Damage evaluation of RC building with SSI by seismic interferometry: A numerical case study

Fernando Lopez-Caballero[1]
E. Diego Mercerat[2]

[1]Lab. MSS-Mat - CentraleSupélec
fernando.lopez-caballero@centralesupelec.fr
[2]CEREMA Méditerrannée, MouvGS
diego.mercerat@cerema.fr

16th ECEE

16TH EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING THESSALONIKI 18 - 21 JUNE 2018

June 18, 2018

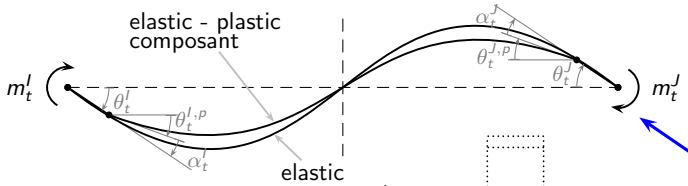
Objectives

The aim of this work :

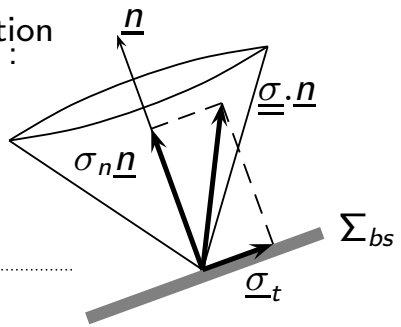
- To assess numerically the role of the non-linear soil behaviour on both the seismic response of structure and on its seismic damage assessment ($\Rightarrow$ SSI);
- To track the evolution of **induced structural damage** using seismic interferometry by deconvolution;
- interesting characteristics of the dynamic response of the building can be estimated, e.g. frequencies and **damping**.

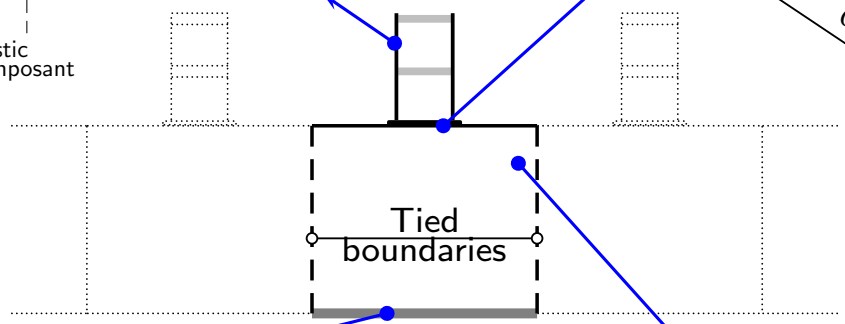
Fully Non linear approach - GEFDyn Code

plastic hinge
beam-column elements :



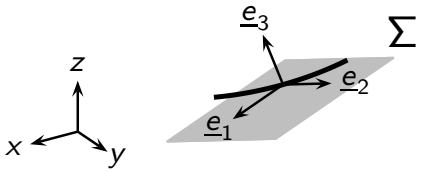
soil-foundation
interface :



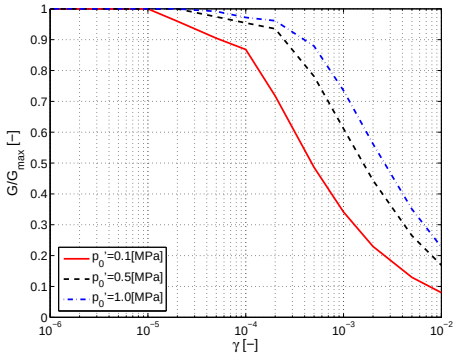


ECP's elastoplastic multi-mechanism model

paraxial approximation :
incident waves and
absorbing boundaries

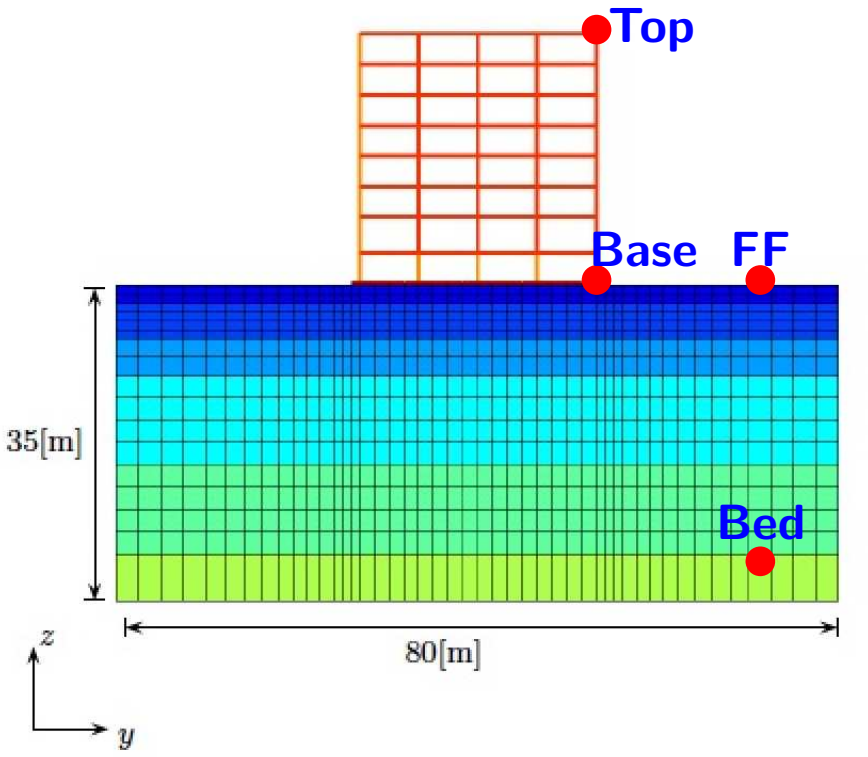


$$\underline{u}_\Sigma = u^{PSV}\,\underline{e}_k + u^{SH}\,(\underline{e}_3 \wedge \underline{e}_k)$$

