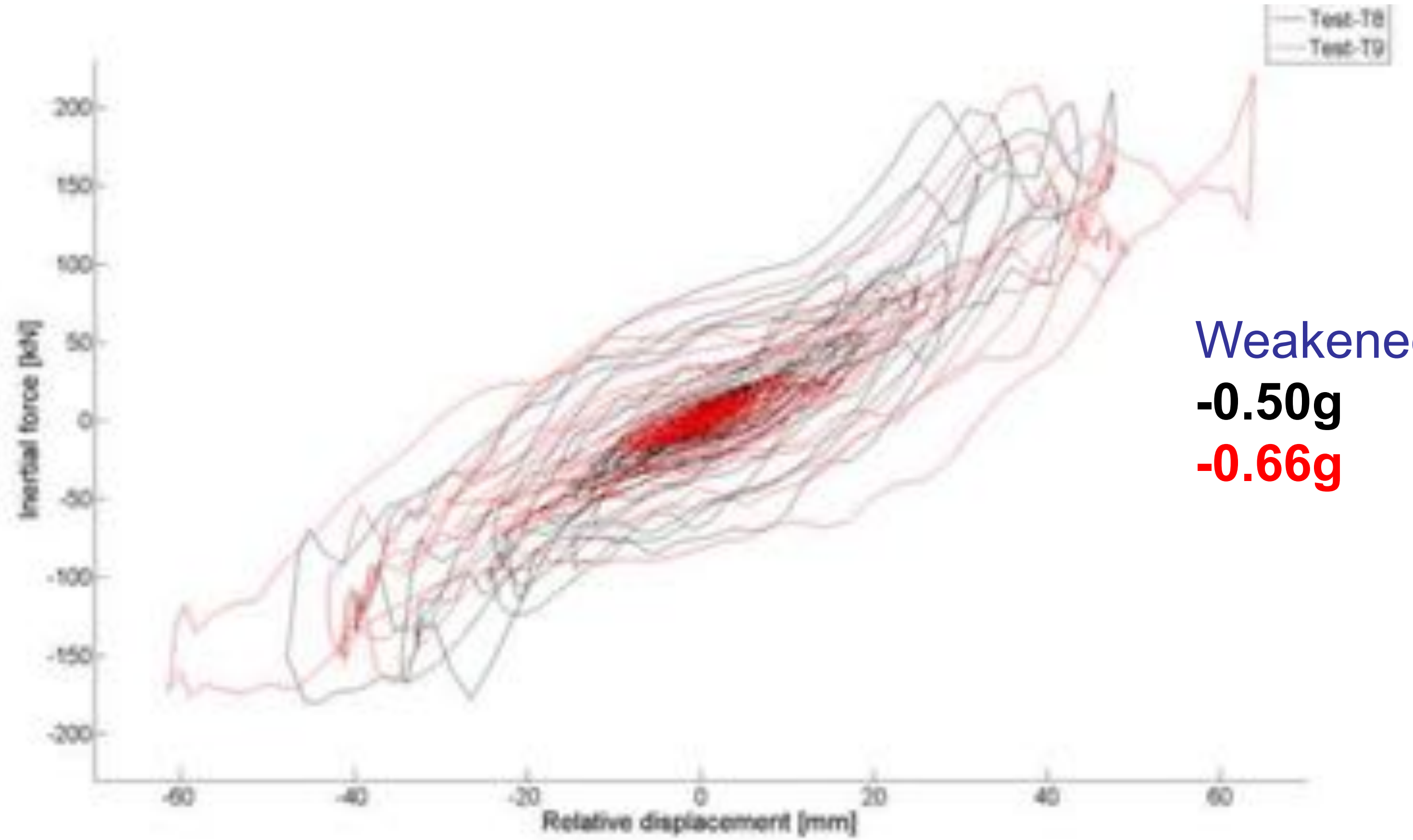
-Unweakened

-Weakened

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Action FP1004

