ICOLD
INTERNATIONAL
COMMISSION ON
LARGE DAMS

ICOLD-BW 2019
9th-11th September
MILANO
Numerical analysis of dams

ICOLD COMMITTEE ON COMPUTATIONAL ASPECTS OF ANALYSIS AND DESIGN OF DAMS

15th INTERNATIONAL BENCHMARK WORKSHOP ON NUMERICAL ANALYSIS OF DAMS

Theme A - Formulation

SEISMIC ANALYSIS OF PINE FLAT CONCRETE DAM

9 September 2019, Milan, Italy

Seismic Excitation of a Concrete Dam

Analysis of the Influence of Modelling Approaches and Concrete Material Non-Linearity

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The finite element model

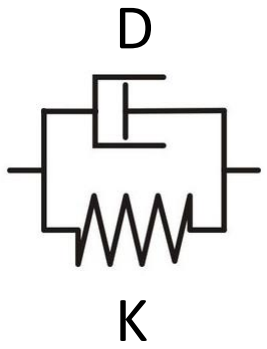
- Solver: ANSYS 19.2
- Fluid-structure interaction: acoustic-structural coupling
- Model: 2,5 D
- Mesh:
  - 2,5 m
  - SOLID185, FLUID30, COMBIN14, SURF154
- Boundary conditions:
  - acoustic impedance boundary
  - Rayleigh viscous damping
  - viscous spring approach

Loads

- Static dam weight: 1. load step (static)
- Hydrostatic pressure: 2. load step (static)
- Earthquake loading: vertically propagating SH wave: 3. load step (dynamic)
  - massless foundation approach: acceleration signal sufficient
  - viscous spring model: acceleration signal + correction by discrete force time histories

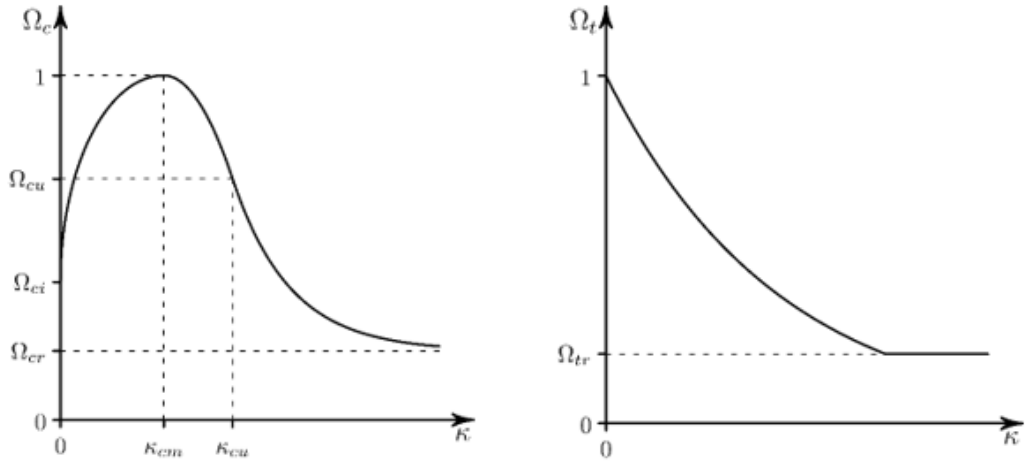
Acceleration at the base of the foundation due to the SH wave

