2nd « DAMS & SEISMS » EWG workshop
Lessons learn from earthquakes occurring in Italy.
Qualification of dynamic analyses of dams and their equipments and of probabilistic assessment of seismic hazard in Europe
6th-7th February 2017 – Roma

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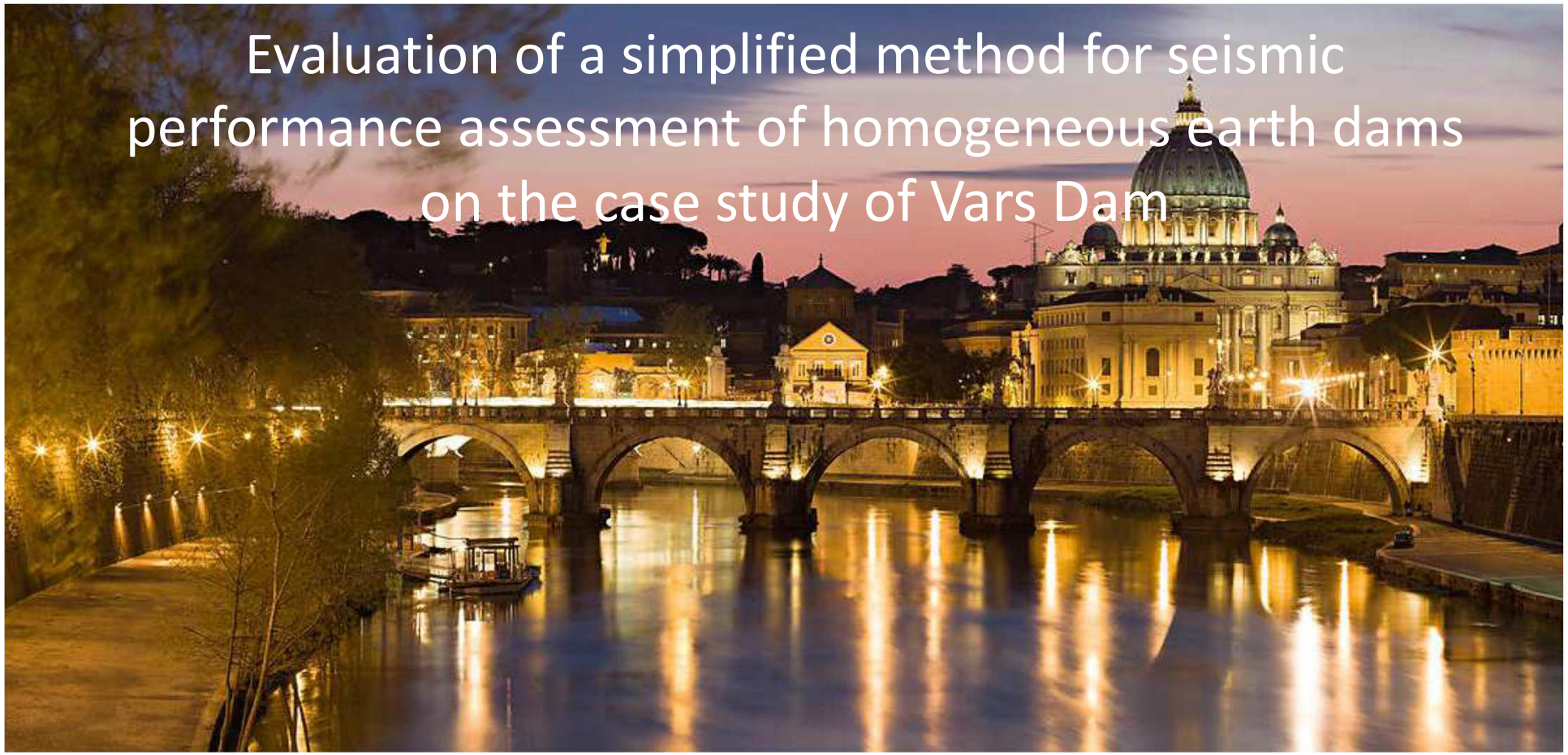
P.-Y. Bard - ISTerre

Session 4: Modeling of seismic embankment dam behaviour

Evaluation of a simplified method for seismic performance assessment of homogeneous earth dams on the case study of Vars Dam