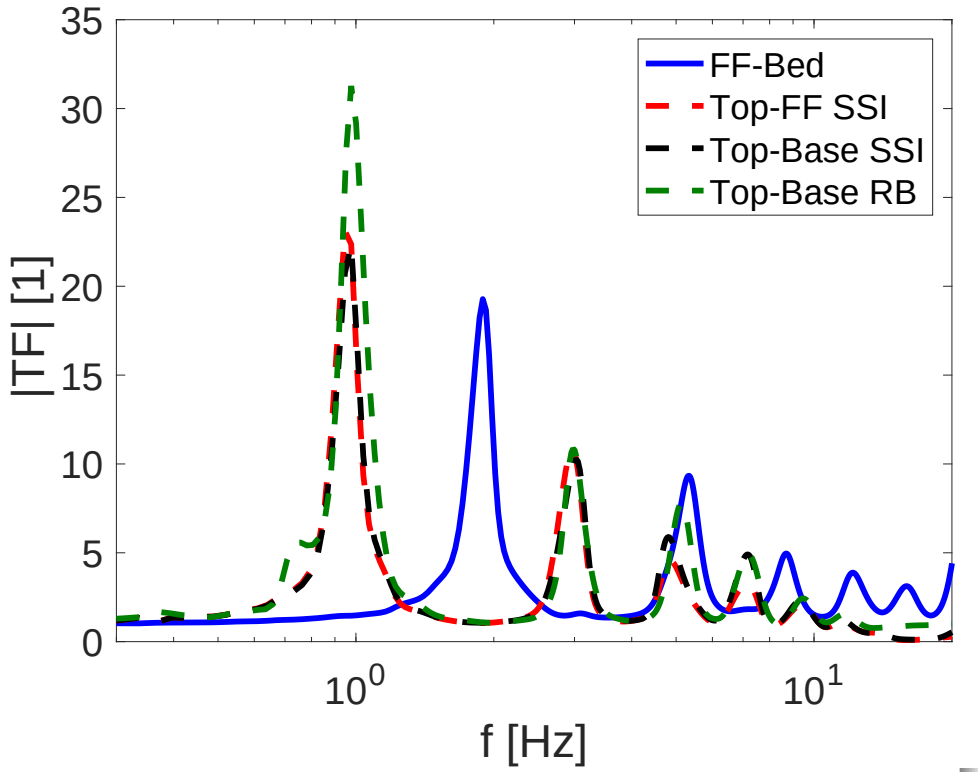


[Saez09]

