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Modal characterization of structure and soil-structure interaction using accelerometric data of the French permanet network (RAP-RESFIF): Apllication to a french indies structure in Basse-pointe, Martinique

Julie REGNIER: Phd, Project-team MouvGS, Cerema, Sophia-Antipolis, France, julie.regnier@cerema.fr
Anne DUCHEZ: Engineer, DREC, Cerema, Aix-en-Provence, anne.duchez@cerema.f
Nathalie DUFOUR: Phd, Project-team MouvGS, Cerema, Aix-en-Provence, France, nathalie.dufour@cerema.fr
Philippe GUEGUEN : Phd, ISTerre-IFSTTAR, Grenoble, France, philippe.gueguen@cerema.fr

ID: 11556

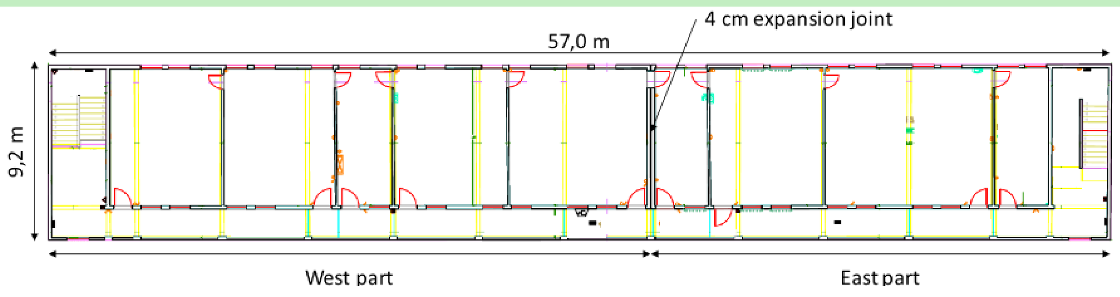
ISTerre Institut des Sciences de la Terre — Cerema

CASE OF STUDY

Objectives

(1) Use earthquake and noise recordings to assess the dynamic behavior of a soil-foundation-structure system
(2) Understand the behavior of each part of the system
(3) Performed numerical modelling of the seismic response of the structure