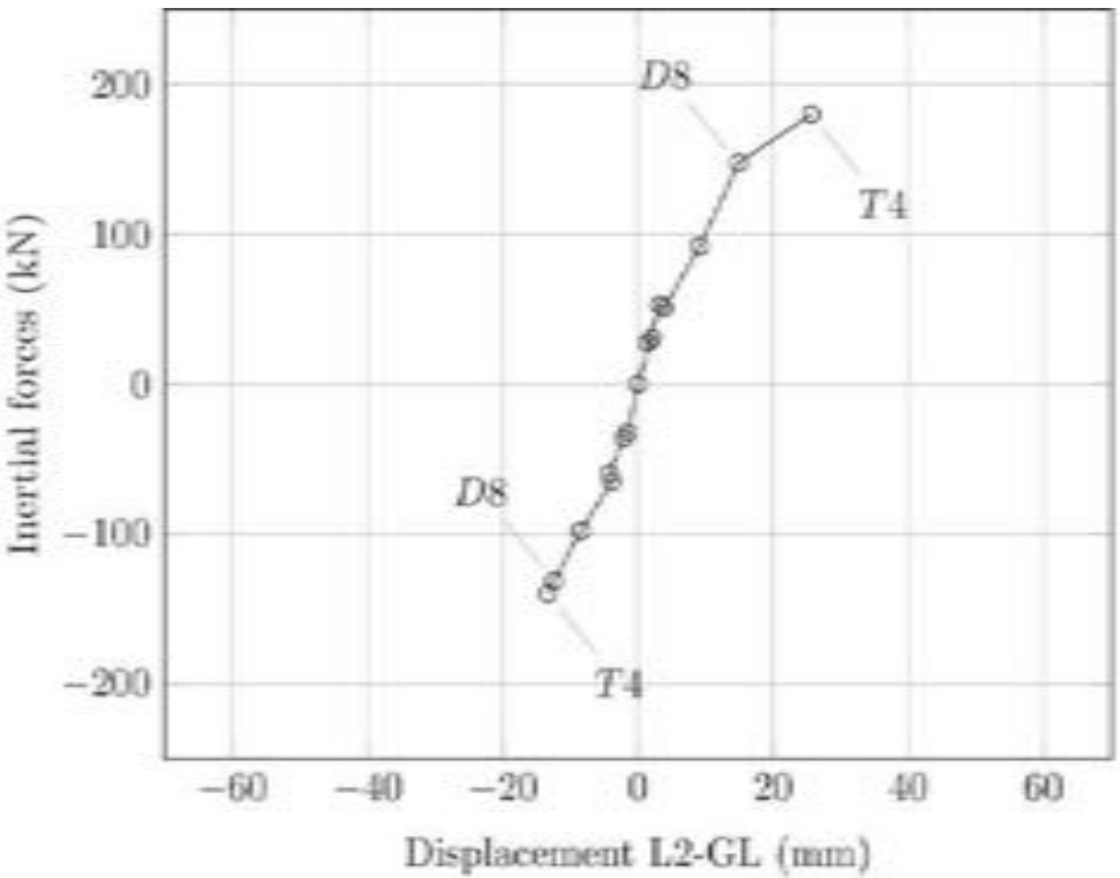
Analysis of results – Global hysteresis behaviour along Y-direction