1. INTRODUCTION

- **Context**

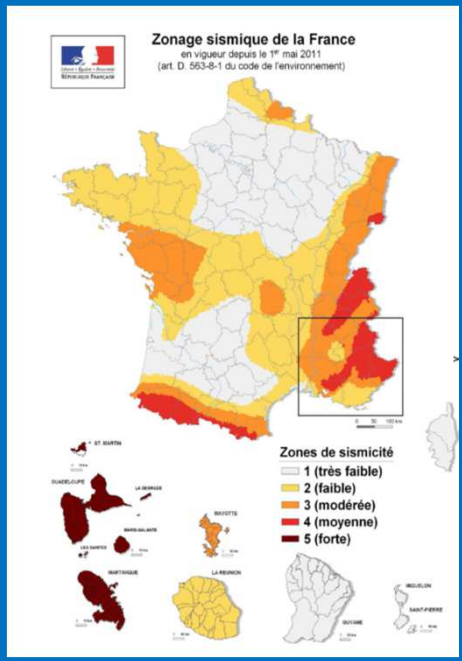
Alpine Mountain reservoirs :

- homogeneous earth dams (H< 20 m)
- altitude between 1200 and 2800 m
- Significant seismic risk, often critical for design
- Potential disastrous consequences (upstream ski resorts)
- Geotechnical investigations difficult and expensive → *scarce data*

→ *Strong need for rapid and preliminary methods, to evaluate their seismic performance based on easily available data.*