Case of study

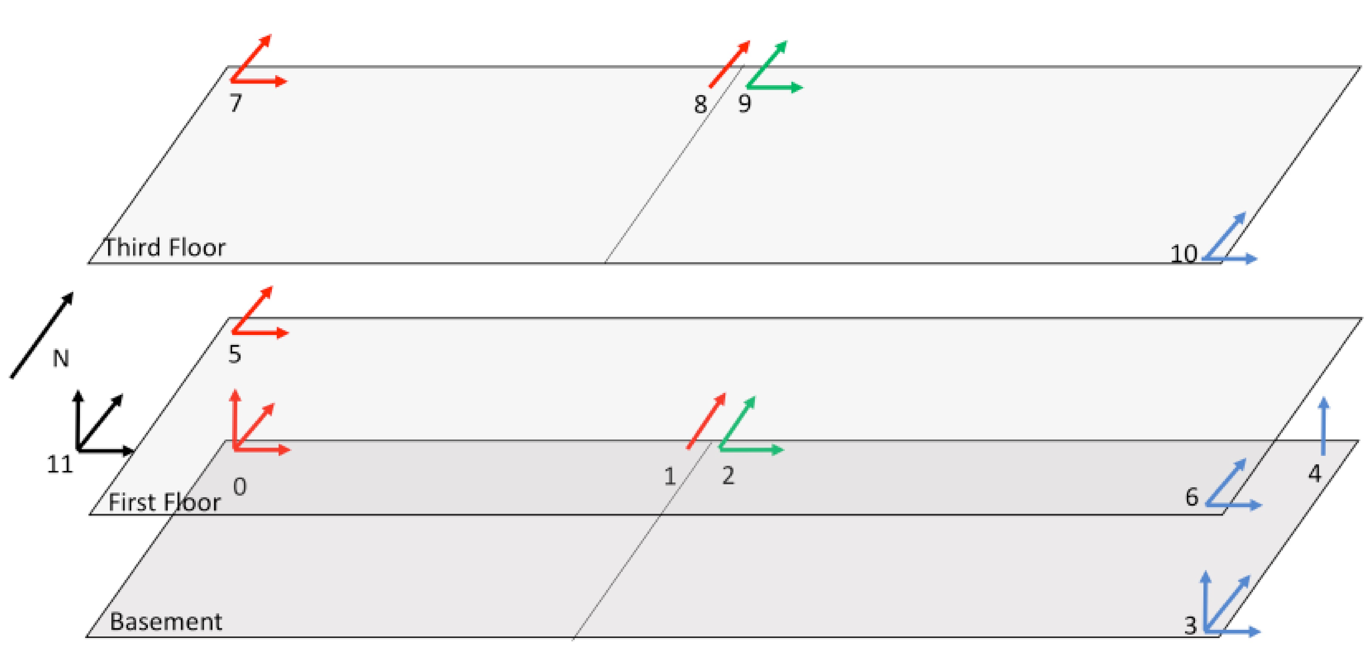


This is a 3-story building built in the 1970's and made of two parts (west and east part).

- Reinforced concrete frame in the transverse direction
- Walls have been considered as masonry,
- Partition walls between classrooms considered as non-structural elements.
- Roof terrace

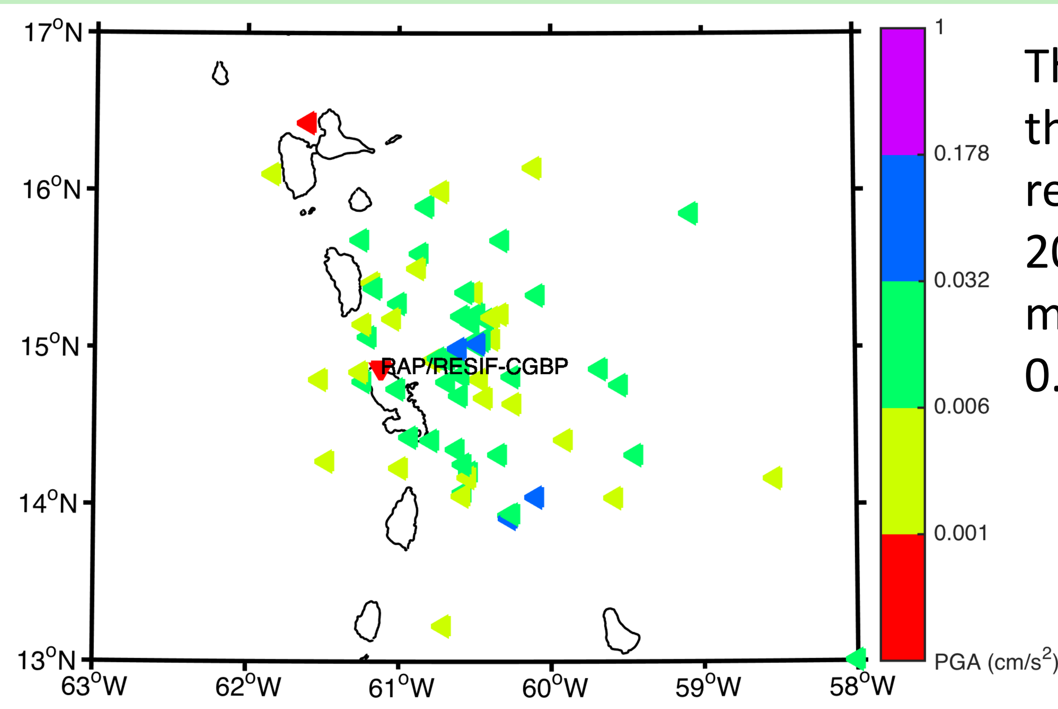
EARTHQUAKES AND AMBIENT VIBRATIONS DATA

Plan of installation



24 channels with 3-D and 1-D episensors from Kinematics, linked at the same acquisition station Kephren. The free-field (sensor n° 11) is located 10 m from the building.
Continuous recordings of ambient vibrations and earthquakes database

Earthquakes data recorded



The database contains the earthquakes recorded from 2011 to 2014 with a very low maximum PGA up to 0.2 cm/s²