Effect of non linear soil behaviour on SSI



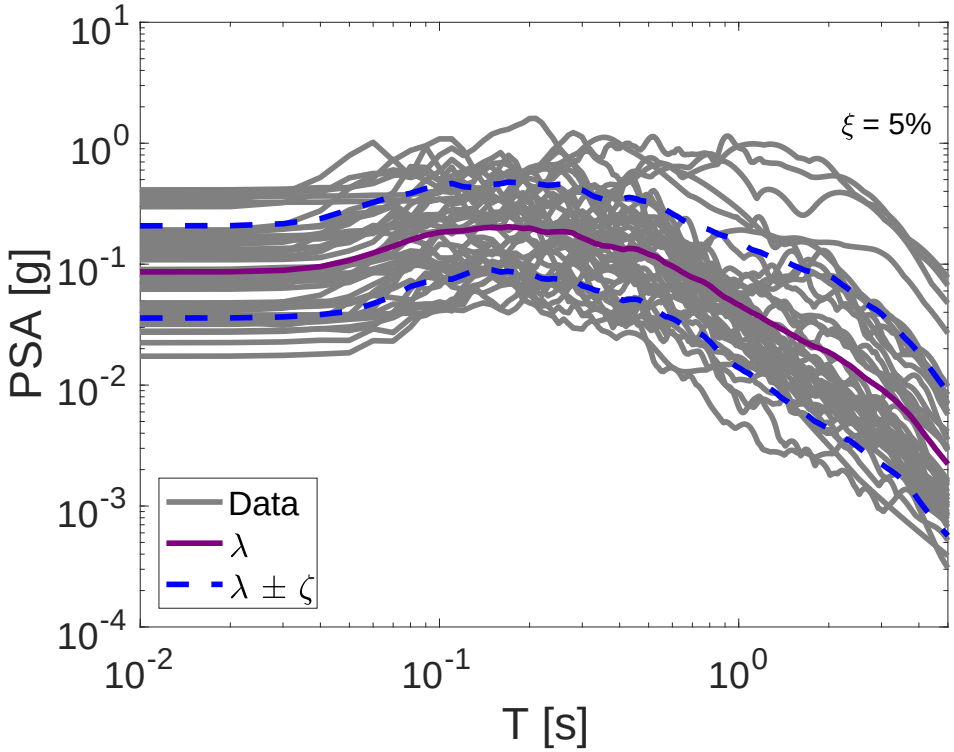
Structural model



Transfer function - Elastic Soil behaviour

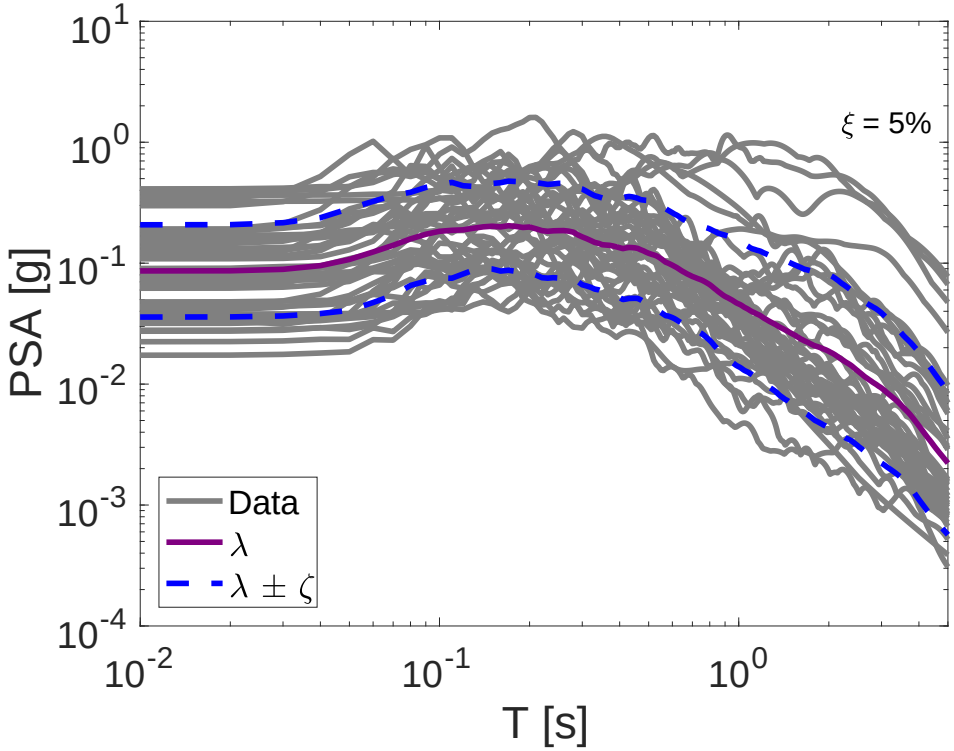
8-story structure - 28m height - $f_{str} = 1$Hz - $f_{soil} = 1.7$Hz

Seismic Hazard

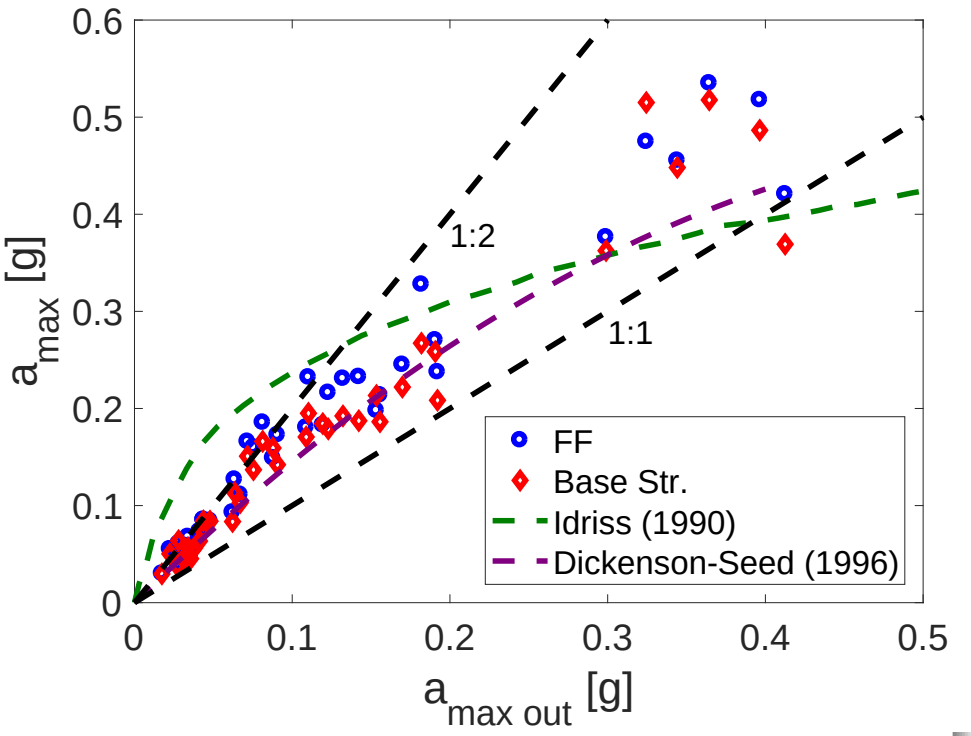


40 Real signals

Seismic Hazard



40 Real signals



Soil response

Effect of non linear soil behaviour on SSI

Structural response - Overall damage index DI_{ov}

- Overall damage index Park and Ang (1985):

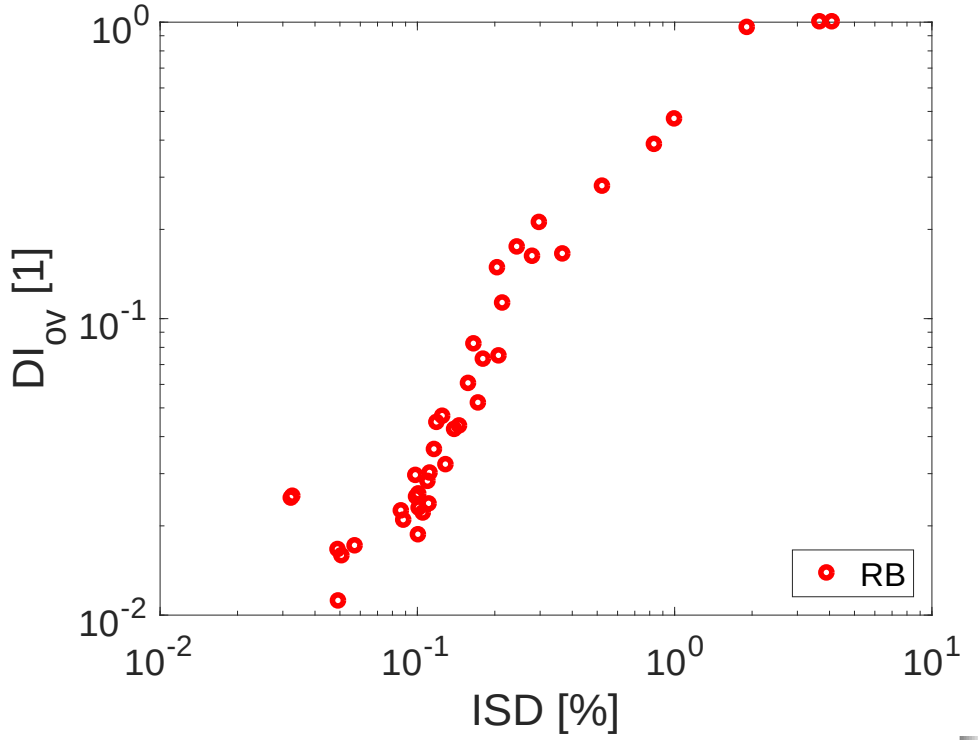
$$DI_{loc,i} = \frac{\theta^p_{m,i}}{\theta^p_u} + \lambda_p \frac{1}{M^p_{y,i}\,\theta^p_u} \int_t M^p_i \, d\theta^p_i$$

$$DI_{ov} = \sum_i \lambda_i \, DI_{loc,i}$$

with $\lambda_i = \dfrac{\int_t M^p_i \, d\theta^p_i}{\sum_i \int_t M^p_i \, d\theta^p_i}$

