COMSOL CONFERENCE ROTTERDAM 2013

RSE Ricerca Sistema Energetico

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The Seismic Assessment of a Concrete Arch Dam-Reservoir-Foundation System using COMSOL

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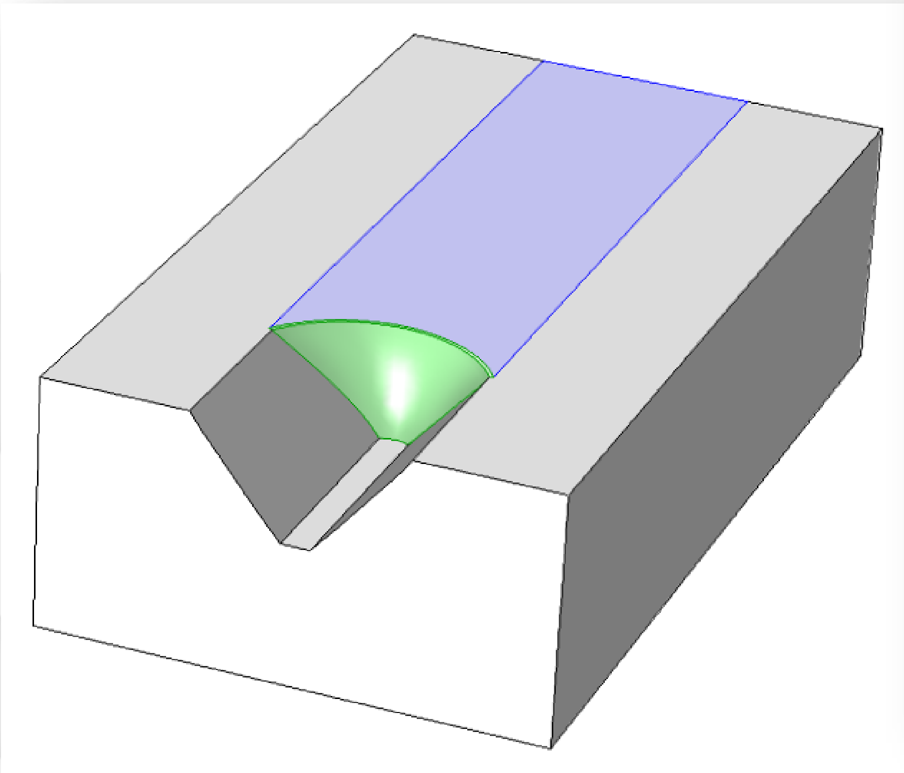
- Aim of the work
- Geometric model and material parameters
- Boundary and loading conditions
- Numerical analyses
- Results
- Future challenges