MODAL IDENTIFICATION

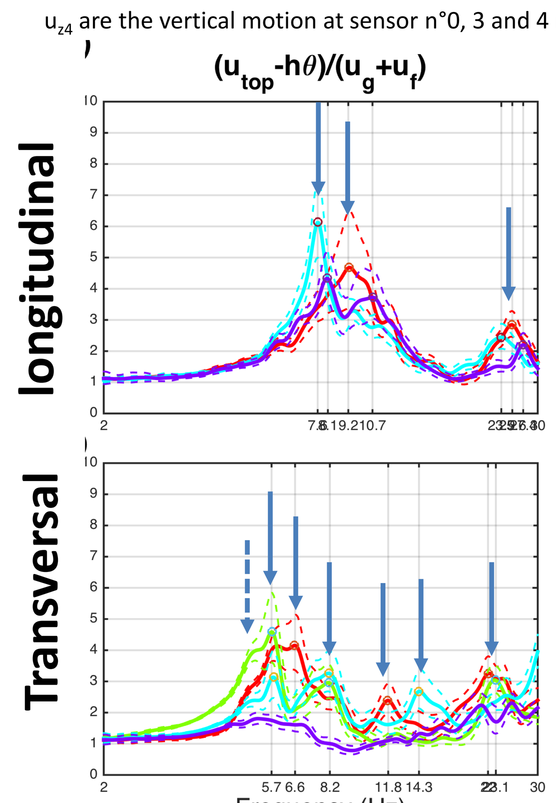
Resonance Frequencies

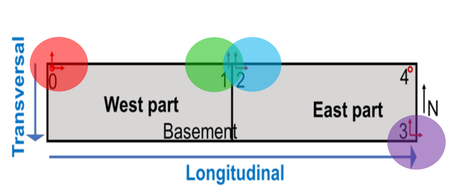
From earthquakes data

- **For the structure** : f_{stru} obtain by removing from the top recording the rocking displacement and performing the transfer function between top sensors and base sensors
- **Rocking motion** using the vertical recordings

$$h\theta_{trans} \approx h\frac{|u_{z3}-u_{z4}|}{l} \quad (2)$$

h, l and L are the height, the width and the length of the structure respectively. u_{z0}, u_{z3} and u_{z4} are the vertical motion at sensor n°0, 3 and 4 respectively.

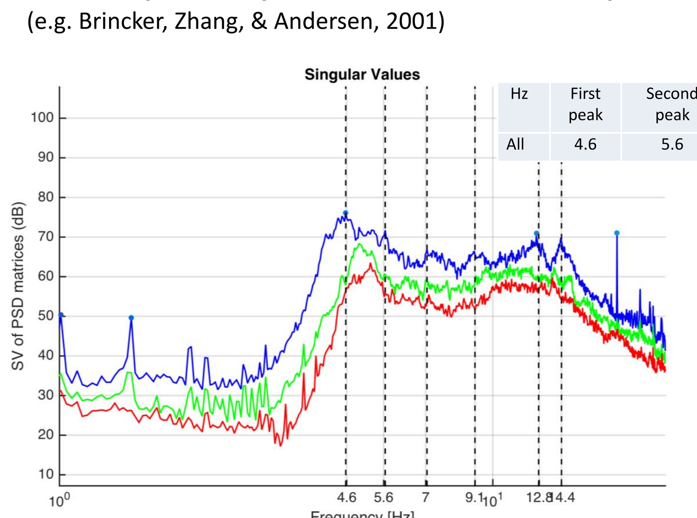




	First longitudinal frequency (Hz)	First transversal frequency (Hz)
West part	9.2	4.6
East part	7.8	5.7

From ambient vibrations

A frequency domain decomposition method
(e.g. Brincker, Zhang, & Andersen, 2001)



Hz	First peak	Second peak	Third peak	Fourth peak
All	4.6	5.6	7	9.1

Numerical simulations

3D structural modelling

- East and west part were modeled separately
- Soil –structure interaction was ignored to first calibrate structural parameters

