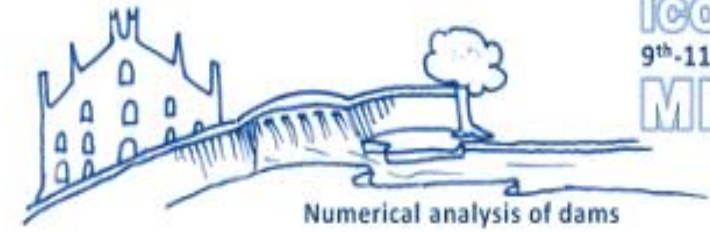




**ICOLD**  
**INTERNATIONAL**  
**COMMISSION ON**  
**LARGE DAMS**



## **ICOLD COMMITTEE ON COMPUTATIONAL ASPECTS OF ANALYSIS AND DESIGN OF DAMS**

### **15<sup>th</sup> INTERNATIONAL BENCHMARK WORKSHOP ON NUMERICAL ANALYSIS OF DAMS**

#### **Theme A - Formulation**

#### **SEISMIC ANALYSIS OF PINE FLAT CONCRETE DAM**

**9 September 2019, Milan, Italy**

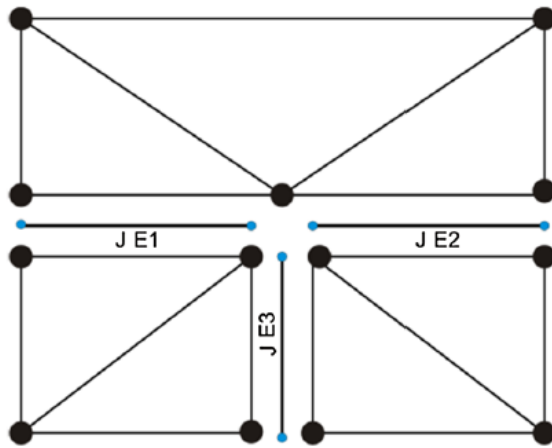
#### *Seismic analysis of Pine Flat concrete dam*

Comparison of numerical results from 2D and 3D analysis

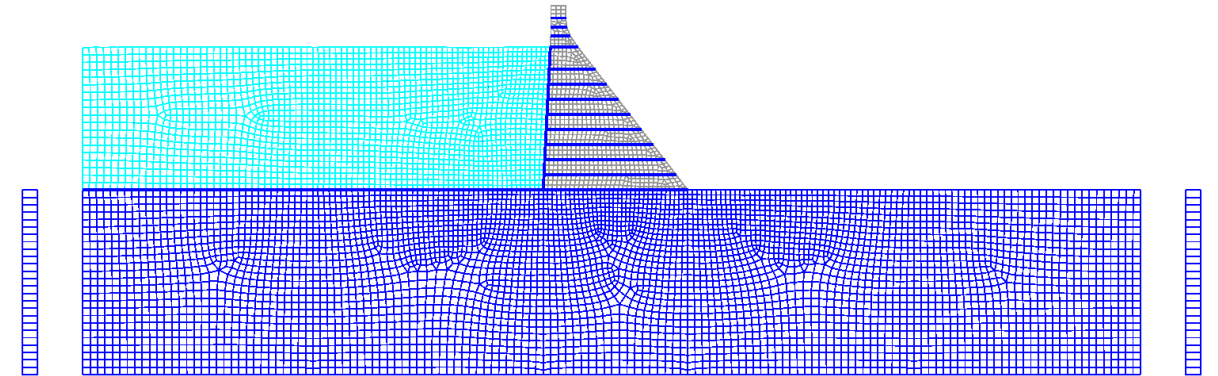


*Nuno Monteiro Azevedo, M. Luísa Braga Farinha, Romano Câmara, Noemi Schclar Leitão*

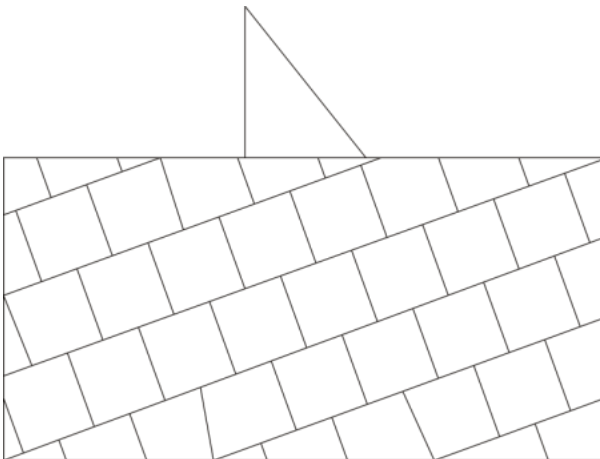
# Mechanical model in small displacements - 2D