- Maximum Interstory drift ISD_{max}:

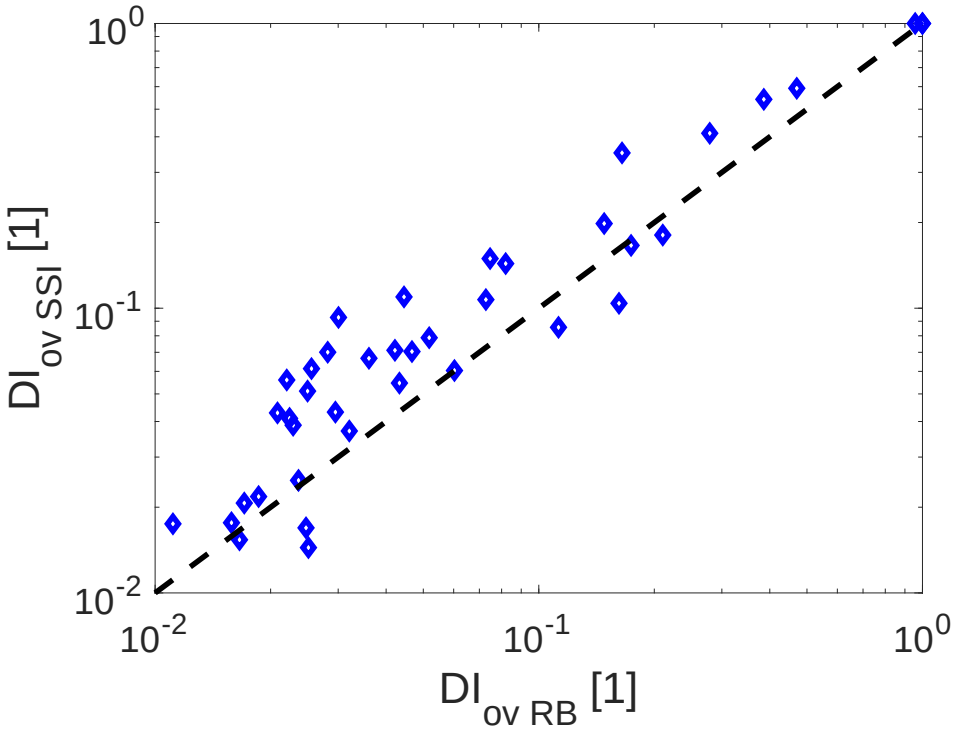
$$ISD_{max} = \max_{i,t} \left\{ \frac{\left| u^{i+1}_y(t) - u^i_y(t) \right|}{z^{i+1} - z^i} \right\}$$



Overall damage index - inter-story drift

Effect of non linear soil behaviour on SSI

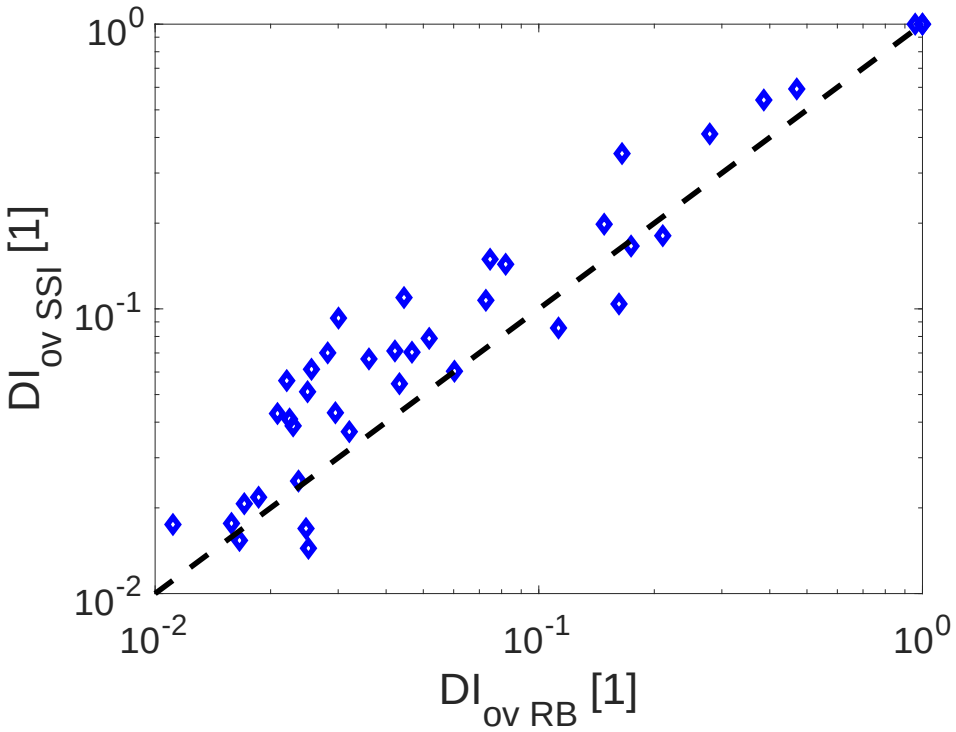
Structural response - Overall damage index DI_{ov}