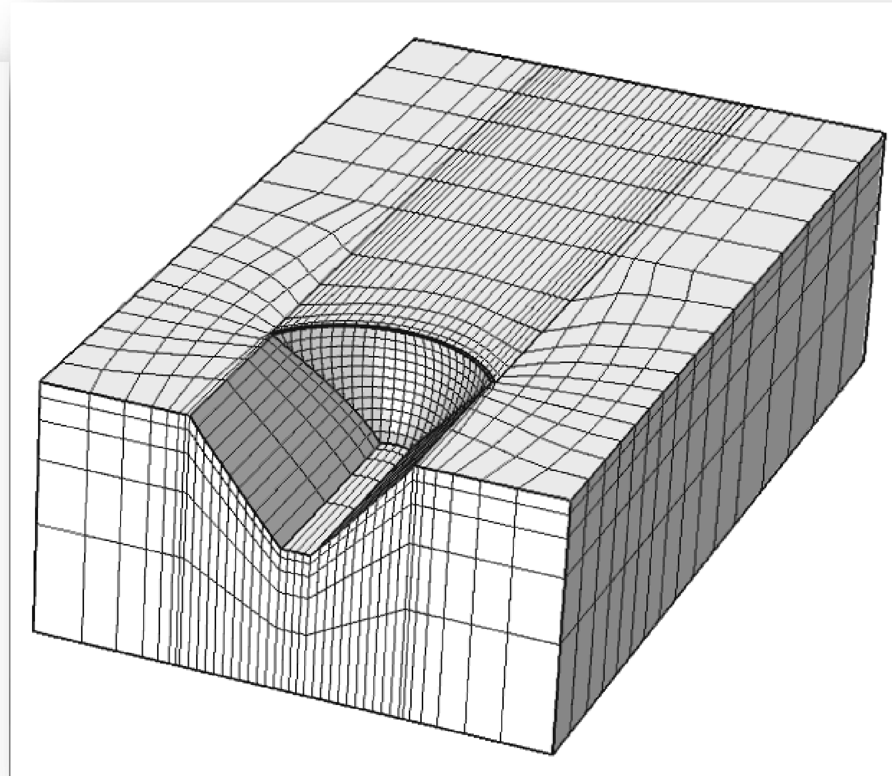
Aim of the work

Take part to the 12th ICOLD* International Benchmark Workshop, solving Theme A (*Fluid Structure Interaction – Arch Dam-Reservoir at Seismic loading*) by means of COMSOL Multiphysics

One of the main aim of these Benchmark Workshops is to compare numerical results attained using different software and methodologies and to validate them on the basis of experimental results as well as the common engineering practice

**International COmmission on Large Dams*





The geometric model consists of three domains:

- *Dam* (220 m height)
- *Impounded water*
- *Foundation rock*

- The mesh is composed of 5.554 solid finite elements, whose ***shape functions*** are ***quadratic*** (more than 100.000 degrees of freedom)
- The ***impounded water*** is modelled by means of ***acoustic elements***

Material parameters of the mechanical and acoustic domains

Material	Density [kg/m³]	Poisson ratio	Young modulus [MPa]	Rayleight mass damping	Rayleight stiffness damping
Concrete	2400	0.167	27000	0.94	2.65E-03
Rock	0	0.200	25000	-	-

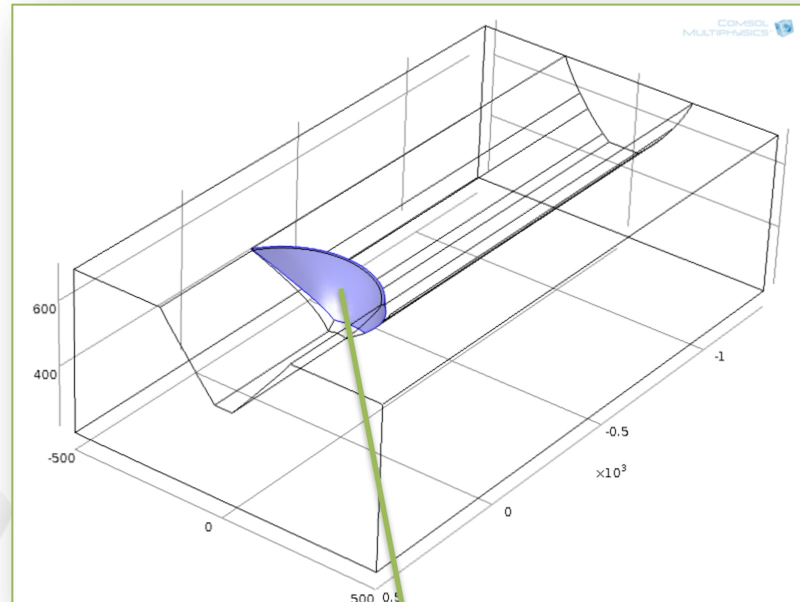
The **Rayleight damping model** has been taken into account to assign a 5% structural damping ratio to the dam during seismic loading conditions

Material	Density [kg/m³]	Speed of sound in water [m/s]	Bulk modulus [MPa]
Water	1000	1500	2200