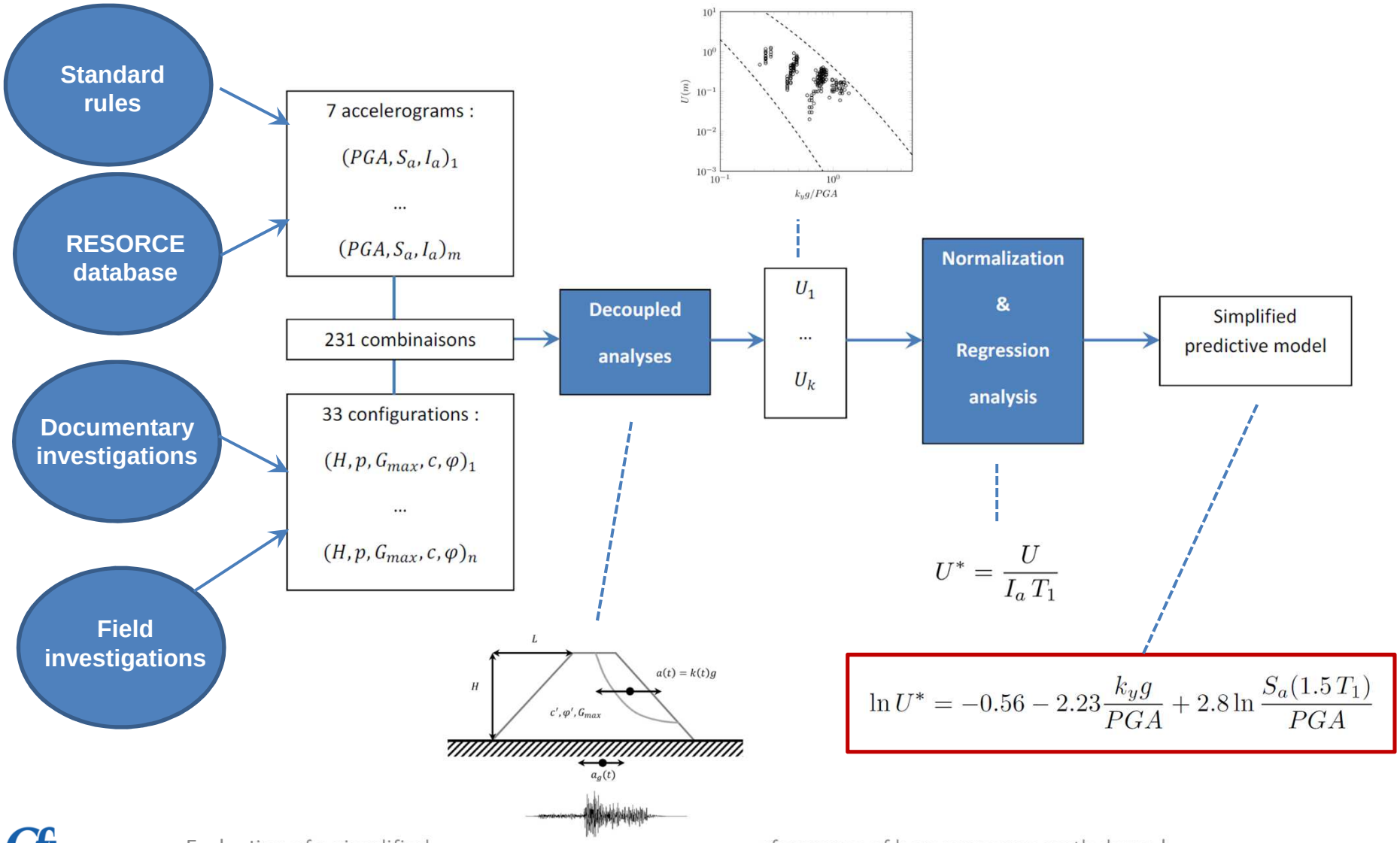
France seismicity map

Highest level in the Alpes area



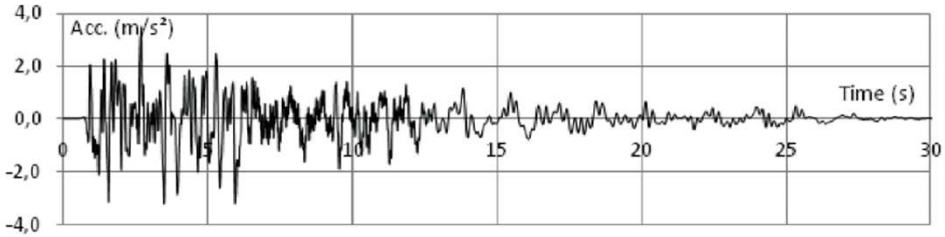
Simplified method

2. SIMPLIFIED METHOD



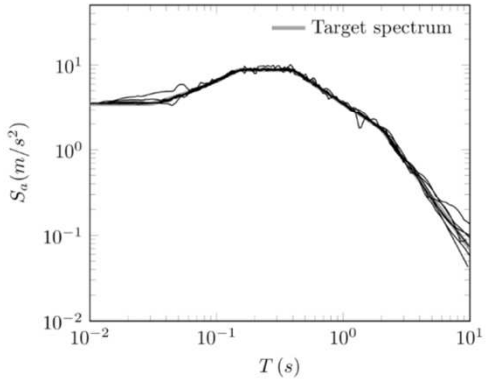
2. SIMPLIFIED METHOD

- **Input data**



Earthquake

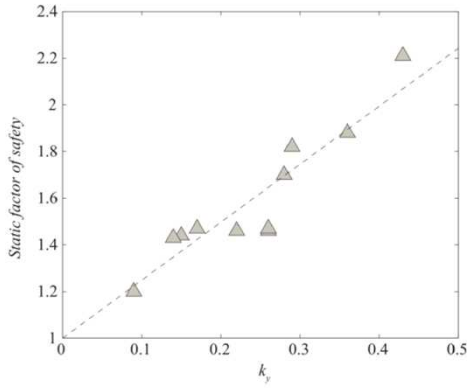
