COMMISSION OF THE EUROPEAN COMMUNITIES
FP7- INFRASTRUCTURES-2008-1
SP4-Capacities

S E R I E S

SEISMIC ENGINEERING RESEARCH INFRASTRUCTURES FOR EUROPEAN SYNERGIES

SERIES Workshop:

"Role of research infrastructures in seismic rehabilitation"

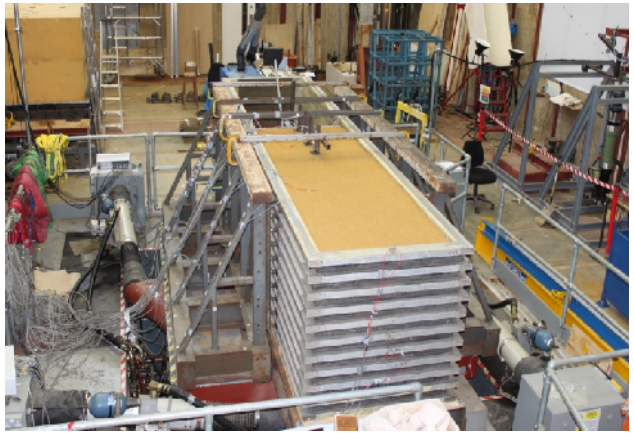
February 8-9, 2012
Istanbul Technical University (Turkey)

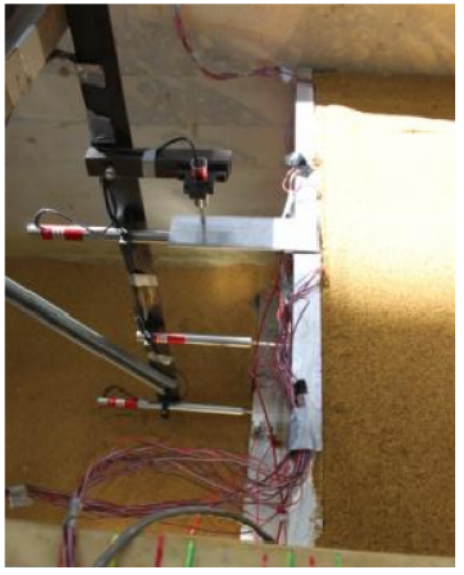
DYNCREW Project (TA-1)

Experimental investigation of the dynamic behaviour of cantilever retaining walls

*P. Kloukinas, **A. Penna**, A. Scotto Di Santolo, S. Bhattacharya, M.Dietz, L.Dihoru, A. Evangelista, A.L.Simonelli, C.A. Taylor, G. Mylonakis*

Experimental investigation of the dynamic behaviour of cantilever retaining walls





Project leader: Prof. A. Evangelista (Univ. of Napoli Federico II).

Main Objective: To investigate salient features of the problem, such as:
(1) The magnitude of earthquake-induced soil thrust and its point of application;
(2) The relative sliding over rocking of the wall base and the corresponding failure mode;
(3)The importance/interplay between soil stiffness, wall dimensions, and excitation characteristics, as affecting the above.

Methodology: Modelled in the large flexible shear stack at UNIVBRIS to impose correct boundary conditions.

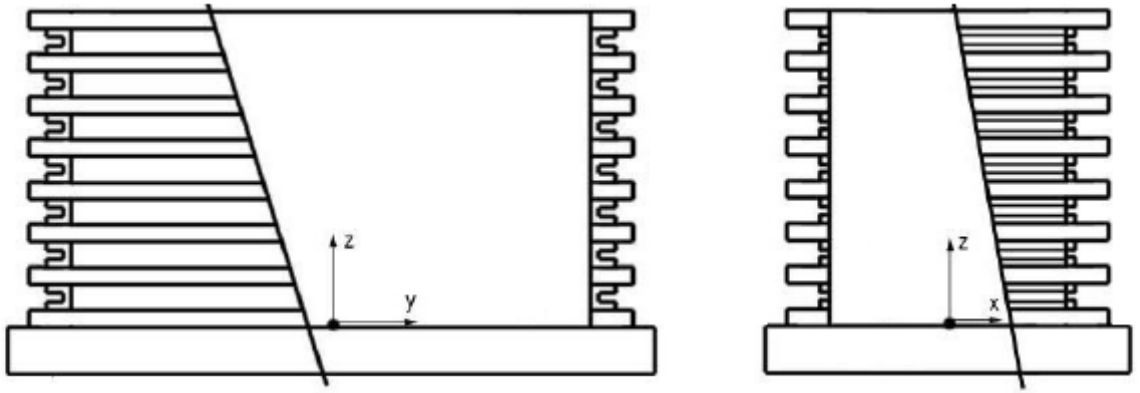
6-DOF Shaking Table of BLADE

- maximum payload of 210KN
- 1000KN isolating block
- eight 300mm stroke, 70kN
- operates up to 100Hz

The Large Laminar Shear Box at UNIVBRIS

- 5 m long
- 1.2 m wide
- 1.2 m high
- Shear beam frequency ~ 3 Hz
- 9 t dry sand payload

The Large Laminar Shear Box at UNIVBRIS



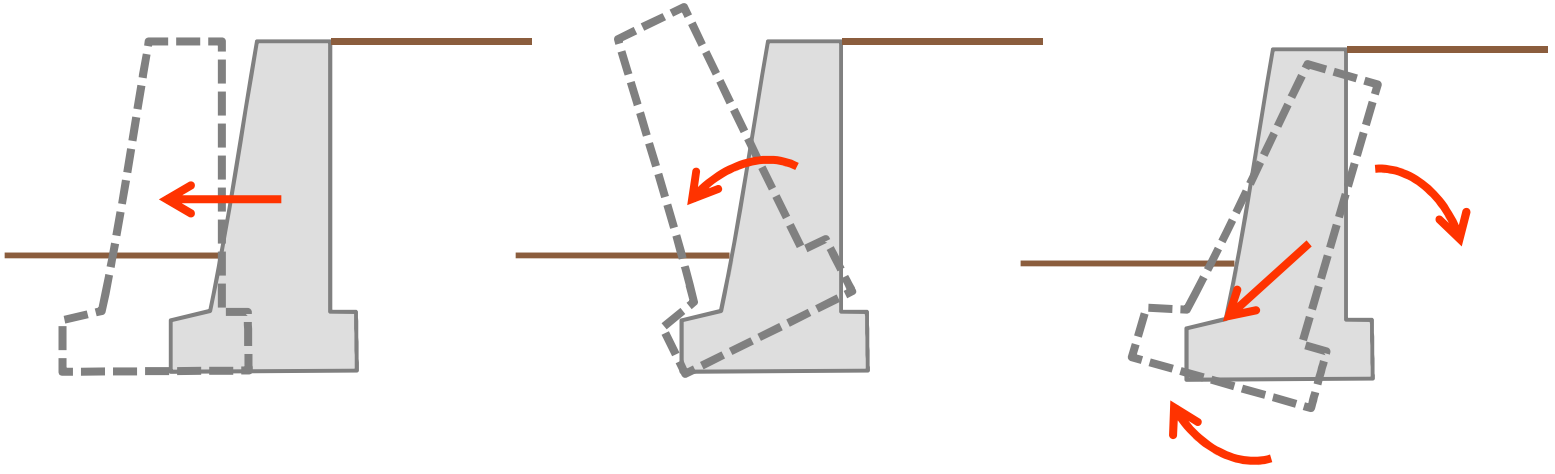
Long section (in direction of shaking) Cross section

- Excited in the *y*-direction
- Horizontal shear wave propagating vertically
- Restraining frame restricts *x* and *z* vibrations
- Rough end walls & base enable complimentary shear stresses, lubricated side walls for plane strain
- Composite impedance (low stiffness and mass) of box significantly less than that of deposit – the soil deposit drives the response

Background

Retaining walls failure under seismic loading

External failure of retaining walls under seismic loading can occur either with sliding, rotation or bearing capacity failure, depending on:
mechanical properties of the foundation soil, interface friction angle and wall dimensions.