Boundary conditions applied to the fluid domain (1/2)

Dam-reservoir interface

COMSOL *acoustic-structure boundary*



$$-n \cdot \left(-\frac{1}{\rho} (\nabla p - q_d) \right) = -n \cdot u_{tt}$$

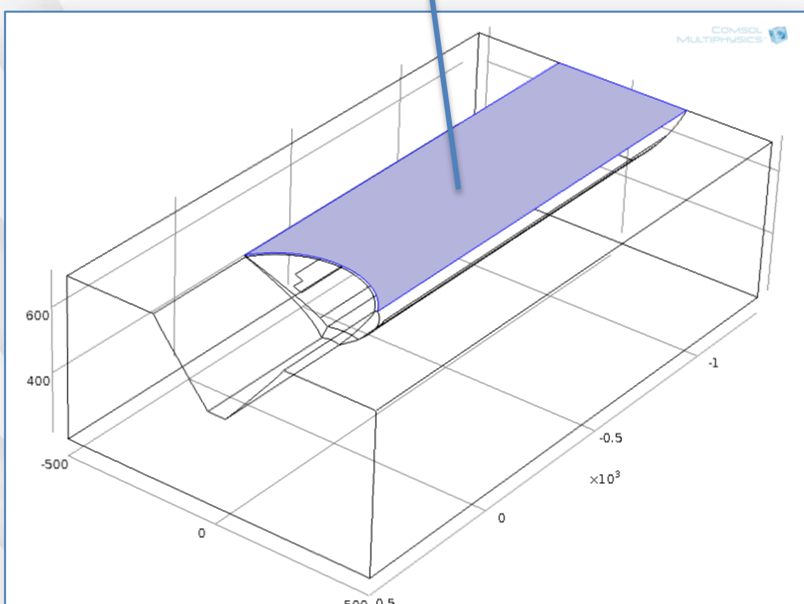
0

$$\sigma \cdot n = p\, n$$

Free surface

COMSOL *sound soft boundary*

$$p = 0$$

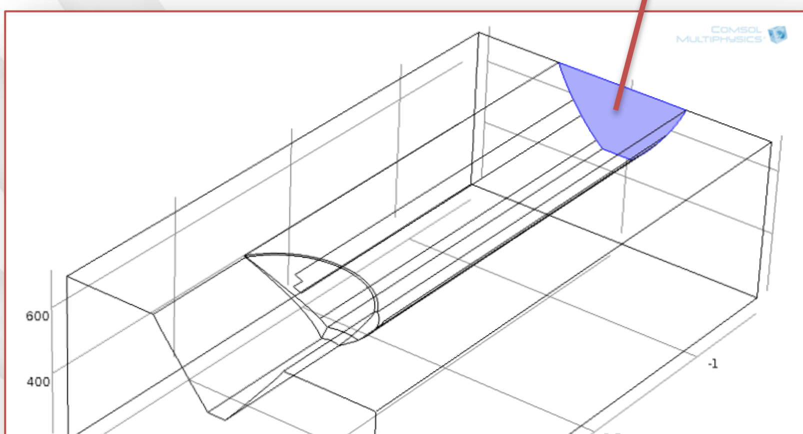


Boundary conditions applied to the fluid domain (2/2)