- Peak ground acceleration : *PGA*
- Arias intensity : $I_A = \frac{\pi}{2g}\int_0^\tau [a_g(t)]^2$



Dam

yield seismic coefficient : *ky*

Fundamental period : $T_1 = \frac{2\pi}{2.4}\frac{H}{\sqrt{G_{max}/\rho}}$



Coupling term

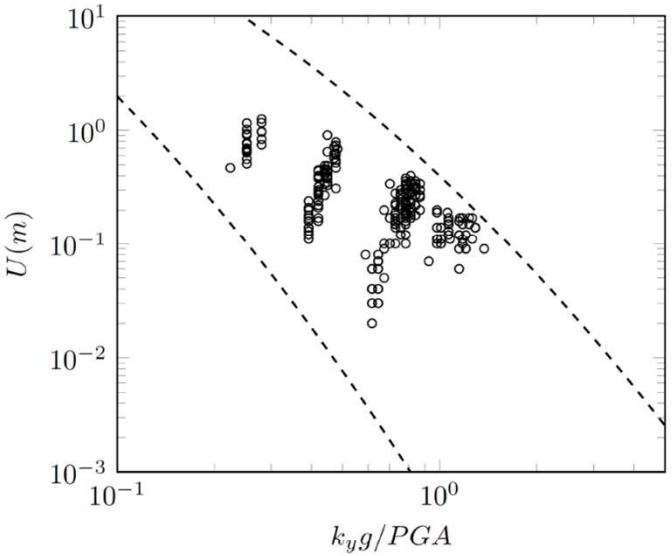
Spectral acceleration at a degraded fundamental period :