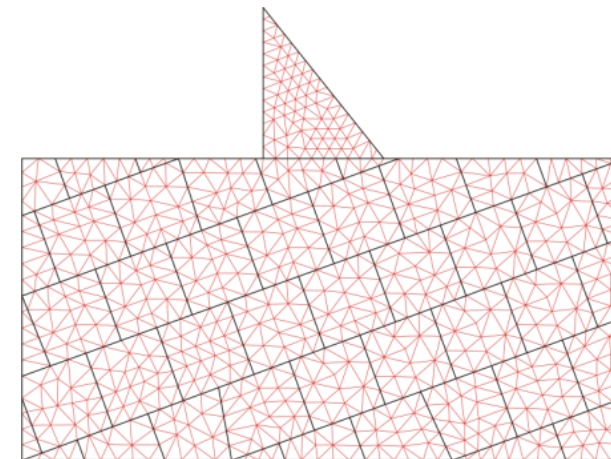
J E – joint elements



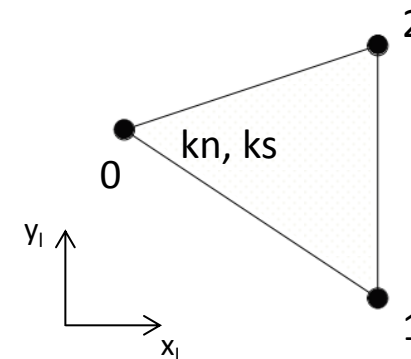
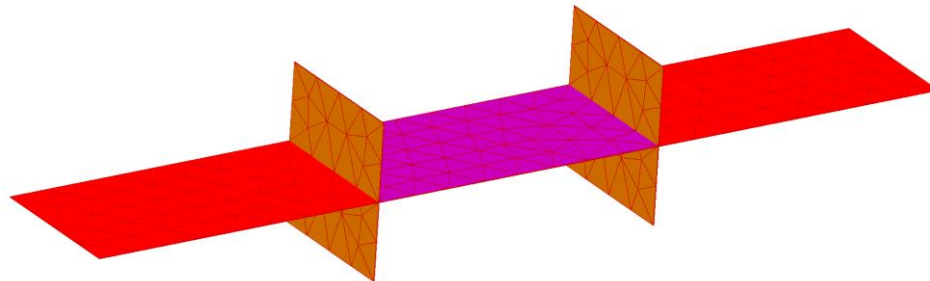
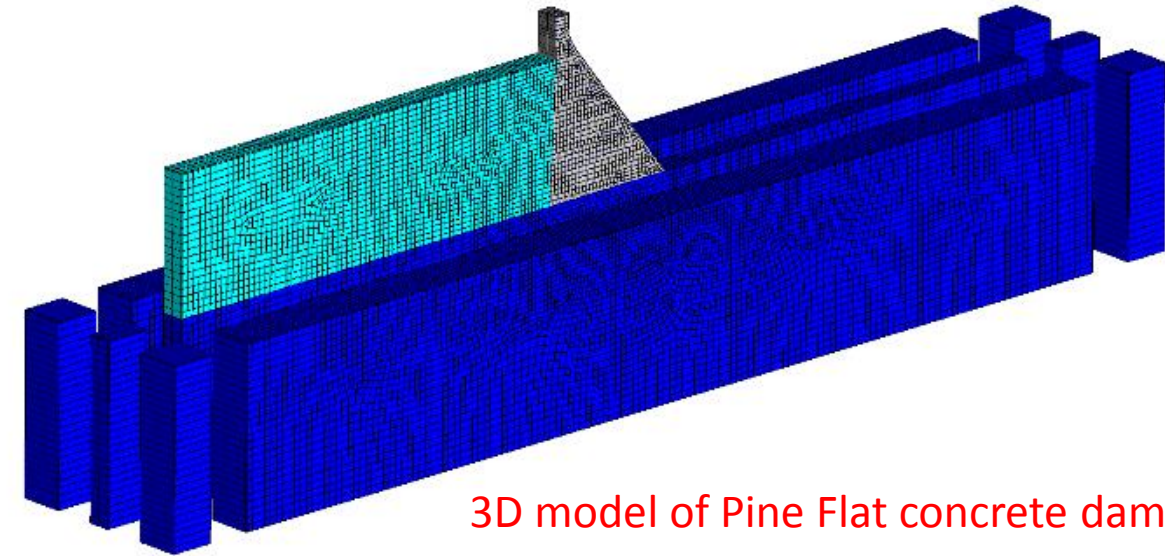
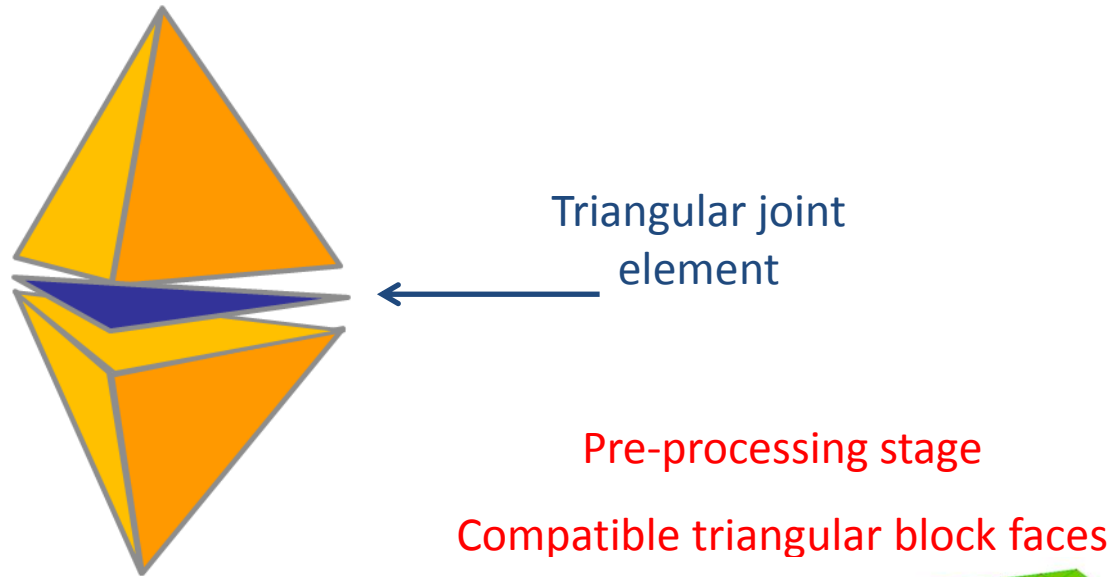
2D model of Pine Flat concrete dam