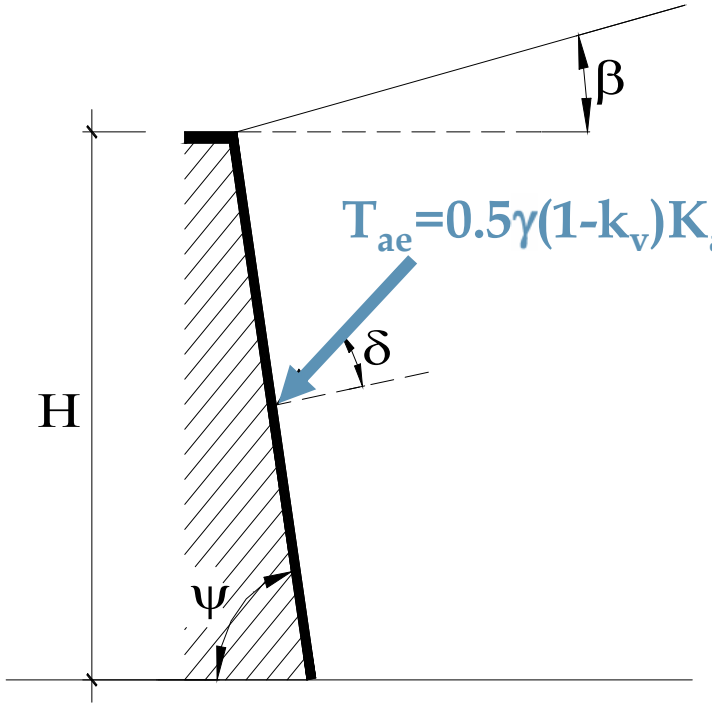
SLIDING
along the base

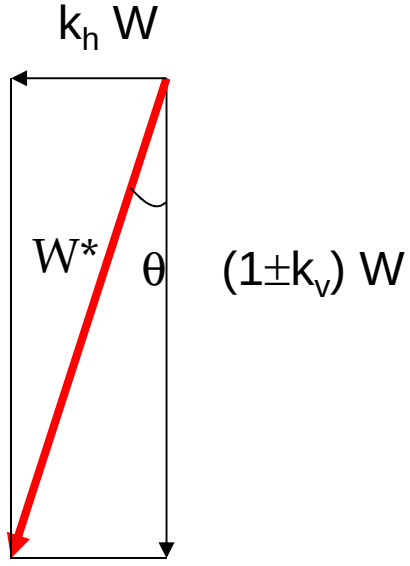
OVERTURNING
about toe

BEARING CAPACITY
failure of supporting base

Background

Mononobe-Okabe (1929)



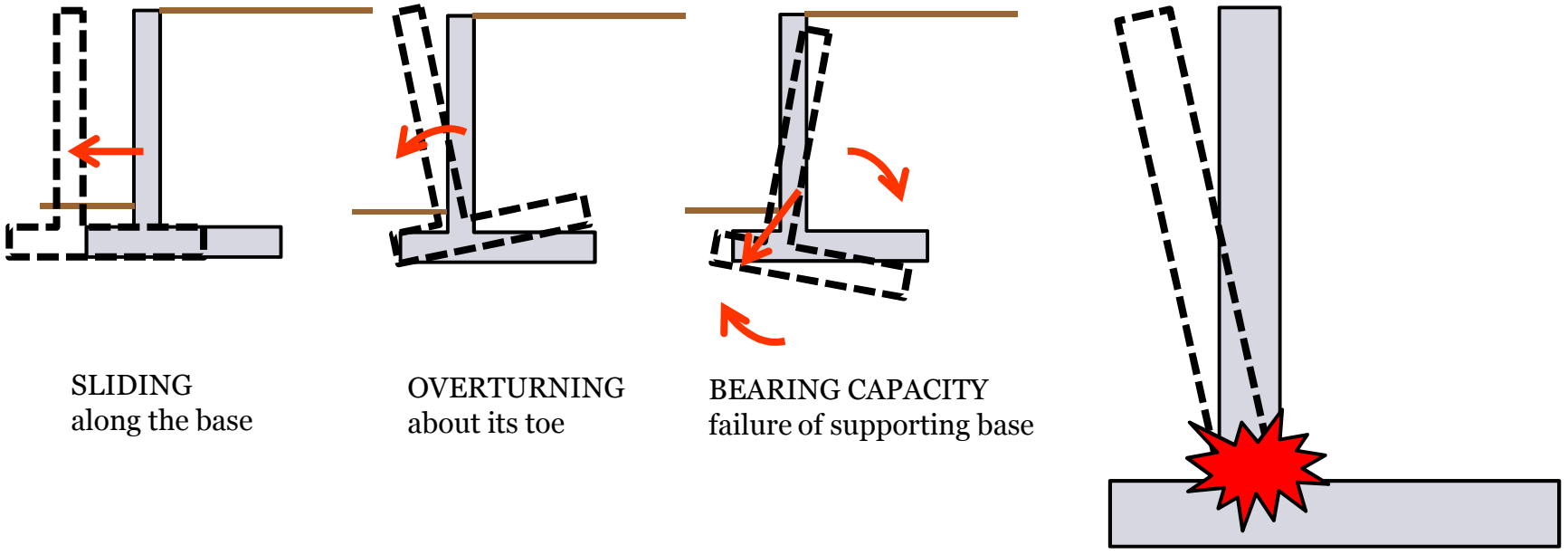


$\tan\theta=k_h/(1+k_v)$

$$\beta \le \phi - \theta: \quad Kae = \frac{\operatorname{sen}^2(\psi+\phi-\theta)}{\cos\theta\,\operatorname{sen}^2\psi\,\operatorname{sen}(\psi-\theta-\delta)\left[1+\sqrt{\frac{\operatorname{sen}(\phi+\delta)\operatorname{sen}(\phi-\beta-\theta)}{\operatorname{sen}(\psi-\theta-\delta)\operatorname{sen}(\psi+\beta)}}\right]^2}$$