Parametric study

	Model of structure	Modulus of elasticity E of concrete (Mpa)	Modulus of elasticity E of masonry (Mpa)	Weight combination	First frequency (Hz) longitudinal	First frequency (Hz) transversal
1	Model A (*)	20 000	-	G + 0,24 Q	1.4	1.6
2	Model A (*)	20 000	-	**G**	1.4	1.5
3	**Model B (*)**	20 000	**1 000**	G + 0,24 Q	2.6	3.3
4	**Model B (*)**	20 000	**10 000**	G + 0,24 Q	5.0	6.8
5	**Model C (*)**	20 000	**10 000**	G + 0,24 Q	8.4	6.8
	(*) models are presented below.	Bold type highlights parameters which differ from the reference model (yellow line)				

- **Simulation 1 and 2 :** Change in live load Q has little impact on the value of the periods (difference of less than 10%)
- **Simulation 3, 4 and 5 :** three models tested

Model A - concrete frame only
Model B - take into account in addition the masonry walls continuous on entire levels
Model C - considering additional masonry walls below the openings and bodyguards

Adding masonry walls (from model A to B), even with low modulus of elasticity, make the structure significantly more rigid.
Contrary to earthquake and ambient data, model B shows higher frequency in transversal direction than in longitudinal one. Adding masonry walls below the openings in the model C let get closer from recorded data.
These results highlight that the ambient vibration and weak motion data are sensitive to the filling masonry and non-structural elements.

Resonance frequencies

	First longitudinal frequency (Hz)	First transversal frequency (Hz)
West part	8.4	6.8
East part	7.5	7.2

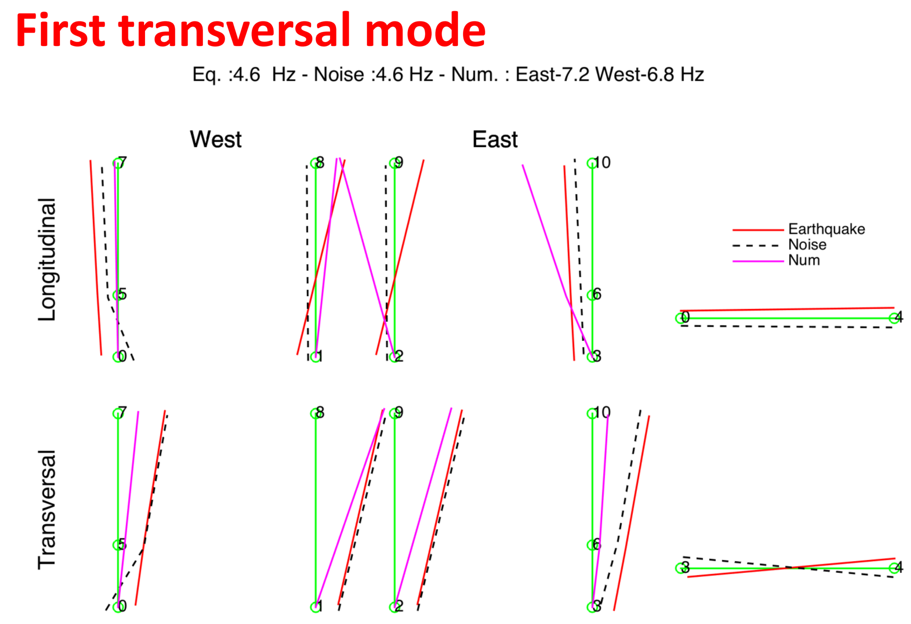
Numerical simulation frequencies are close to recorded data especially in longitudinal direction

Mode shapes

From earthquakes data, the mode shapes : relative displacement of each component to a reference
From ambient vibration, from frequency domain decomposition