Sa (1,5 T1)

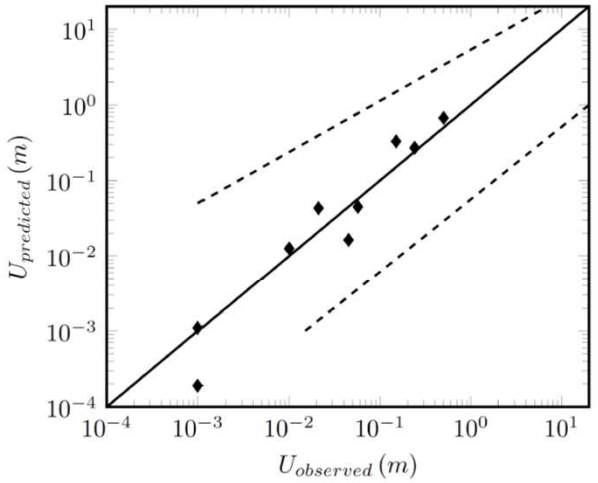
2. SIMPLIFIED METHOD

- **Validation**

Field data from Harder et al.(1998), Singh et al.(2007), Bray and Travasarou, (2009)



Validation of decoupled analysis results on field data



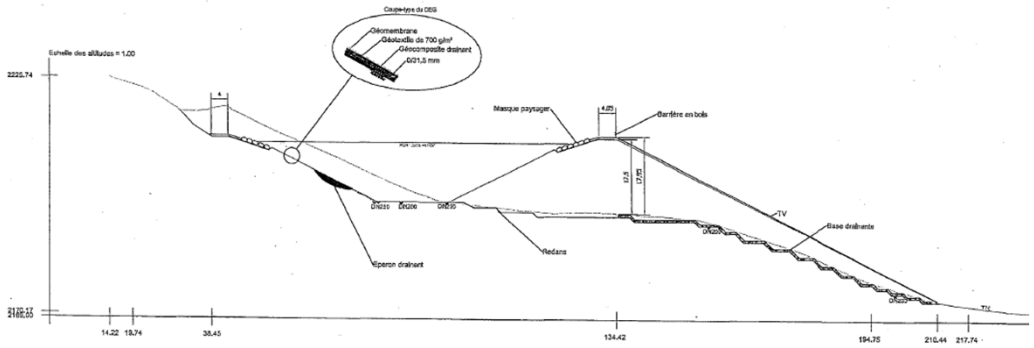
Validation of simplified method on field data

Dam	Earthquake	k_y	T_1 (s)	PGA (m/s^2)	I_a (m/s)	$S_a(1.5\,T_1)$ (m/s^2)	$U_{observed}$ (m)	$U_{predicted}$ (m)
Austrian Dam	LP	0.14	0.33	0.60	1.70	0.94	0.50	0.67
Lexington Dam	LP	0.11	0.31	0.40	1.05	0.61	0.15	0.33
Anderson Dam	LP	0.12	1.08	0.13	1.14	0.10	0.021	0.043
Guadalupe Landfill	LP	0.20	0.64	0.42	0.90	0.21	0.045	0.016
Pacheco Pass Landfill	LP	0.30	0.76	0.20	0.30	0.12	≤ 0.01	0.001
La Villita Dam	MI	0.20	0.60	0.10	0.40	0.33	0.057	0.046
Chabot Dam	SF	0.14	0.55	0.56	0.60	0.26	≤ 0.05	0.013
Cogswell Dam	WN	0.12	0.69	0.06	0.13	0.04	≤ 0.01	0.0002
Chiquita Canyon Landfill	NR	0.09	0.64	0.33	1.15	0.35	0.24	0.27