Background

Cantilever retaining walls under seismic loading



SLIDING
along the base

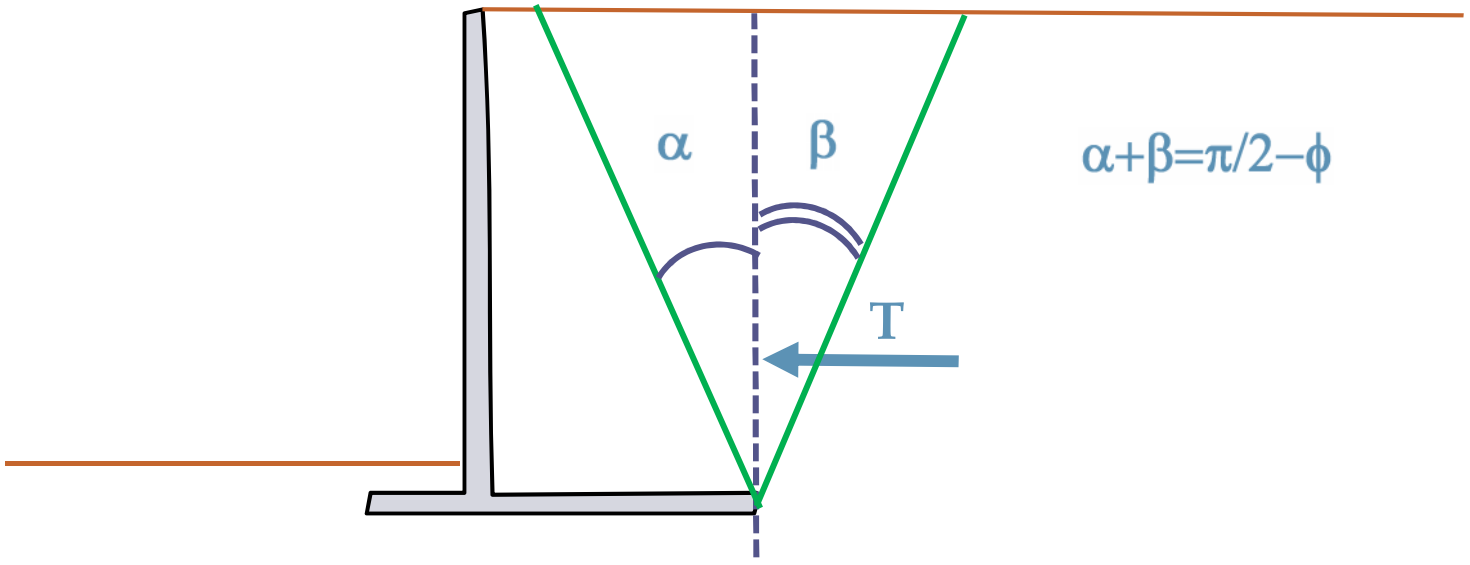
OVERTURNING
about its toe

BEARING CAPACITY
failure of supporting base

For cantilevered retaining walls, internal failure is also possible, when:

1. movement of base of the wall is restrained;
2. the wall is founded on competent ground;
3. insufficient reinforcement (for older walls).

Limitation of cantilever retaining wall ordinary design (EC8/NTC2008)



- The active thrust acting along an ideal surface passing through the innermost point of the base is usually calculated
- Load on the stem is assumed to be equal to the thrust acting on the ideal vertical surface

Unclear issues on cantilever retaining wall behaviour

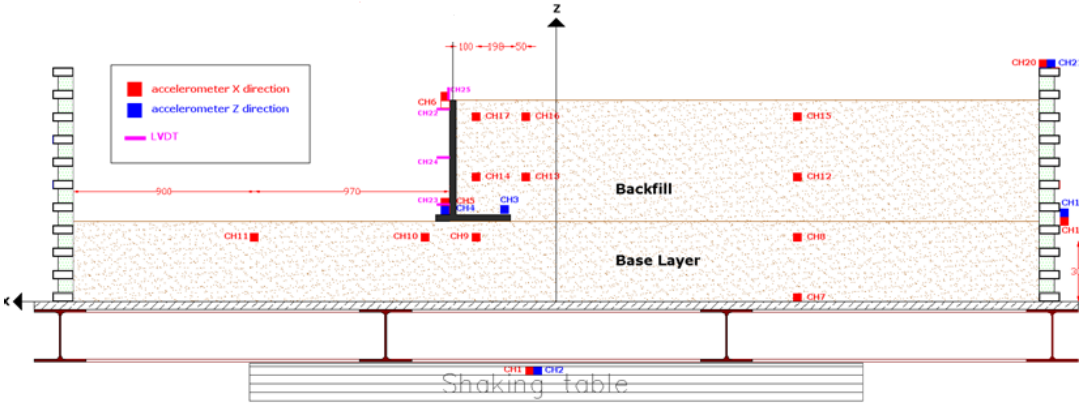
?

- The role of wall base compliance on failure mode (sliding, rocking, bearing capacity failure)
- The role of the backfill and the foundation soil in modifying the response of the system
- The role of soil friction and wall roughness in the development of wall tractions and its associated arching effects in the soil

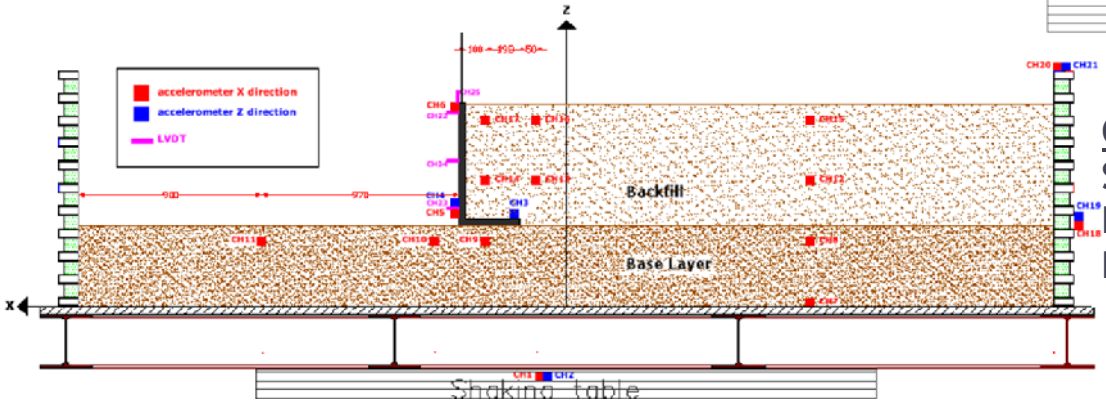
Need of experimental investigation

Model configurations

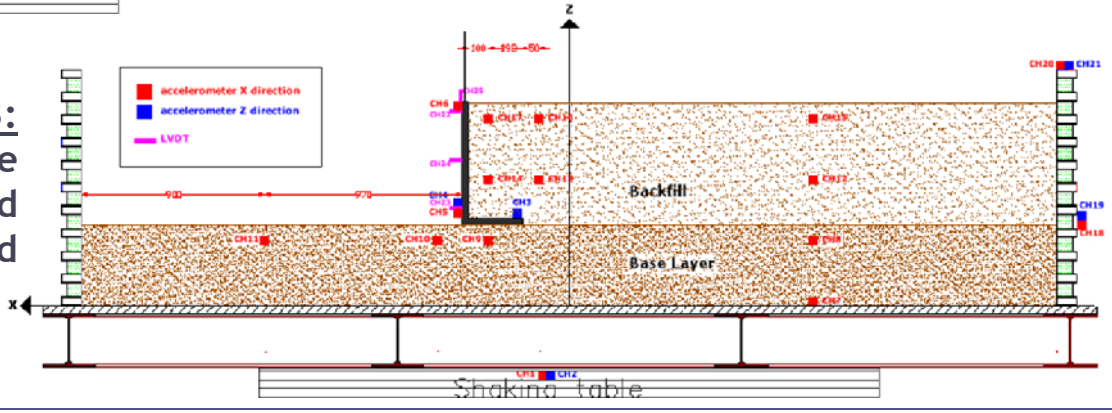
CONFIGURATION 1:
Long heel wall (T-shape wall)-smooth base
Backfill: loose sand
Base layer: loose sand