Upstream-reservoir surface

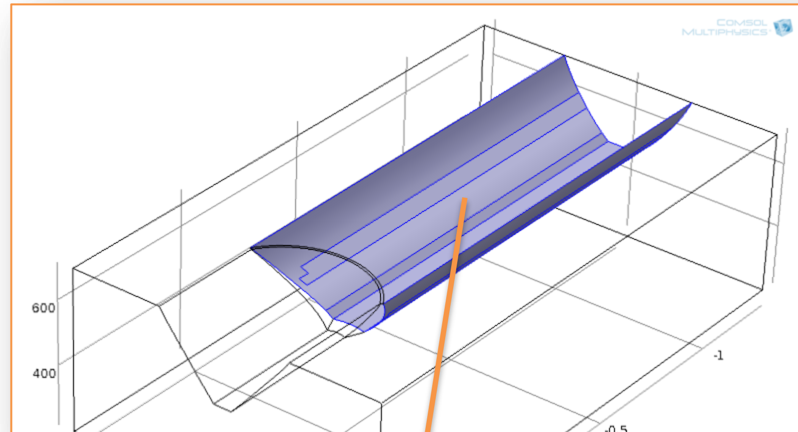
COMSOL *plane wave radiation*

$$-n\cdot\left(-\frac{1}{\rho}\left(\nabla p-\cancelto{0}{q_d}\right)\right)+\frac{1}{\rho}\left(\frac{1}{c}\frac{\partial p}{\partial t}\right)=\cancelto{0}{Q_i}$$