First transversal mode

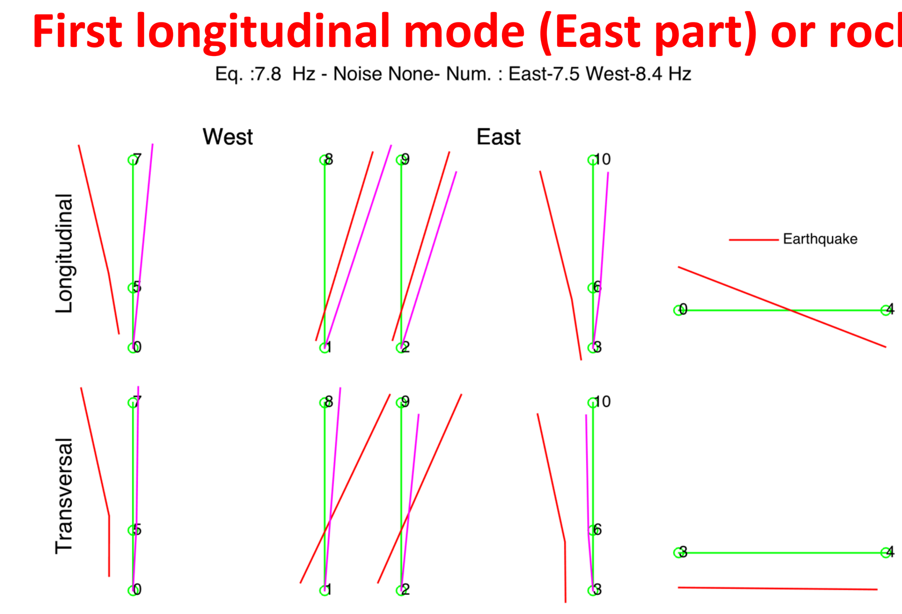
Eq. :4.6 Hz - Noise :4.6 Hz - Num. : East-7.2 West-6.8 Hz



- Good agreement between earthquakes and noise frequencies
- Numerical frequencies above
- Mode shapes similar in the transversal direction

First longitudinal mode (East part) or rocking foundation?

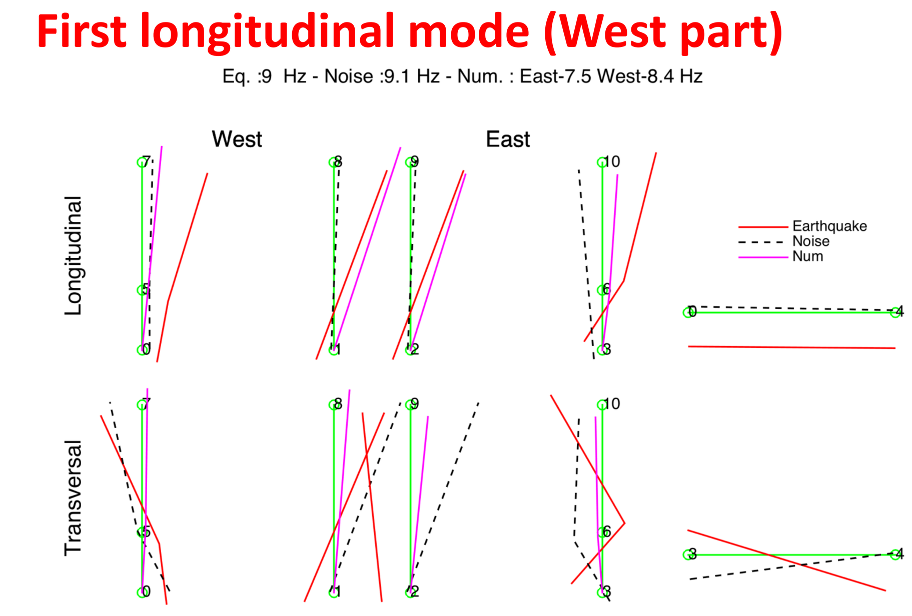
Eq. :7.8 Hz - Noise None- Num. : East-7.5 West-8.4 Hz



- Mode not seen in the noise data
- Could be associated with rocking of the foundations
- Mode shapes similar between earthquakes and numerical model at the expansion join in the longitudinal direction

First longitudinal mode (West part)

Eq. :9 Hz - Noise :9.1 Hz - Num. : East-7.5 West-8.4 Hz



- Earthquake and ambient vibrations provide different mode shapes
- The longitudinal deformations of the models and earthquake data are close at the expansion joint

Conclusions

- The behavior of the high school in Basse-Pointe is complex
- Different behavior of the east and west parts of the building

- Earthquake and noise recordings data provide close results
- Earthquake recordings provide frequencies close to 8.0 Hz not seen in the ambient vibration recordings: Earthquake trigger modes of rocking of the foundation ?
- Numerical simulation provides closer results to the observations when adding all non-structural elements to the model

- Modellings and observations : mode shapes for the first transversal and longitudinal modes are close but frequencies differ
- The modelling was performed considering that east and west part of the building are completely separated