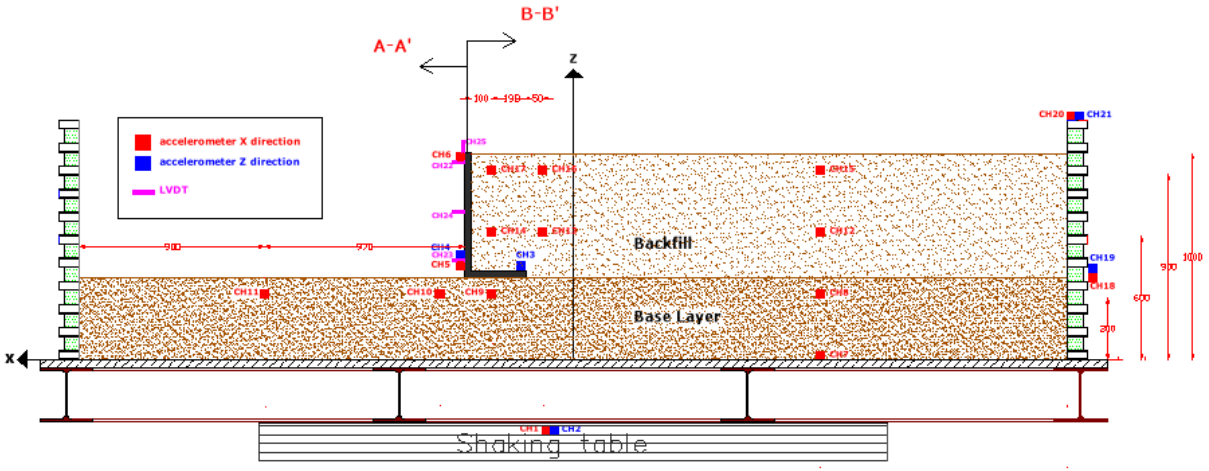
CONFIGURATION 2:
Short heel wall (L-shape wall)-smooth base
Backfill: loose sand
Base layer: dense sand



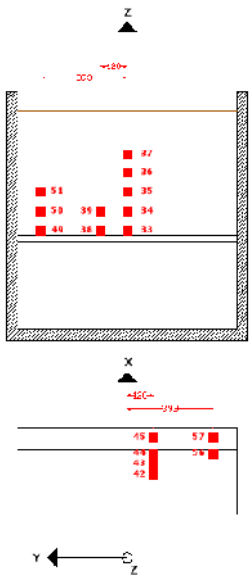
CONFIGURATION 3:
Short heel wall (L-shape wall)/ rough base
Backfill: loose sand
Base layer: dense sand



Model details

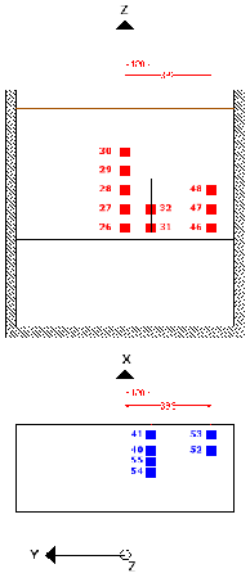


section A-A'



plan of the wall - top

section B-B'

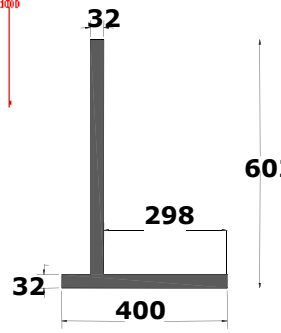


plan of the wall - bottom

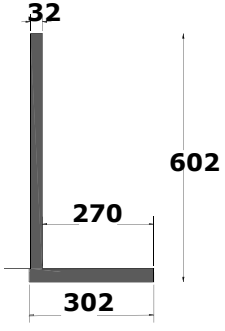
Instrumentation:

15 Horizontal Accelerometers;
4 Vertical Accelerometers;
3 Horizontal LVDTs;
1 Vertical LVDT;
20 Strain gauges on the stem;
12 Strain gauges on the base.

WALLS: Aluminium alloy (E=70GPa, ν=0.33)



Long heel wall
(T-shape wall)



Short heel wall
(L-shape wall)

SOIL: Granular 2-layer deposit

Base layer: 400 mm thick Leighton Buzzard loose or dense sand (LB-Fraction B).

Backfill: 600 mm thick Leighton Buzzard loose sand layer (LB-Fraction B).

Test details

Type	*Input*	*Objective*
Hammer test	Hit by an hammer on the base or on the top of the wall	Check natural frequencies of the walls
White noise tests	White noise signals applied on the vibrating table along x direction	Check natural frequencies of the system and shear stack influence on the system motion
Sinedwell tests	Sinedwell signals applied on the vibrating table along x direction	Observe the behavior under cyclic loading
Earthquake tests	Frequency scaled seismic motions applied on the shaking table	Observe the behavior under seismic motion

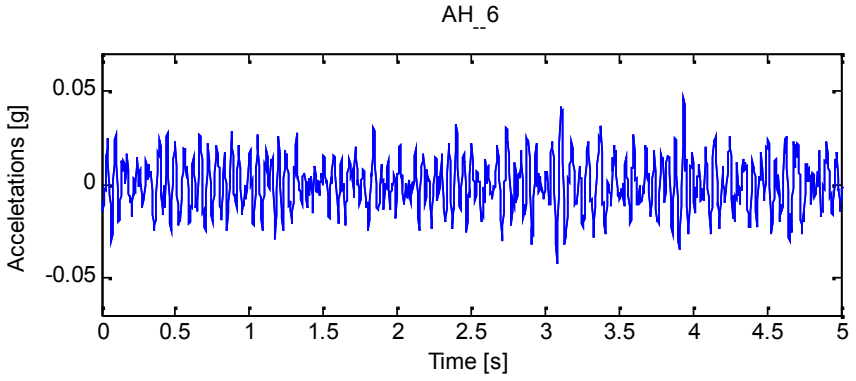
Tests carried out

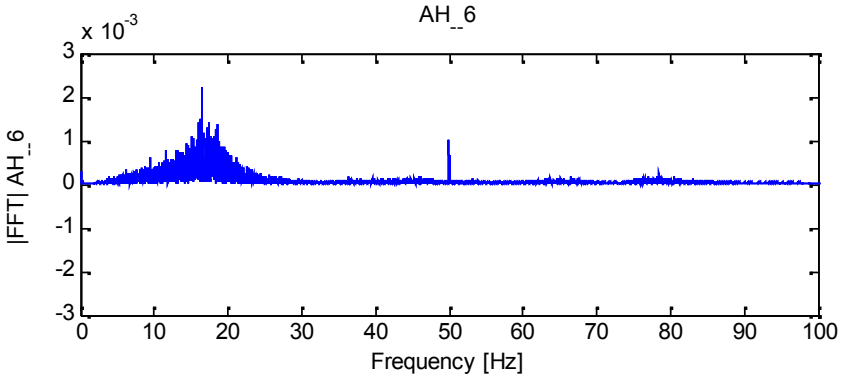
	Configuration 1 (T-Shape wall – Smooth base)	**Configuration 2 (L-Shape wall - Smooth base)**	**Configuration 2 (L-Shape wall - Roughened base)**	**Total**
Hammer tests	9	9	6	24
White Noise tests	7	5	5	17
Sinedwell tests	20	12	20	52
Earthquake tests	13	6	9	28
				121