Foundation-reservoir interface

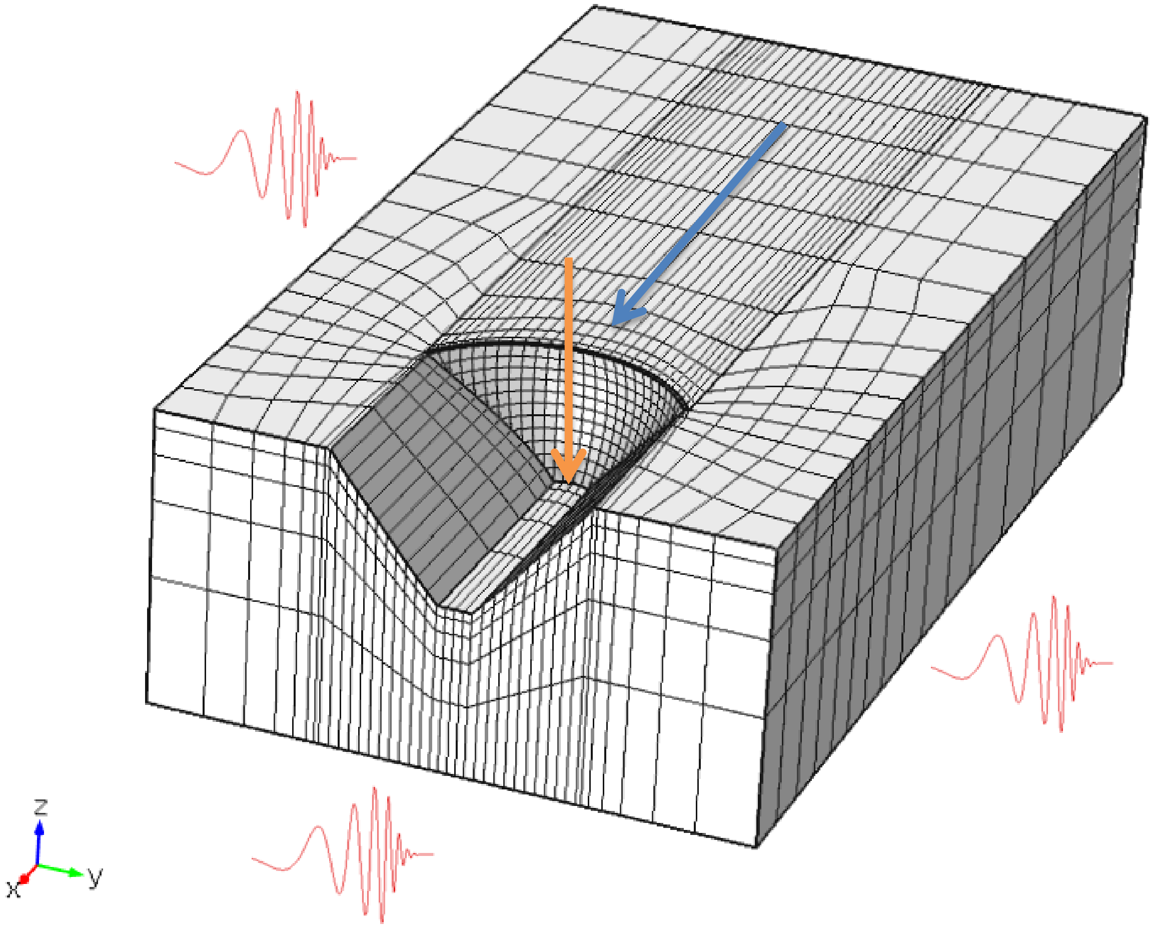
COMSOL *impedance*



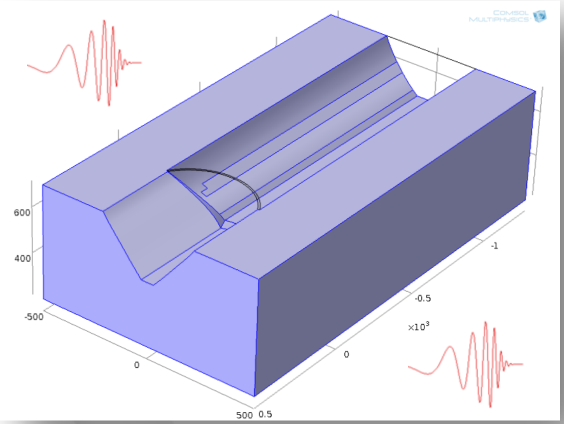
$$-n\cdot\left(-\frac{1}{\rho}\left(\nabla \mathrm{p}-\cancelto{0}{q_d}\right)\right)=\frac{1}{Z_i}\frac{\partial p}{\partial t}$$

$$Z_i=\rho/\mathrm{q} \qquad q=\frac{1}{c}\,\frac{1-\alpha}{1+\alpha}$$

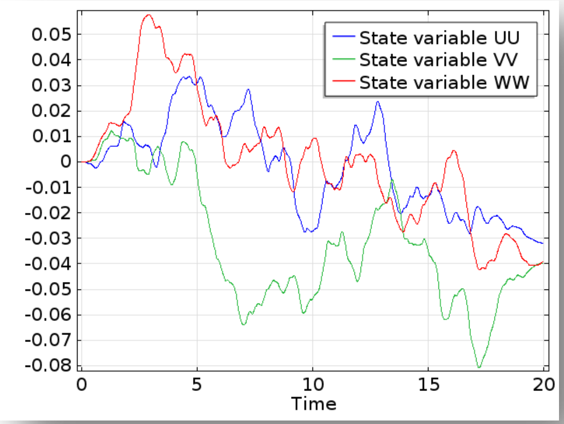
- ***Dead weight*** of the dam
- ***Hydrostatic pressure*** with the maximum water level equal to the dam crest height (i.e. 715 m a.s.l.)
- ***Seismic loads*** in terms of accelerations along the three Cartesian directions applied to the lateral wall and basement rock