3. CASE STUDY OF VARS DAM

- **Presentation of the structure**

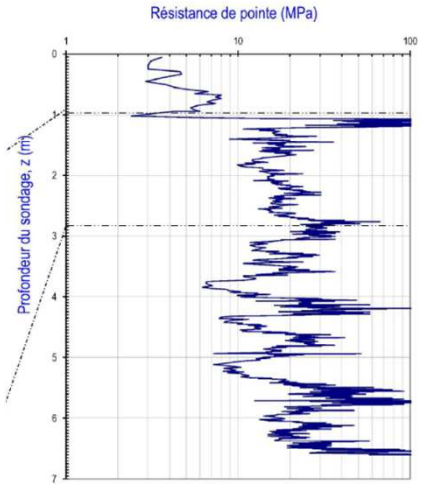
H= 21 m
Store volume = 125 000 m3
Altitude = 2200 m

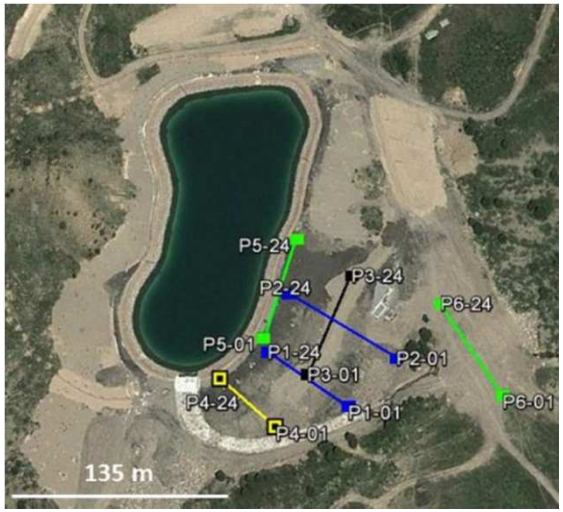


3. CASE STUDY OF VARS DAM

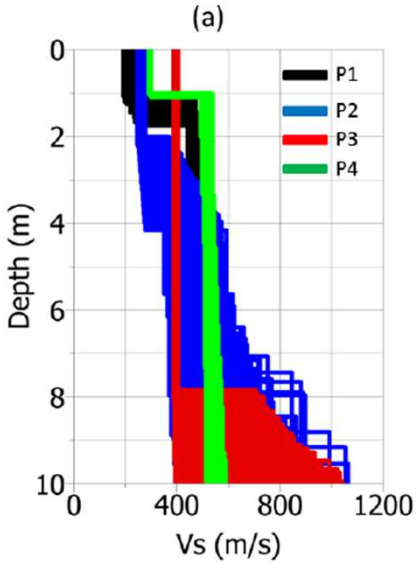
- **Geotechnical in situ investigations**

• Dynamic penetration tests (Sol Solution)





•Analyses surface waves (MASW) on 7 profiles (4 ISTerre & 3 Sol Solution)



→ Embankment : homogeneous moraine
Vs = 450 ± 100 m/s

3. CASE STUDY OF VARS DAM

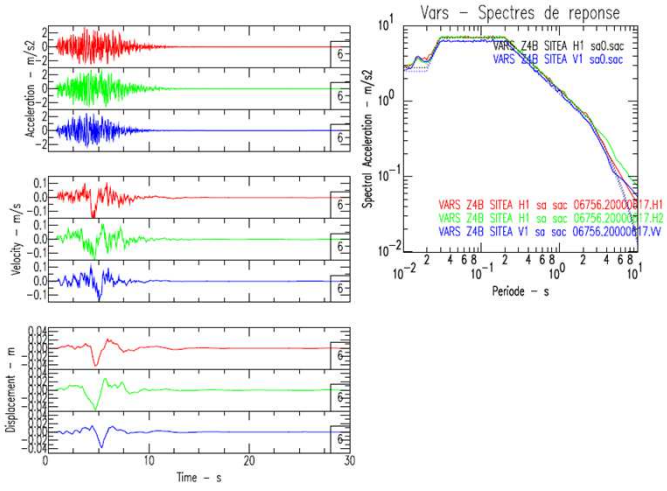
- **Input ground motion**

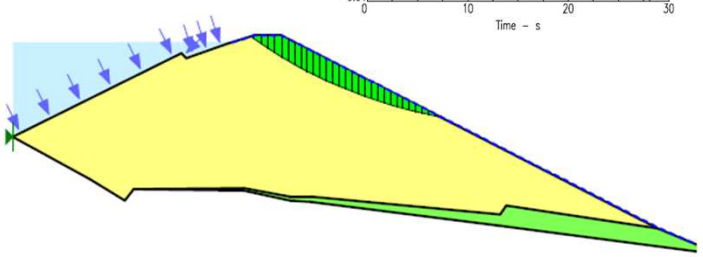
11 synthetic accelerograms (ISTerre)