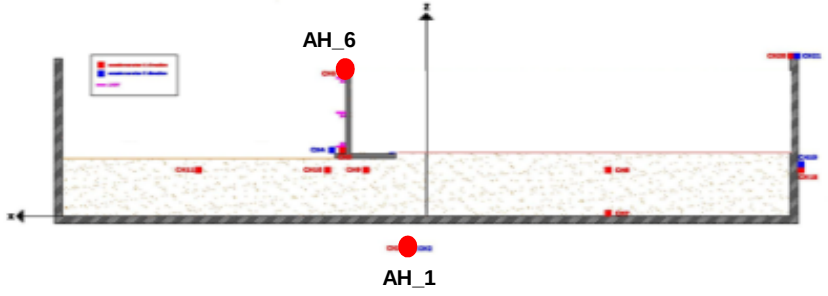
Typical results

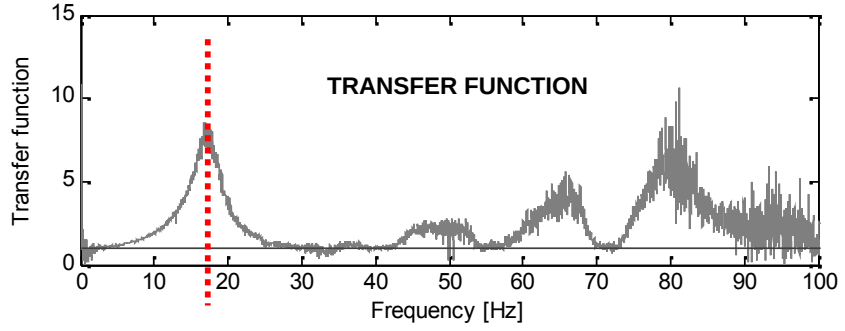
White noise test

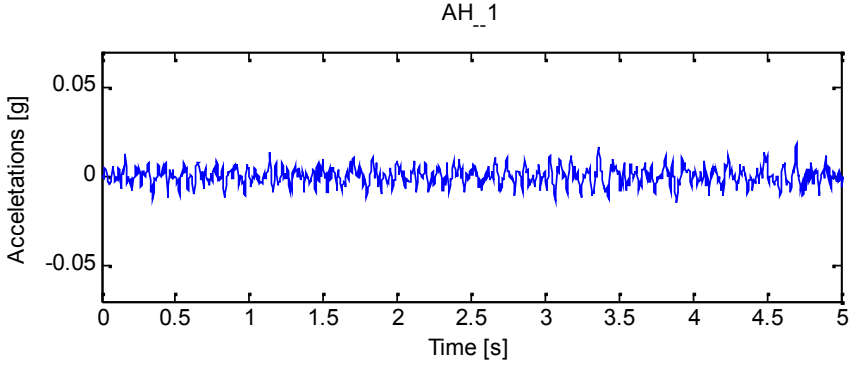
Test TA1_110704_X1R1

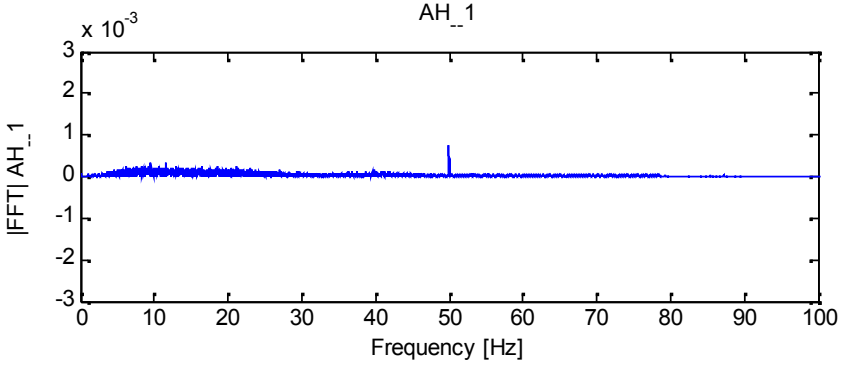




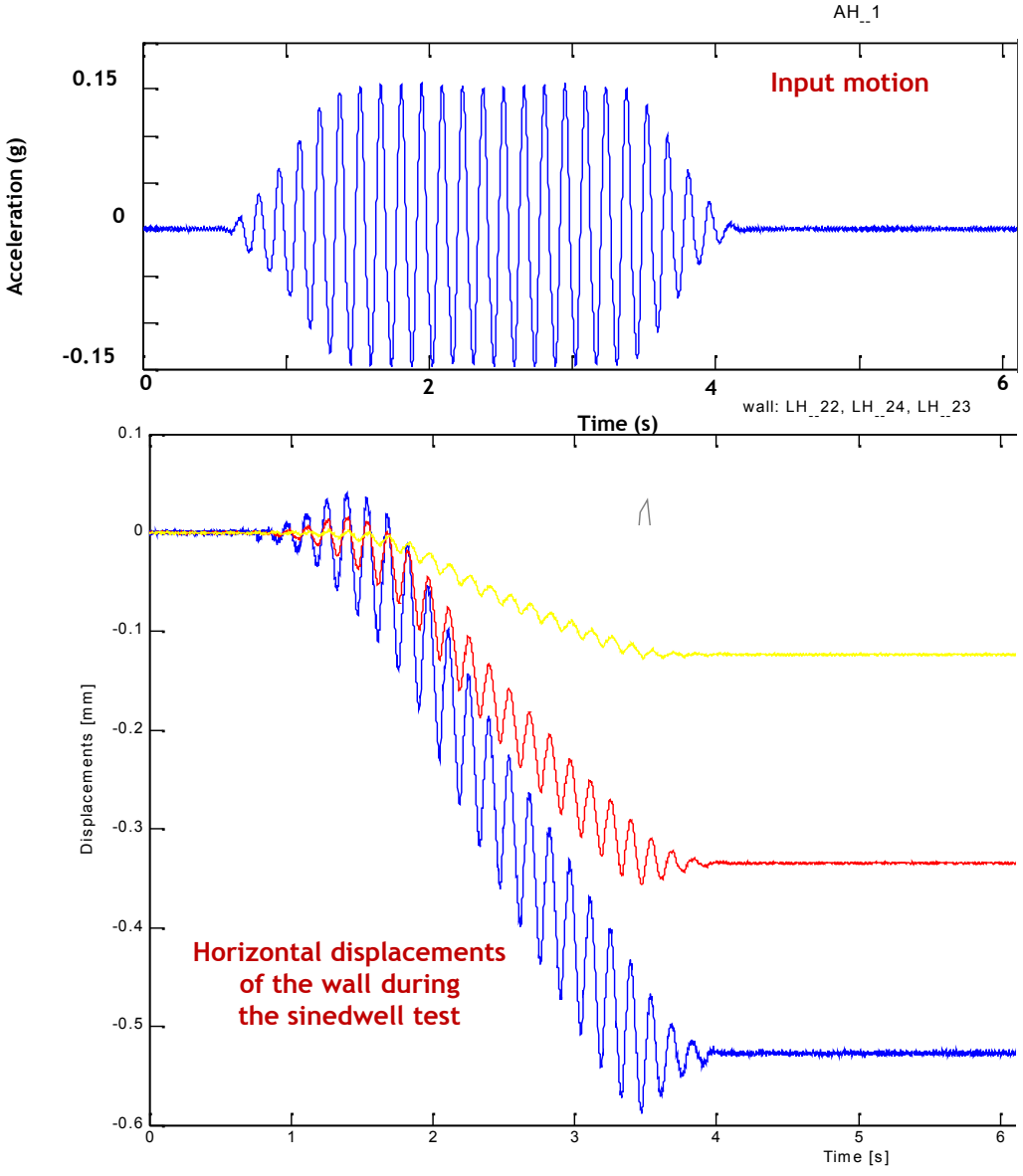