Pre-processing stage  
Compatible block edges



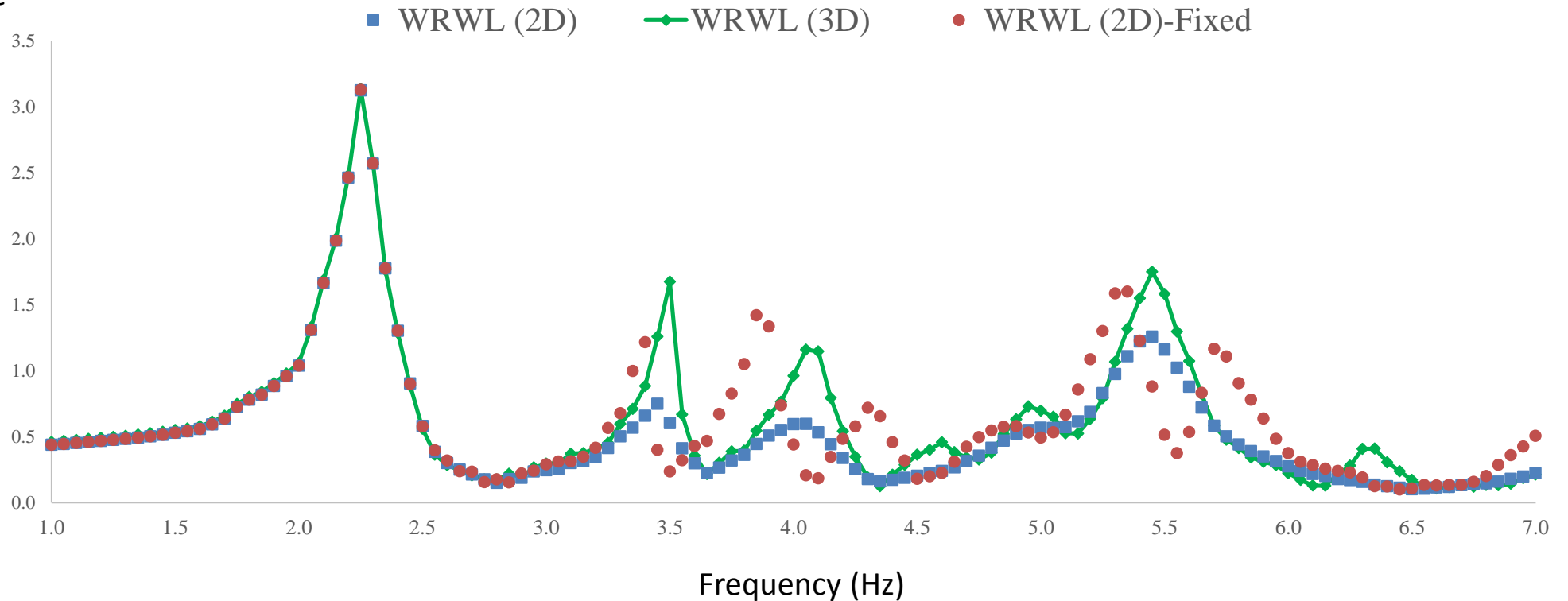
# Mechanical model in small displacements - 3D