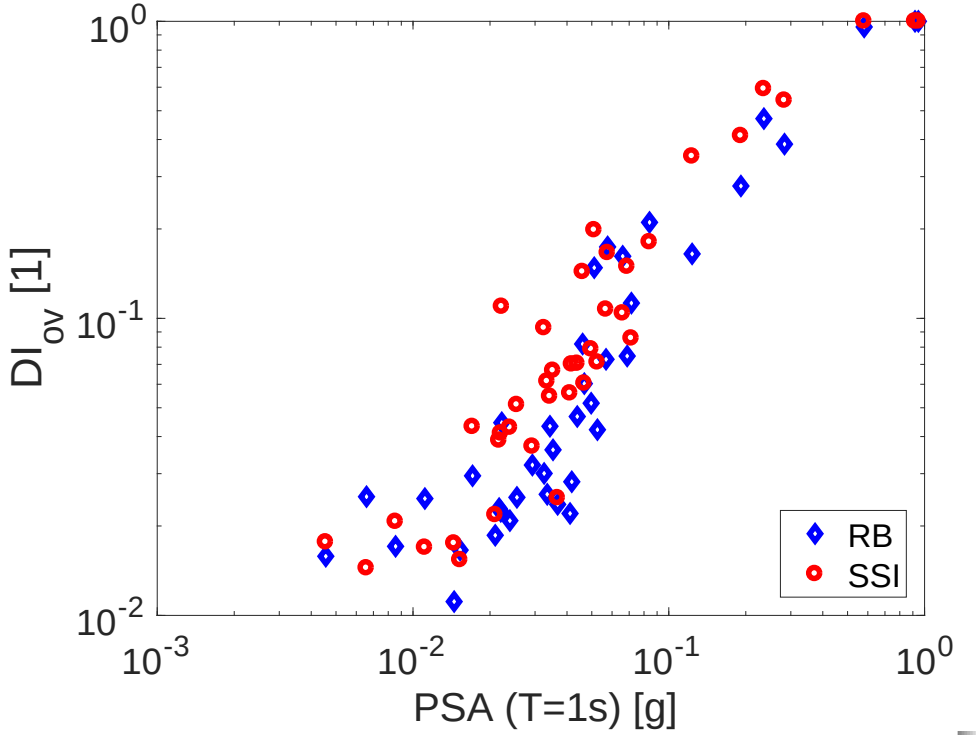
Overall damage index - SSI/Rigid Base

Effect of non linear soil behaviour on SSI

Structural response - Overall damage index DI_{ov}



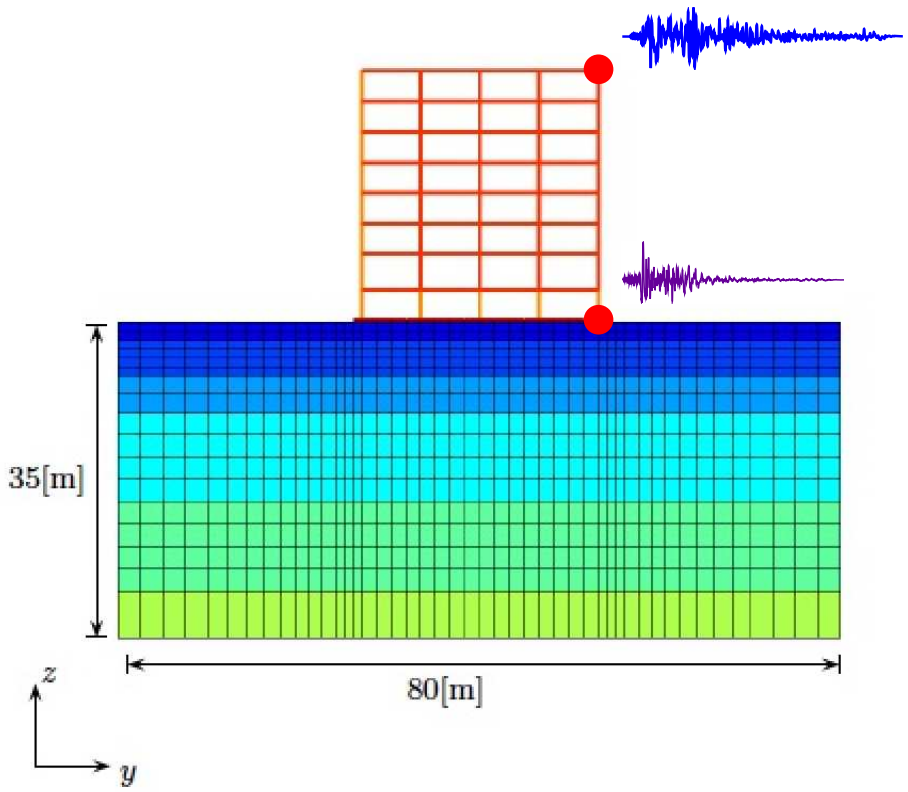
Overall damage index - SSI/Rigid Base



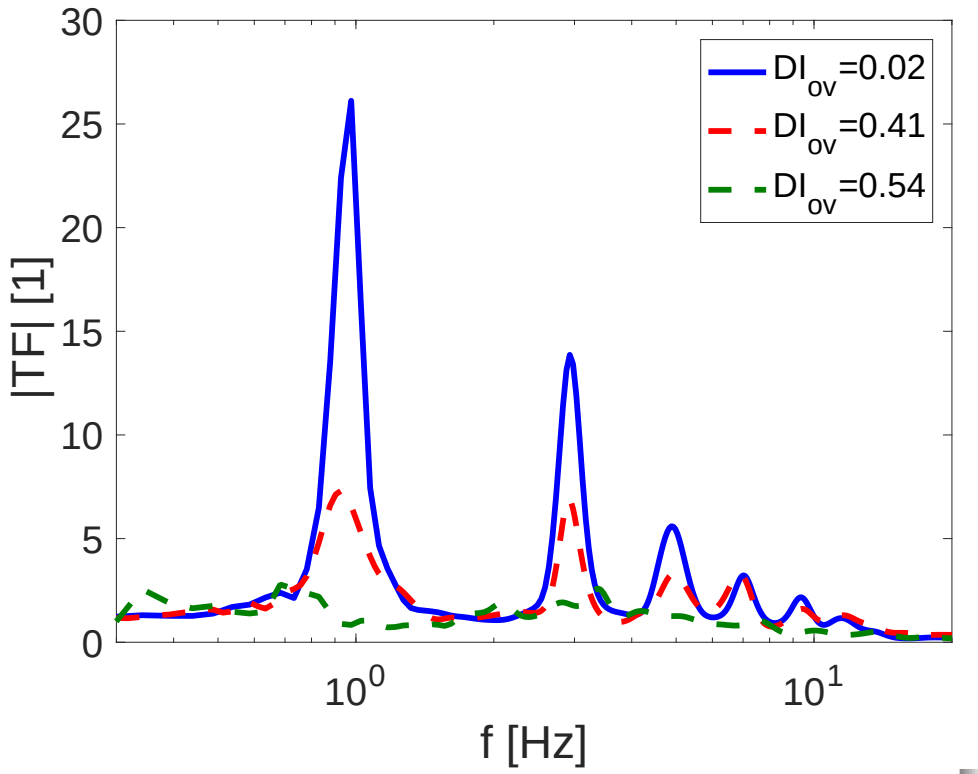
Overall damage index - PSA($T = 1$s)