Standard return period : T = 2500 years

Peak Ground Acceleration : PGA = 0.285 g

Arias intensity : I_A = 0.4 - 2.9 m s^{-1}



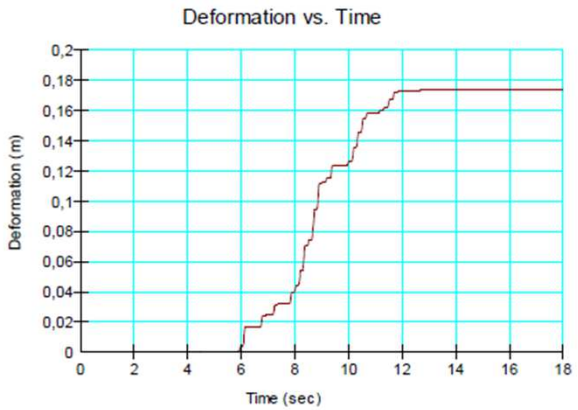


- **Decoupled analysis**

→ U = 1.7 – 17.5 cm

- **Simplified method**

→ U = 3.0 – 13.0 cm

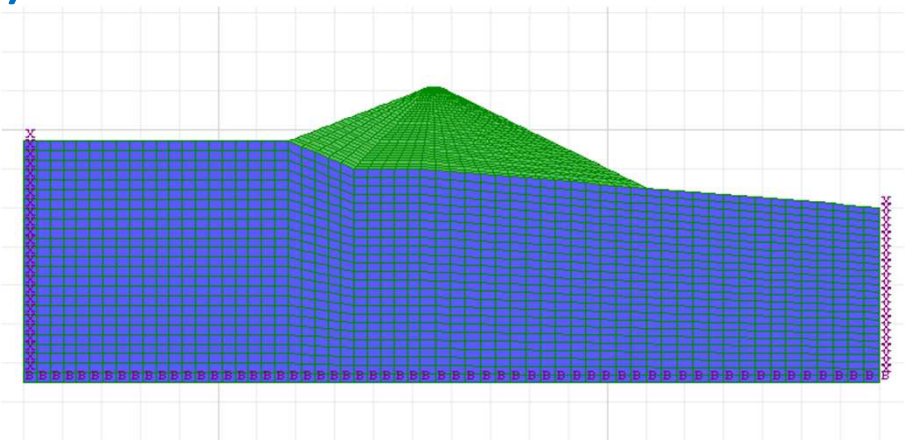


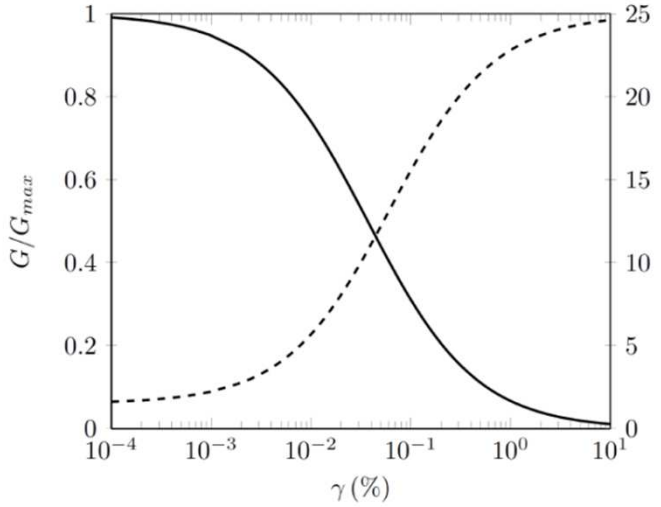
3. CASE STUDY OF VARS DAM

- **Dynamic coupled analysis (FLAC)**

Numerical model

- Mohr Coulomb behaviour laws
- Hysteretic damping





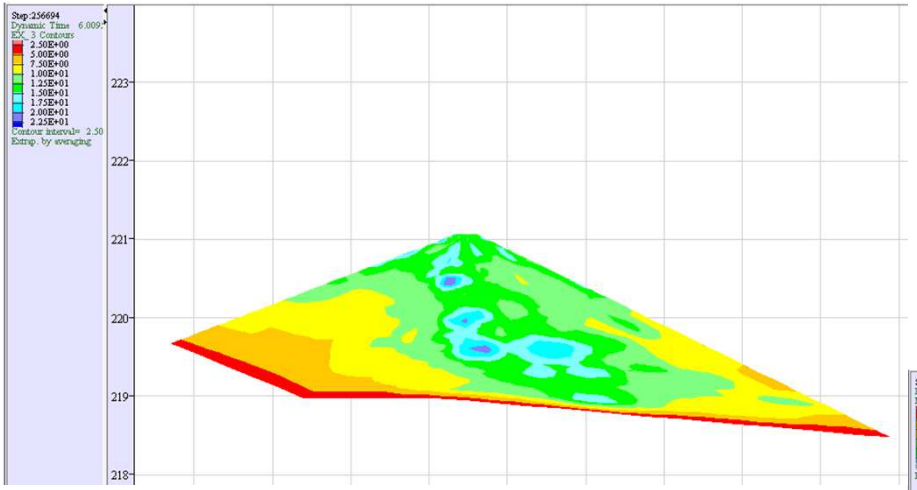
Boundary conditions

- Water pressure defined as an external load
- Free field motion conditions on the lateral sides of the model
- Input ground motion (shear stress) at the base of the model (after deconvolution)