# Influence of fluid boundary conditions

- Forced vibration dynamic tests for the Winter reservoir water level (268.21 m)

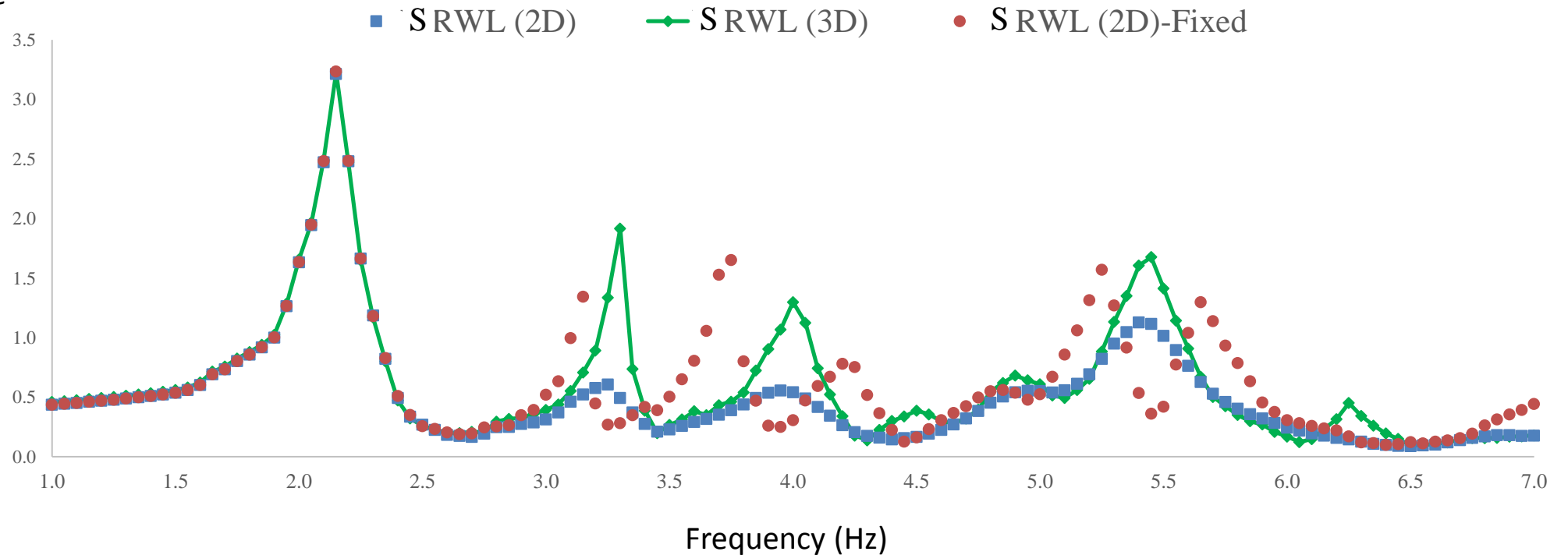
Displacement at the  
dam crest  
( $\times 10^{-6}$  m/kN)