Solid mechanics analysis



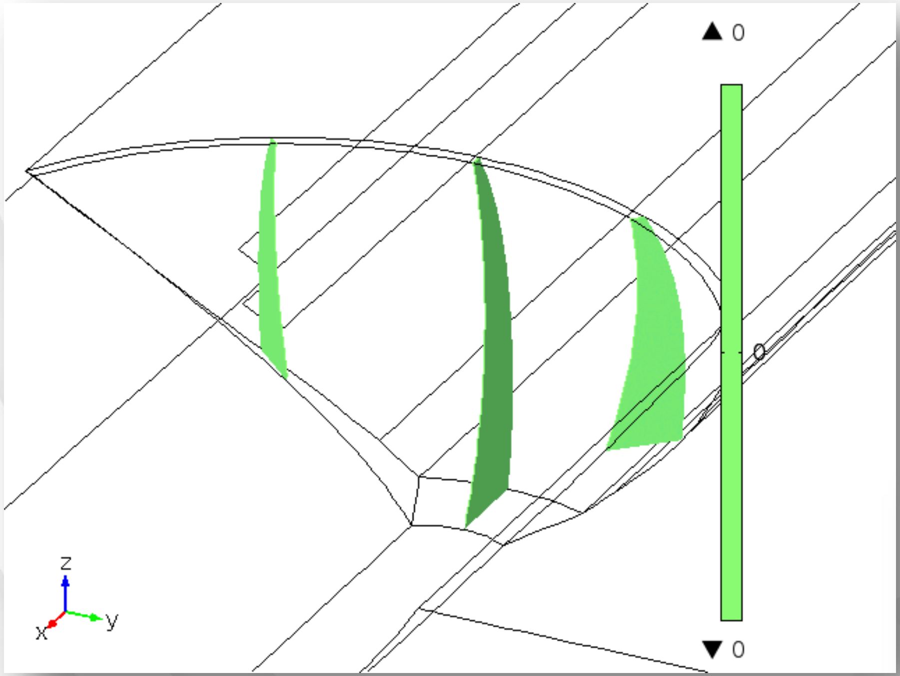
Making reference to the foundation domain, a ***global ordinary differential equations problem*** has been solved to compute the displacements associated to the earthquake motions



$$f(\boldsymbol{u}, \boldsymbol{u}_{tt}, t) = 0$$

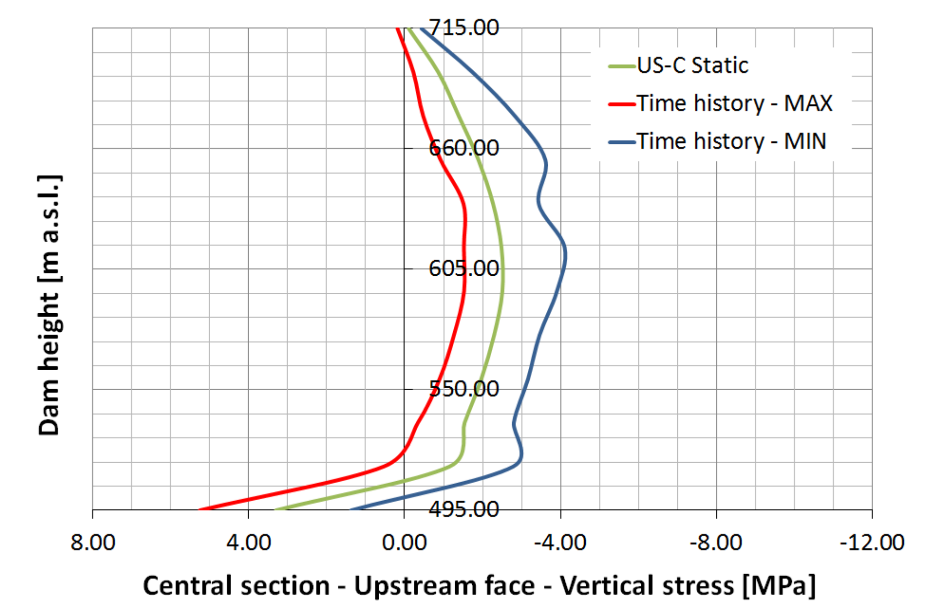
Acoustic-solid interaction analysis

A massless foundation is considered
Displacements applied to the lateral wall and basement rock