Effect of non linear soil behaviour on SSI

Structural response - Induced Damage effect



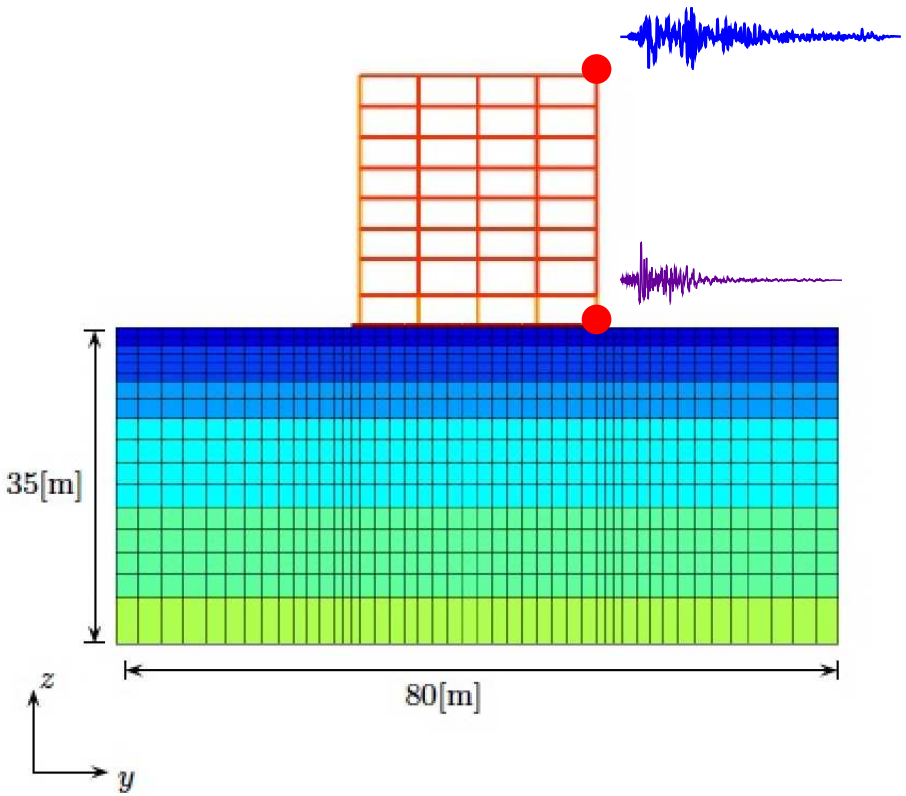
Structural model



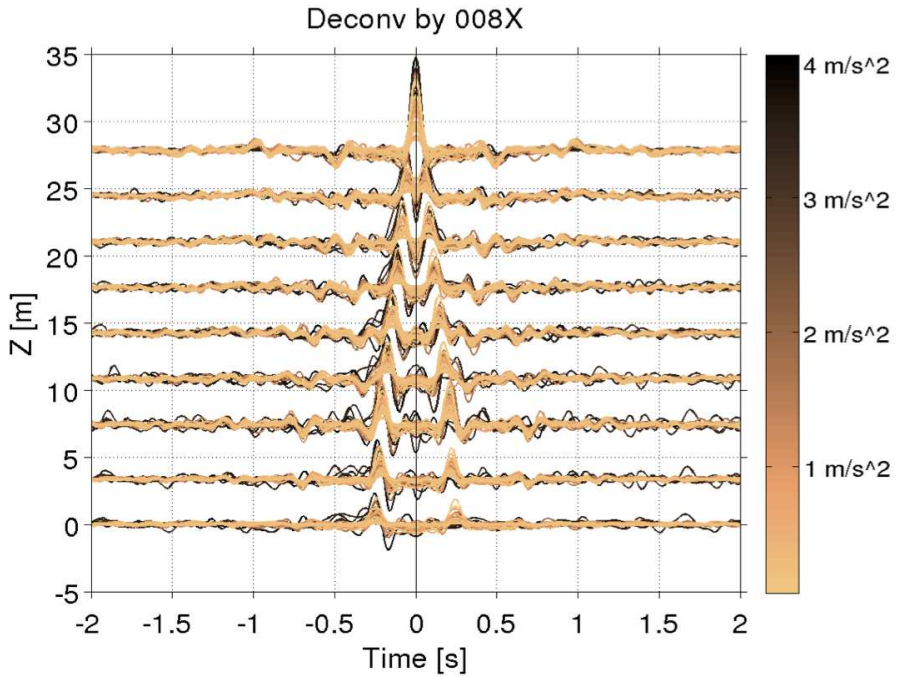
Transfer function - NL Soil behaviour

Effect of non linear soil behaviour on SSI

Structural response - Seismic interferometry by deconvolution



Structural model

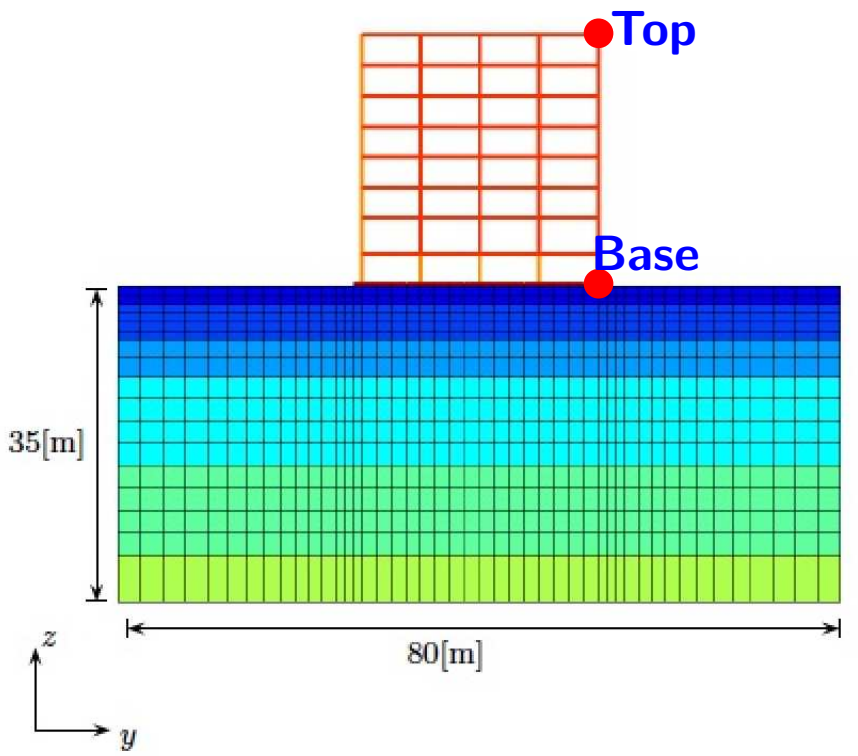