# Influence of fluid boundary conditions

- Forced vibration dynamic tests for the Summer reservoir water level (278.57 m)

Displacement at the  
dam crest  
( $\times 10^{-6}$  m/kN)

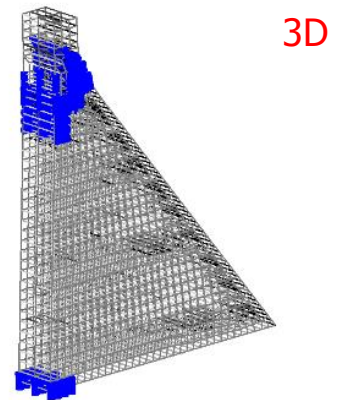
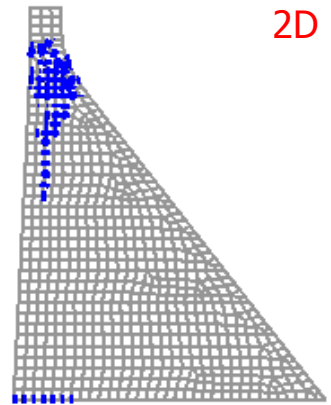




# Main conclusions



- **Case A: Natural frequencies and force vibration analysis**
  - eigenfrequencies for the Pine Flat dam are influenced by the fluid boundary condition
- **Case D: Seismic analysis for various reservoir levels following a linear elastic model**
  - 2D / 3D
    - responses in terms of displacements and stresses at the dam are very close
    - slightly different behaviour in terms of mode shapes
- **Case E: Non-linear seismic type analysis including nonlinear behaviour**
  - 2D / 3D
    - Both models predict similar responses even for the ETAF record which leads to a high complex nonlinear behaviour



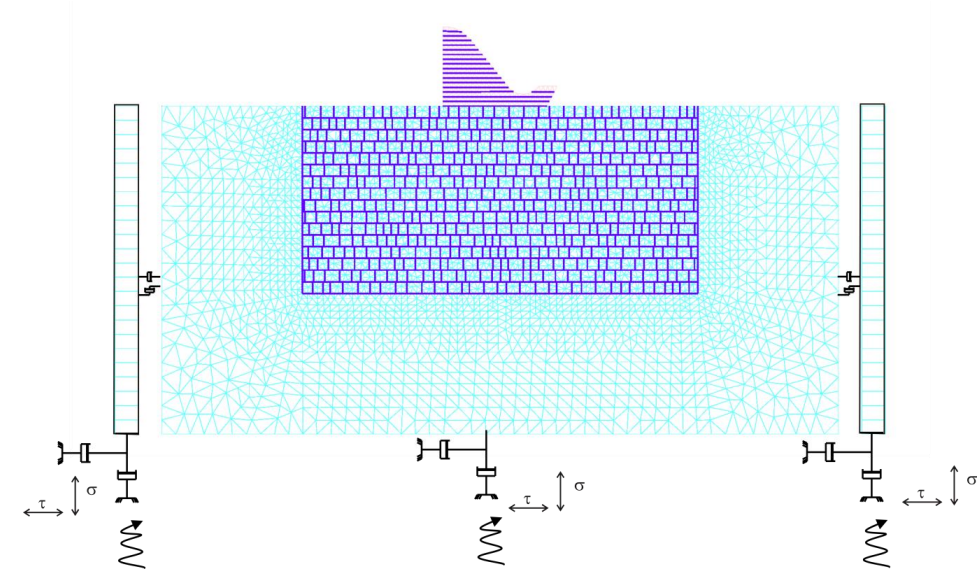
# Lessons learned and issues to be addressed in future investigations



- Seismic analysis of a concrete dam should always be performed step-by-step
  - natural frequencies and static stress distribution
  - linear analysis
  - non-linear analysis
- Analysis using more than one model (2D/3D or different mesh discretization)
- Future work
  - carry out a dynamic characterization for a given range of frequencies
  - assess the fluid structure interaction models for different concrete dam geometries
  - assess whether the Lagrangian based models are able to predict correct responses for refined distorted fluid meshes
  - 3D modelling
  - Predefined finite element mesh for nonlinear modelling



# Seismic evaluation of Pedrógão gravity dam



- hydromechanical model, validated using a real case of an operating dam
- comparison of the results with those obtained with a large displacement discrete model
- 3D analysis