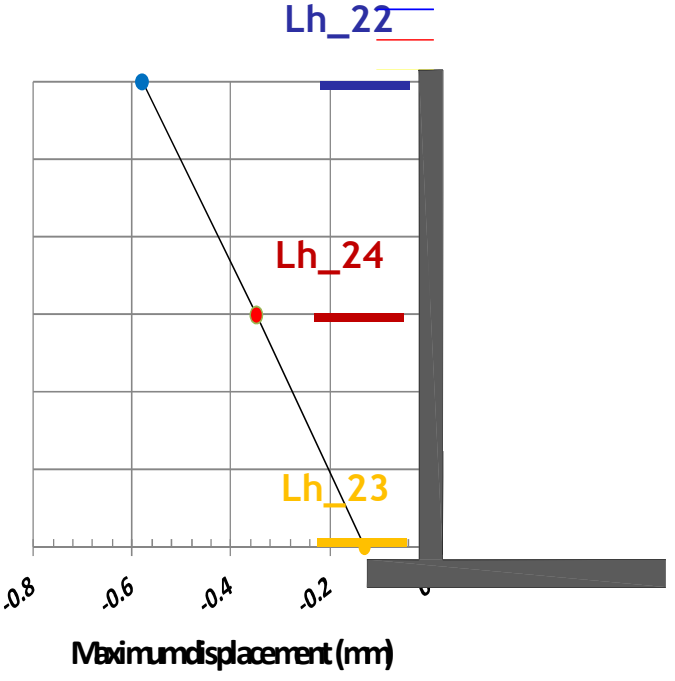


Typical results

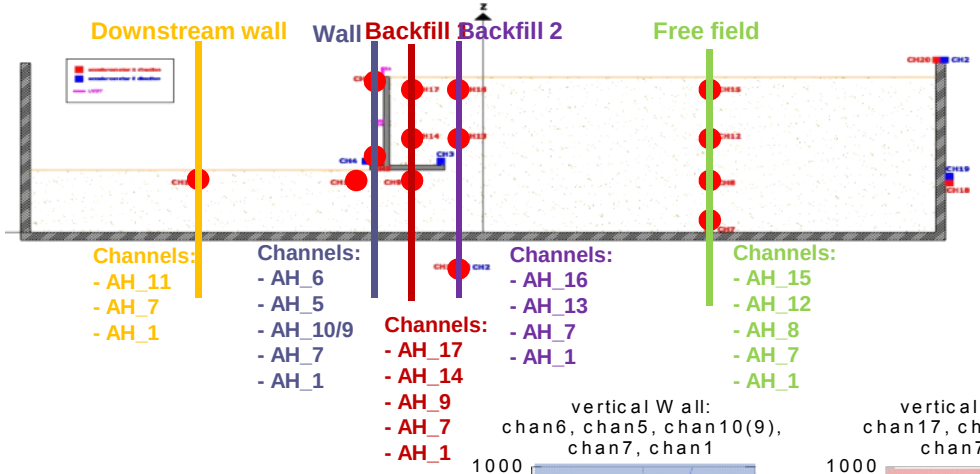


Sinedwell test

Test TA1_110629_D9R1
7 hz sinedwell

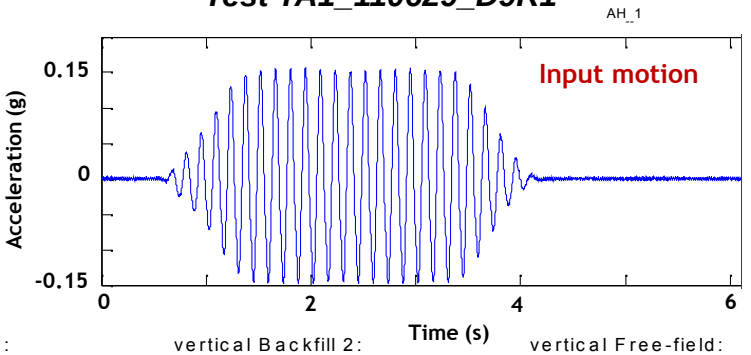


Typical results

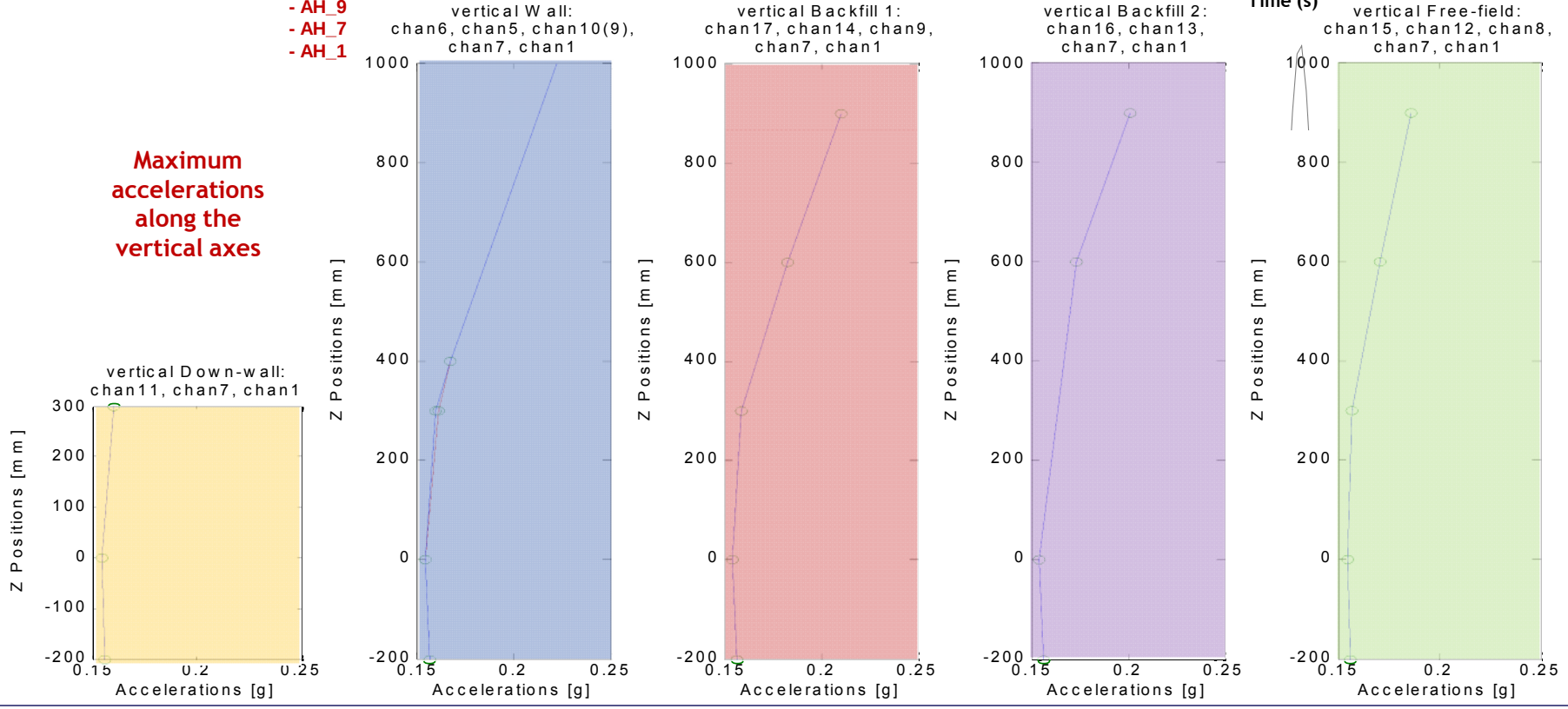


Sinedwell test

Test TA1_110629_D9R1