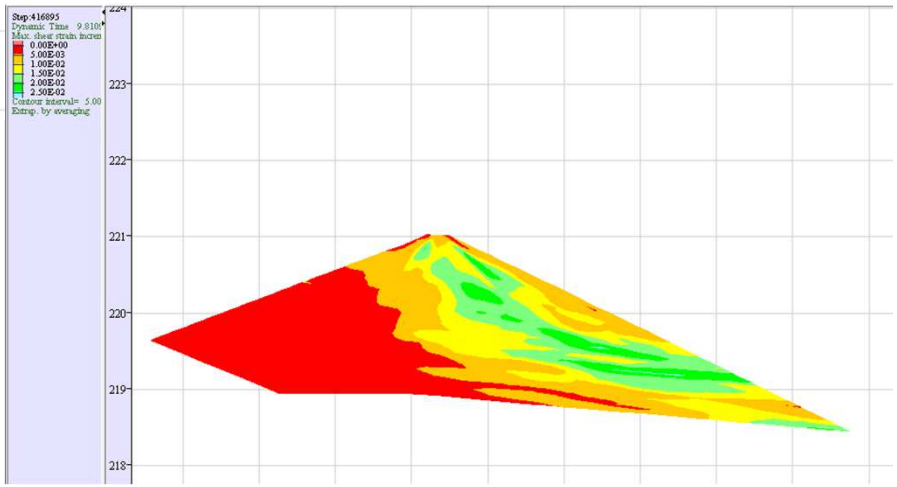
3. CASE STUDY OF VARS DAM

- **Results**

Maximum acceleration

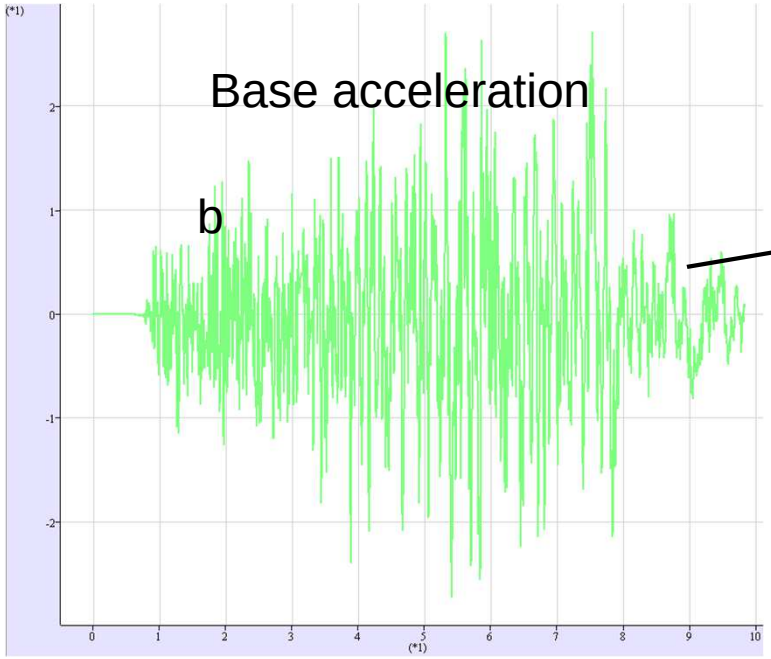


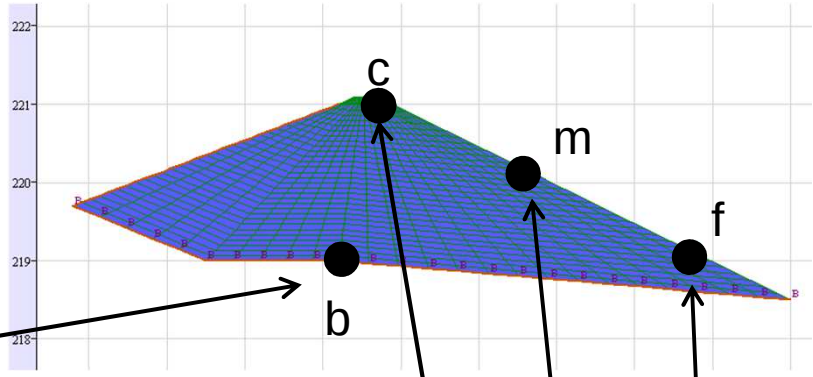
Final shear strain increment

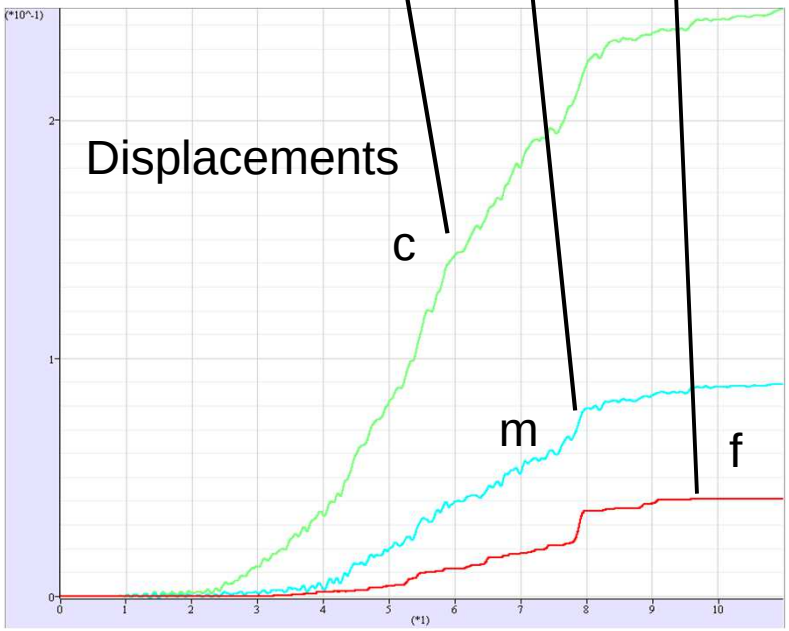


3. CASE STUDY OF VARS DAM

- **Results**







Coupled analysis → U = 5.2 – 27.0 cm

Factor 2 between coupled/decoupled analysis

4. CONCLUSION

- **Evaluation of simplified method**
  - Agreement with field observations
  - Simplified method/decoupled analysis resultst have de same order of magnitude
  - Coupled analysis results give significantly higher displacements than the simplified method
- **Ongoing work**
  - Better modeling of stored water
  - Evaluation of the method on other case studies
  - Reflexion on the definition of more pertinent performance criteria
- **Perspectives**
  - Use of the simplified method for regional or site specific seismic risk assessment (aided decision)

THANK YOU FOR YOUR ATTENTION