building impulse response (IRF)

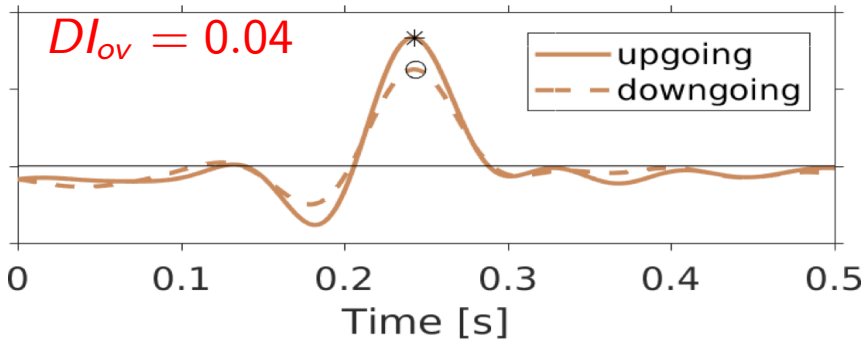
$$D(x,\omega) = \frac{U(x,\omega)U^*(x_{ref},\omega)}{U(x_{ref},\omega)^2+e}$$

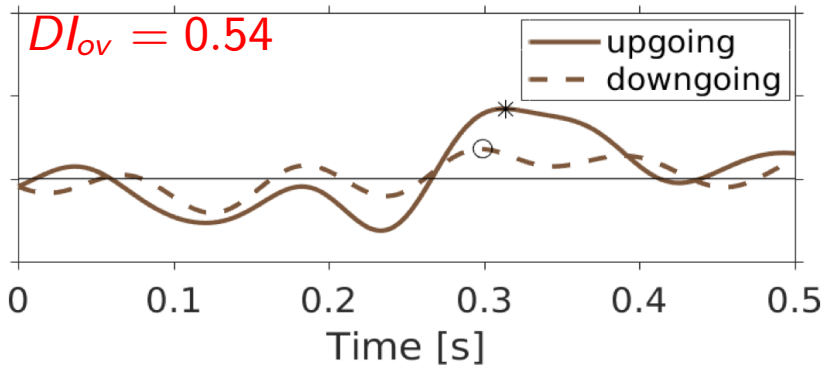
Effect of non linear soil behaviour on SSI

Structural response - Seismic interferometry by deconvolution



Structural model

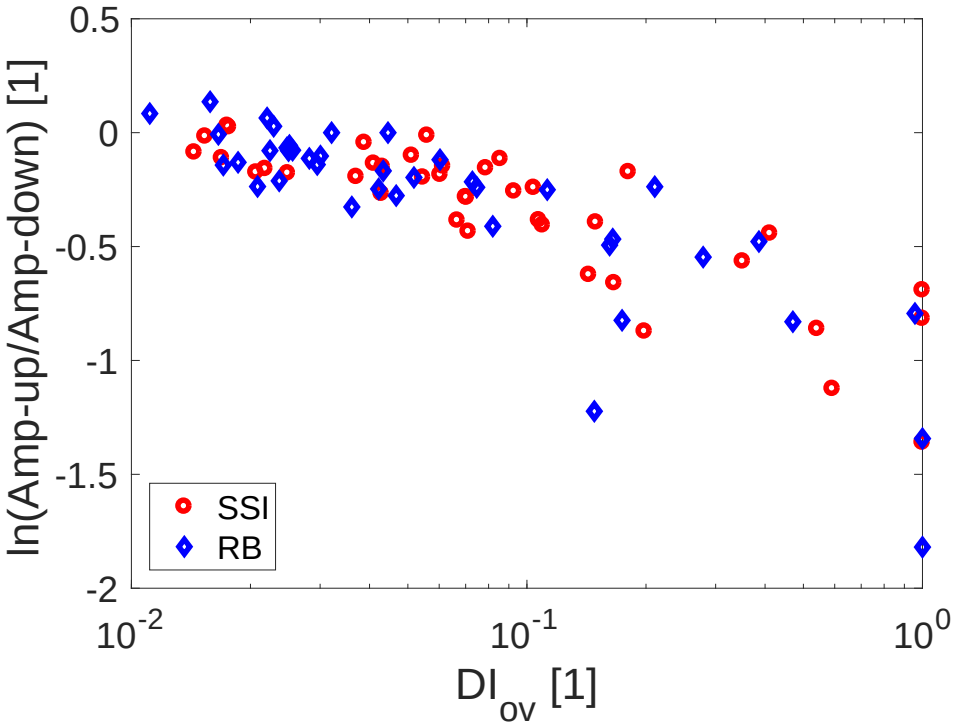




building impulse response (IRF)