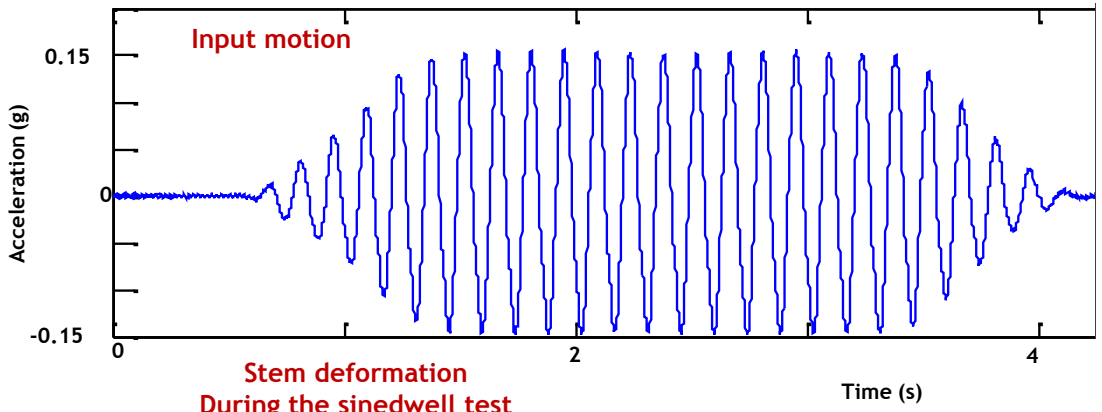


Maximum accelerations along the vertical axes

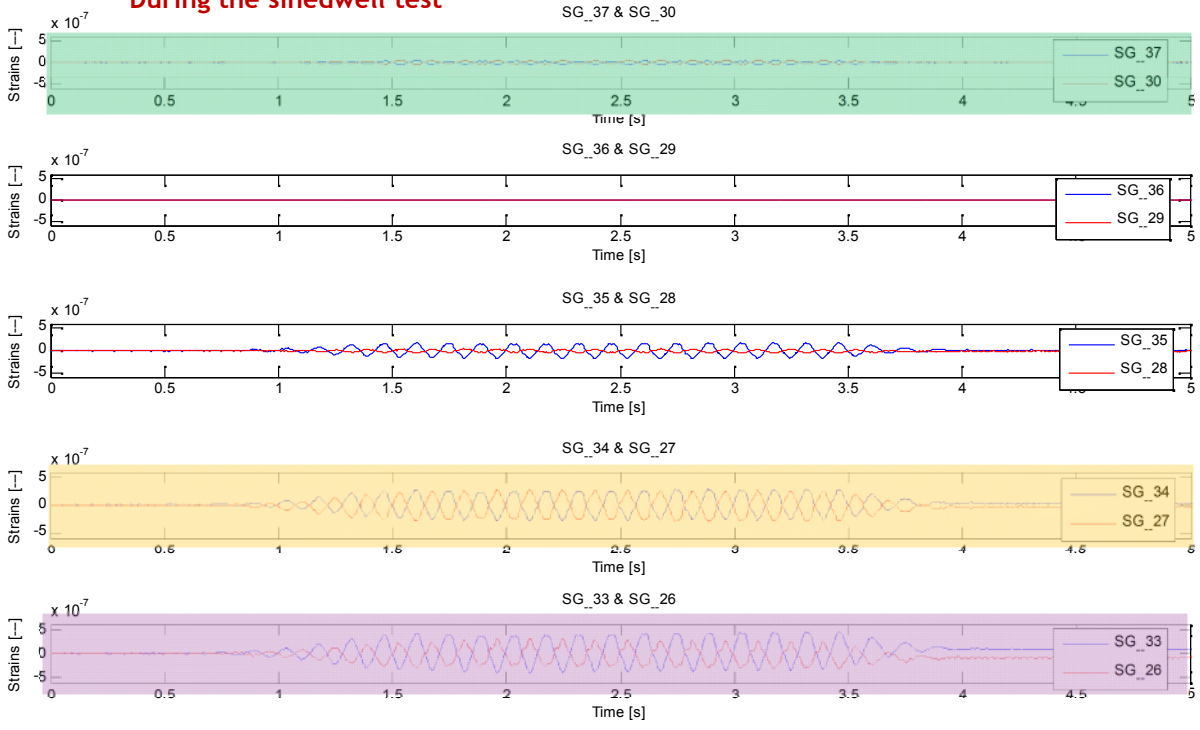


Typical results

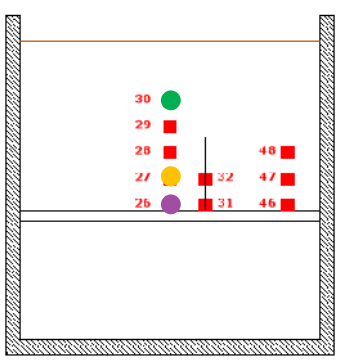
Sinedwell test



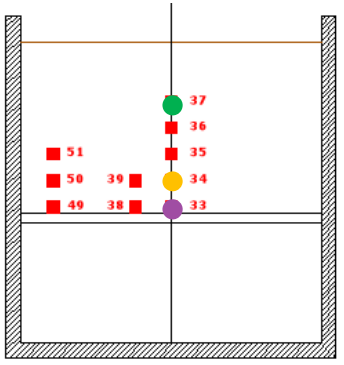
Stem deformation
During the sinedwell test