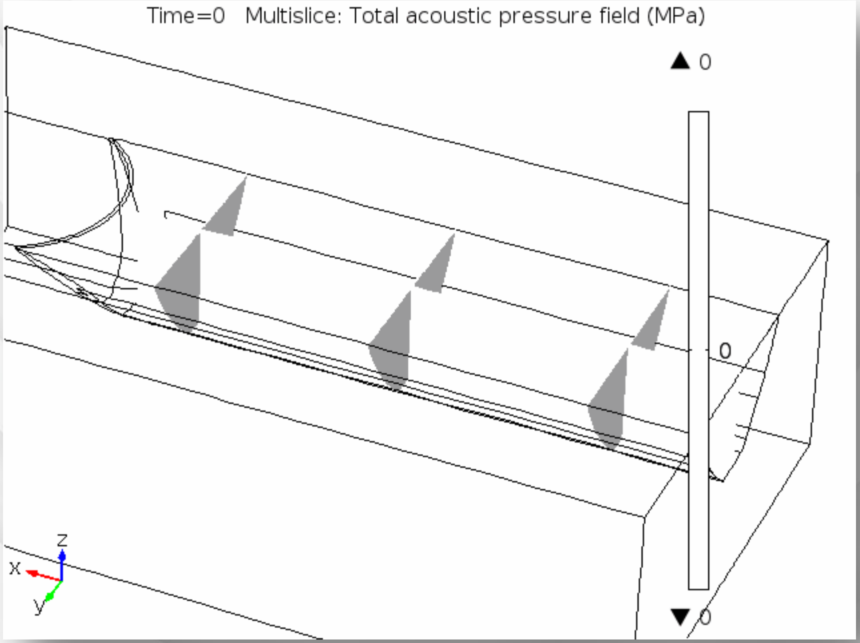


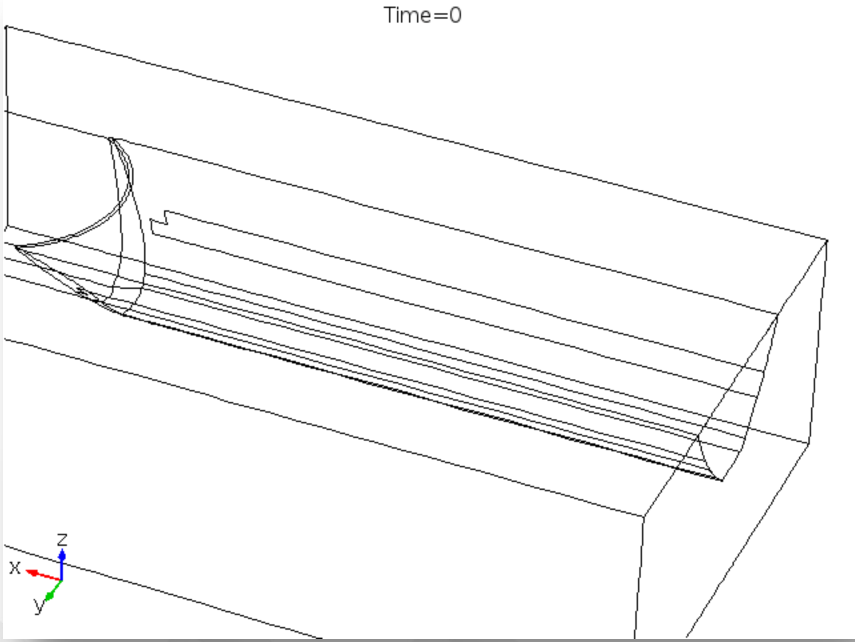
Data points have been selected on the downstream-upstream faces of the dam by means of the ***Model Coupling/General Extrusion command***

Output data have been extrapolated on some points of the model running a ***MATLAB script within COMSOL***



- The *acoustic pressure field* during seismic analysis, visualised on some transversal slices of the fluid domain and in terms of isosurface





- The ***length*** of the ***impounded water*** could be shortened to reduce the computational time
- The behaviour of the different boundary conditions applied to the fluid domain could be observed

- Take into account **geometrical and physical non linearity**; for instance:
  - **Contacts** to simulate the dam-foundation interaction as well as the vertical construction joints on the dam body
  - A **damage elasto-plastic constitutive law**, such as the Fenves one, in order to better represent the concrete behavior under the ultimate strength limit

- Perform a **response spectrum analysis** bearing in mind that in dam design is the simplest and fastest way to assess the maximum displacements of the structure under seismic loadings

The end

Thank you for your attention