Weakened
-0.50g
-0.66g

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

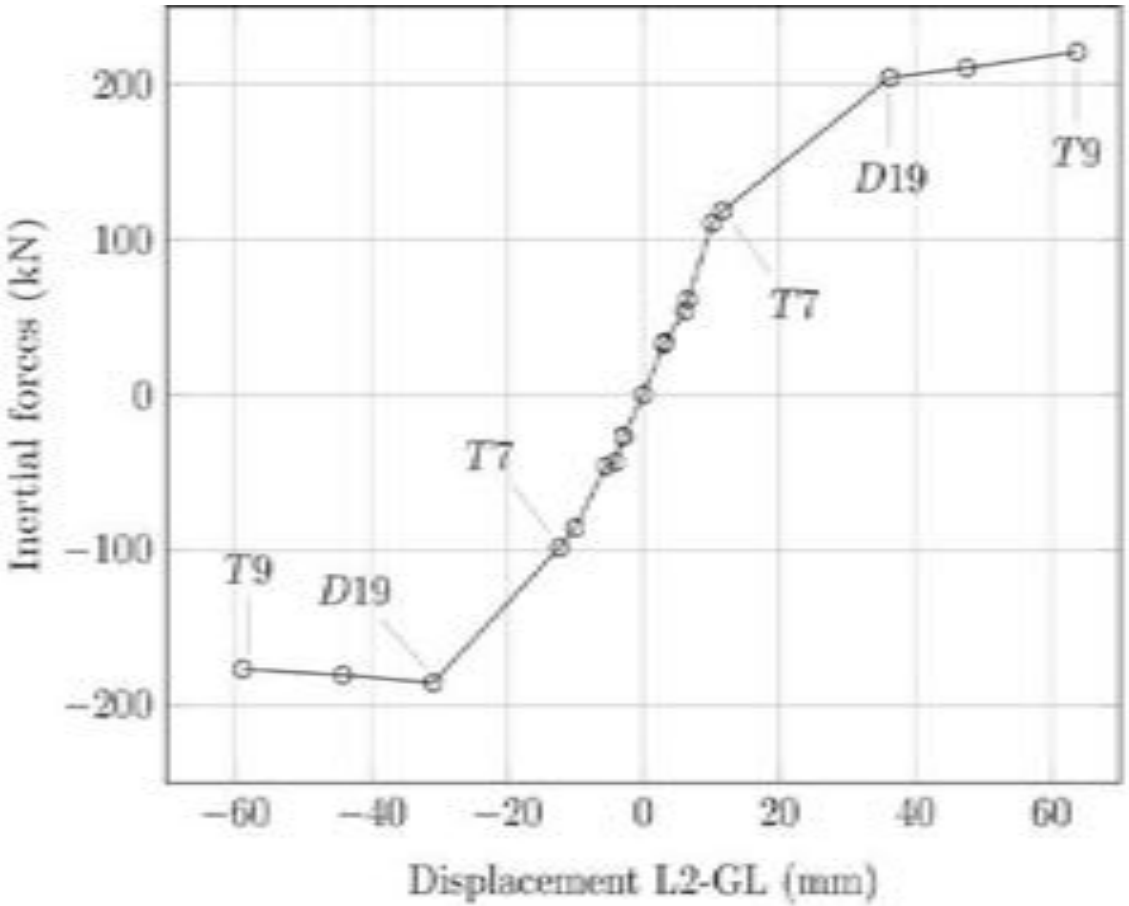
Analysis of results – Capacity spectra



Unweakened

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

Analysis of results – Capacity spectra



Weakened

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

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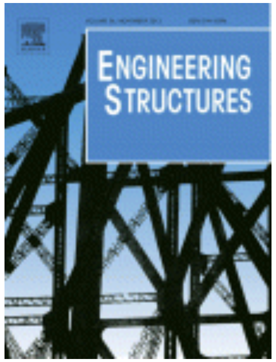
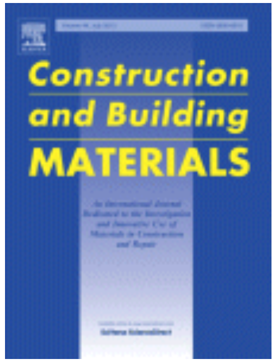
network CHI QUADRATO





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Tomasi R., Sartori T., Casagrande D., Piazza M., **Shaking table test on a full scale three-storey timber framed building** (2015), Journal of Earthquake Engineering, Vol. 19, Iss. 3, 2015

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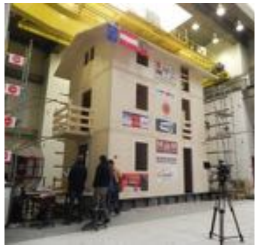



SPECIAL ISSUE ON SEISMIC TESTING OF TIMBER BUILDINGS

1. Piazza M., Tomasi R., Grossi P., Campos Costa A., Candeias P. X. **Investigation of Seismic Performance of Multi-storey Timber Buildings under the framework of EU-project 'SERIES**‘ (2014) Proceedings of the Institution of Civil Engineers: Structures and Buildings, in press.
2. Sartori, T., Grossi, P., Tomasi, R. **Tests on timber frame walls under in-plane forces: PART 2** (2014) Proceedings of the Institution of Civil Engineers: Structures and Buildings, in press.
3. Grossi, P., Sartori, T., Tomasi, R. **Tests on timber frame walls under in-plane forces: PART 1** (2014) Proceedings of the Institution of Civil Engineers: Structures and Buildings, in press.
4. Tomasi, R., Casagrande D., Sartori, T., Grossi, P., **Shaking table test on 3-storey light-frame timber building with OSB sheathing panels: outcomes and results** (2014) Proceedings of the Institution of Civil Engineers: Structures and Buildings, in press.

Shake table tests on a full-scale timber-frame building with gypsum fibre boards

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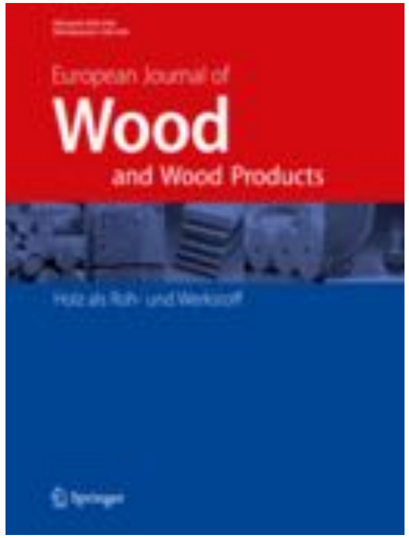

Daniele Casagrande, Paolo Grossi, Roberto Tomasi

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European Journal of Wood and Wood Products

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