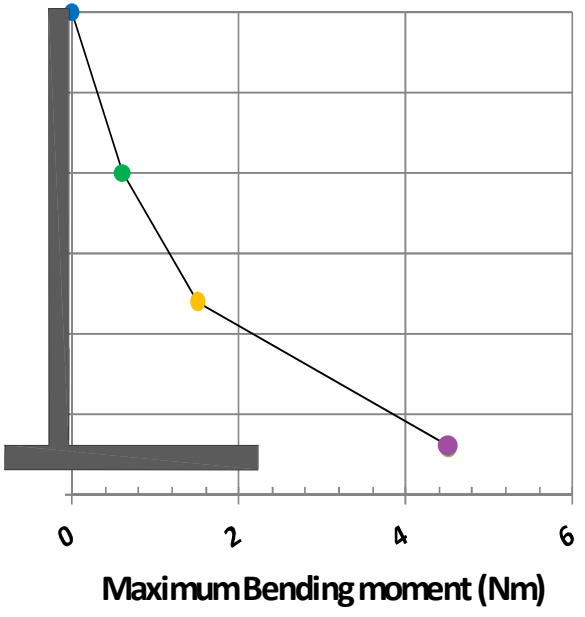
Test TA1_110629_D9R1 - 7 hz sinedwell



Front of the wall



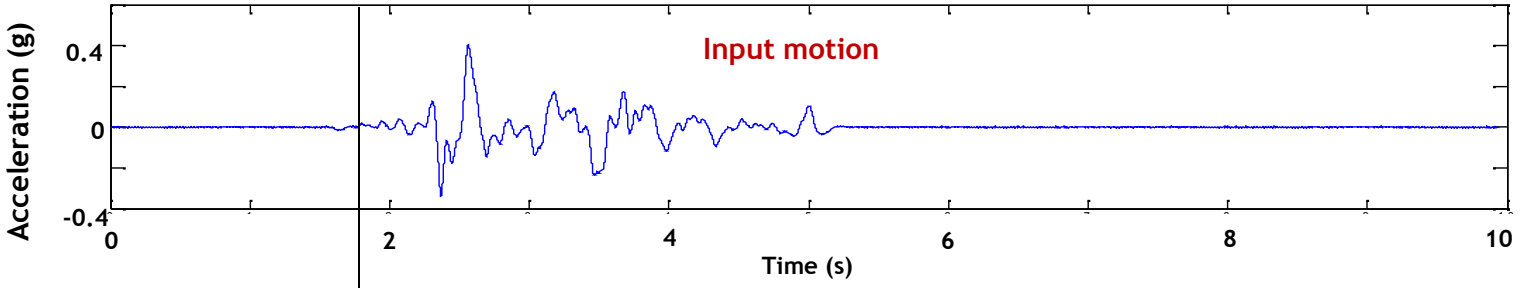
Behind the wall

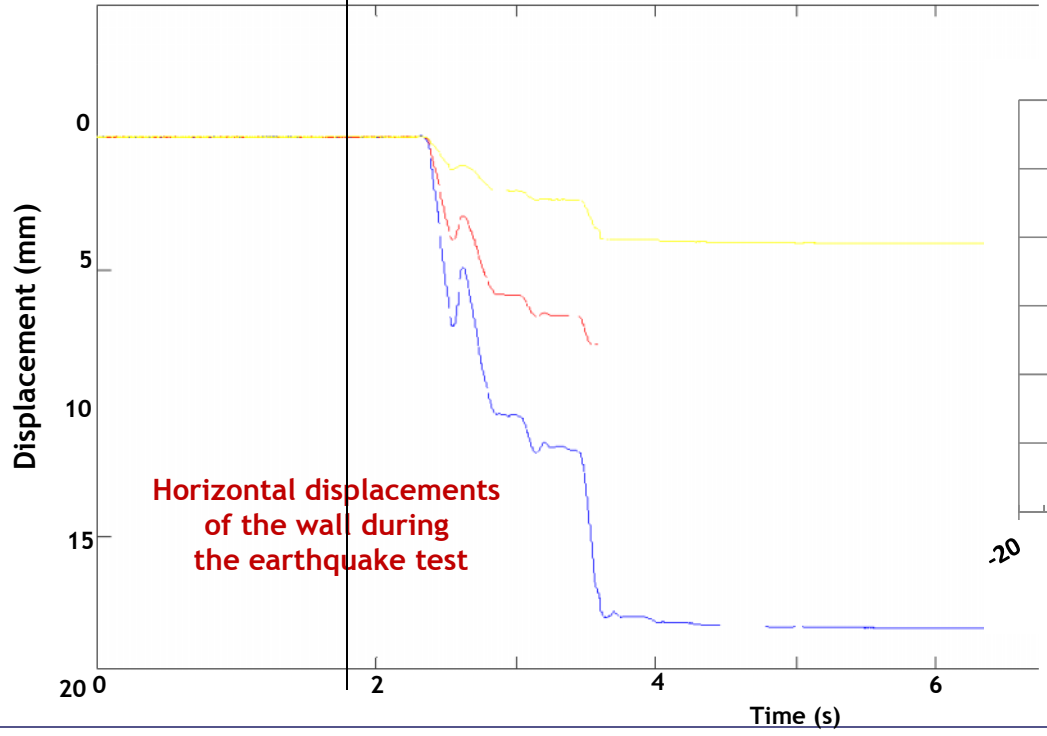


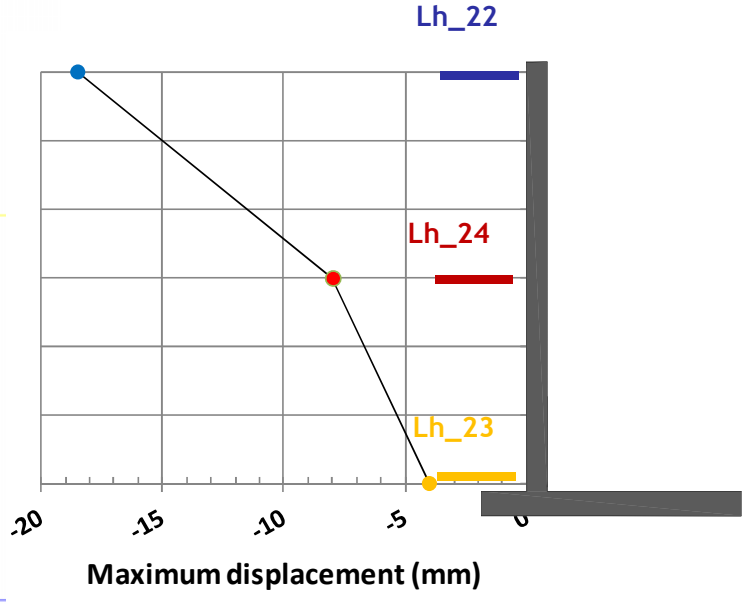
Typical results

Earthquake test

Test TA1_110629_E6R1
Eq: Irpinia 1980 - Sturno 5x freq scale







Thank you for your attention…






We will see in Taormina (II PBD IC, may2012) & Lisbona(15 WCEE, Sep2012) for a further presentation of the data analysis results…