Effect of non linear soil behaviour on SSI

Structural response - Seismic interferometry by deconvolution

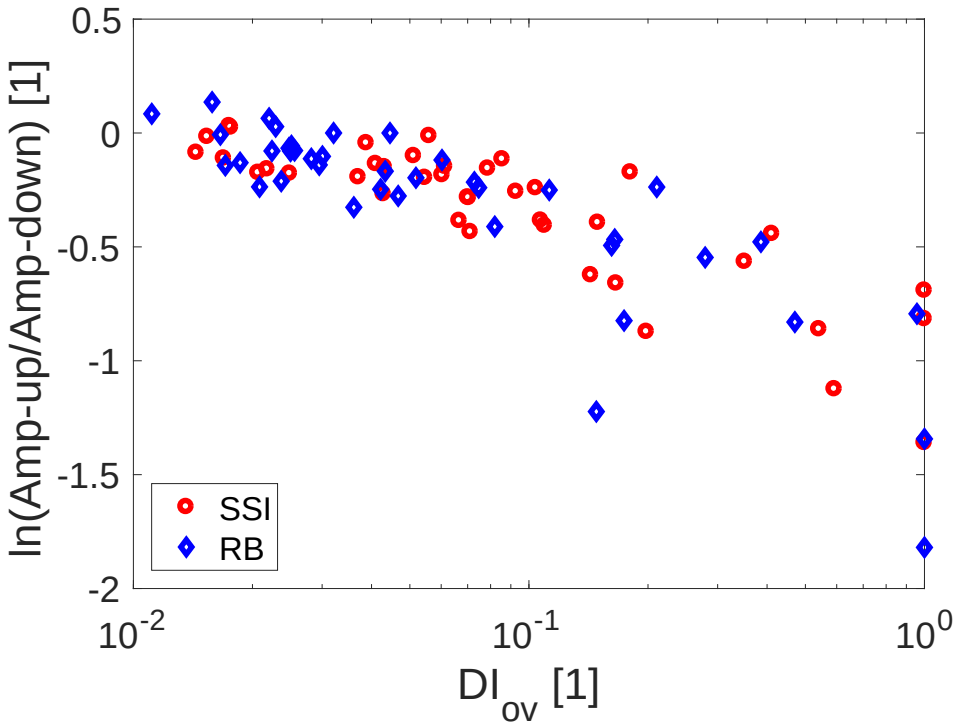


Relative amplitudes
(upgoing/downgoing)

$$\ln(A/A_0) = -\pi \cdot f_{str} \cdot h/(Q \cdot C) \quad \rightarrow \quad Q = 0.5\beta$$

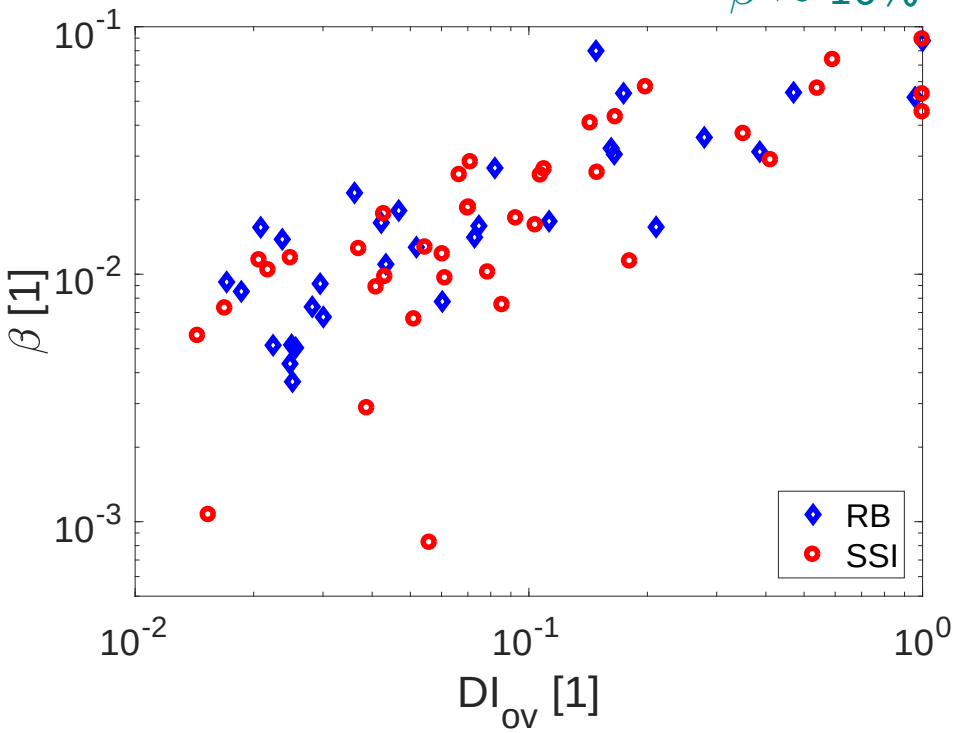
Effect of non linear soil behaviour on SSI

Structural response - Seismic interferometry by deconvolution



Relative amplitudes (upgoing/downgoing)

$\beta \approx 10\%$



Estimated damage building using relative amplitudes

$$\ln(A/A_0) = -\pi \cdot f_{str} \cdot h/(Q \cdot C) \quad \rightarrow \quad Q = 0.5\beta$$

Conclusions

some key points :

- Apparent wave velocities in the building estimated from the deconvolved signals are consistent with the input model parameters and the hypothesis of shear behaviour of the building (**No shown today**);
- Measurement of **relative amplitudes between upgoing/downgoing waves** (as a proxy for attenuation) **in the structure is highly correlated with damage index** independently of soil-structure or rigid-base boundary conditions.

Acknowledgements

AO RAP 2017 French project: *Caractérisation de l'ISS à partir de données accélérométriques et de mesures de vibrations ambiantes* and SEISM Paris Saclay Research Institute

Thank you for your attention

$\sigma\alpha\zeta\ \varepsilon\nu\chi\alpha\rho\iota\sigma\tau\acute{\omega}$