$$\mathrm{F(t)} = Ku(t) + C\dot{u}(t)$$



The material model

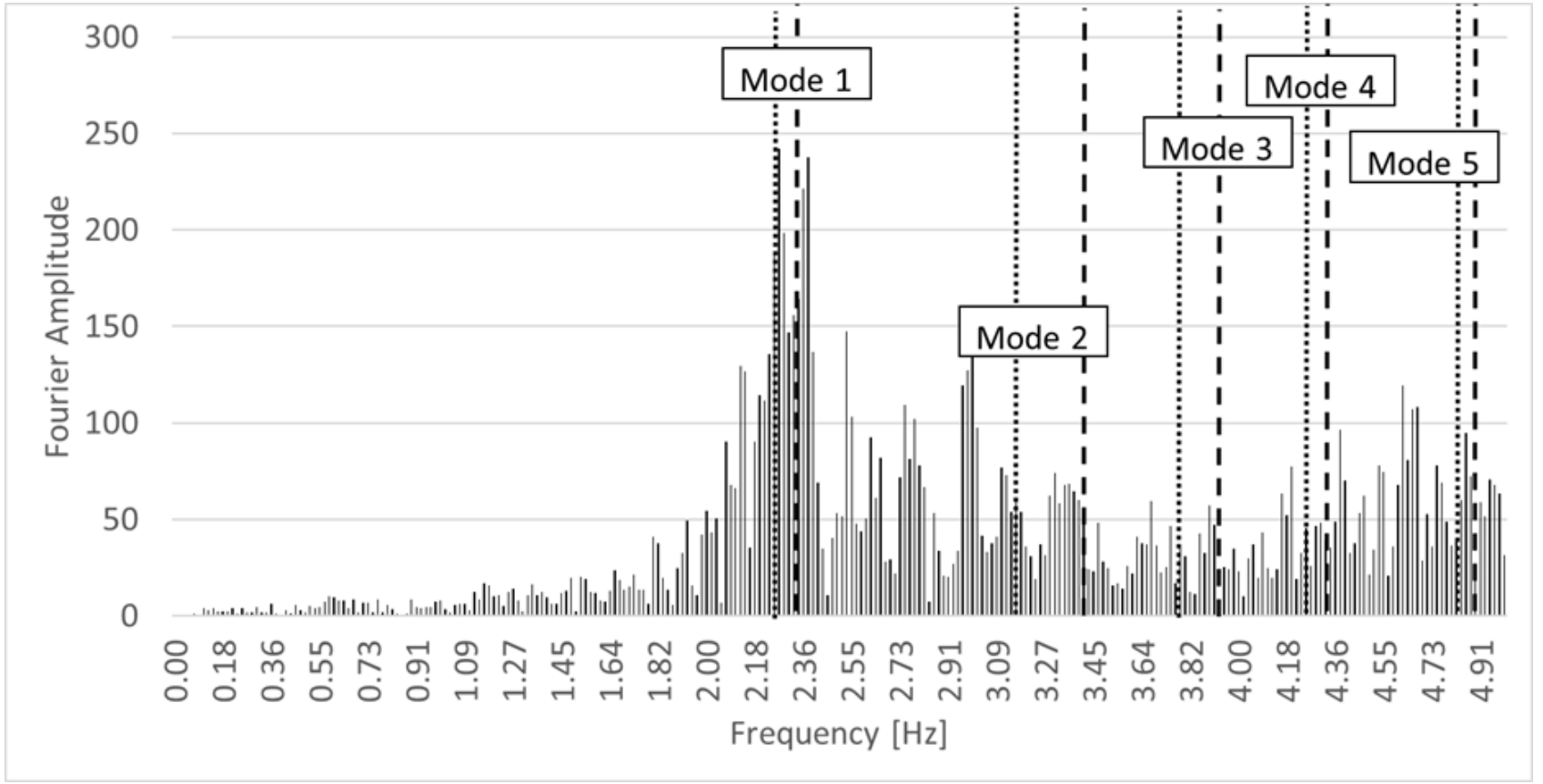
- Concrete plasticity according to Menetrey-Willam
  - Willam-Warnke yield surface
  - concrete softening behavior in compression and tension



(a) Compression (b) Tension

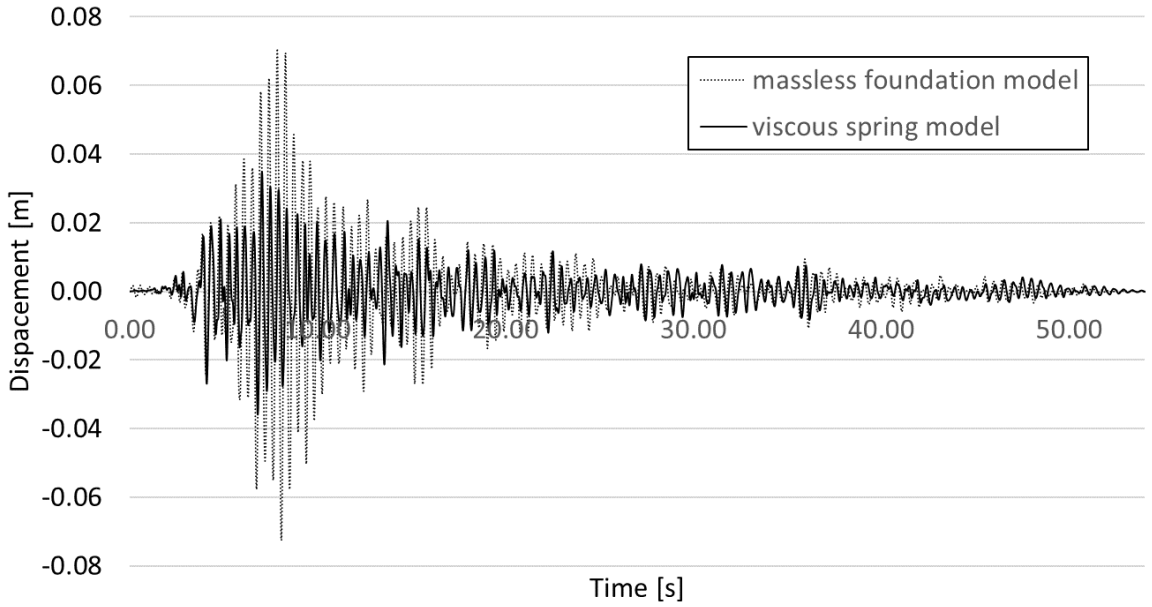
Results of the modal and Fourier analysis

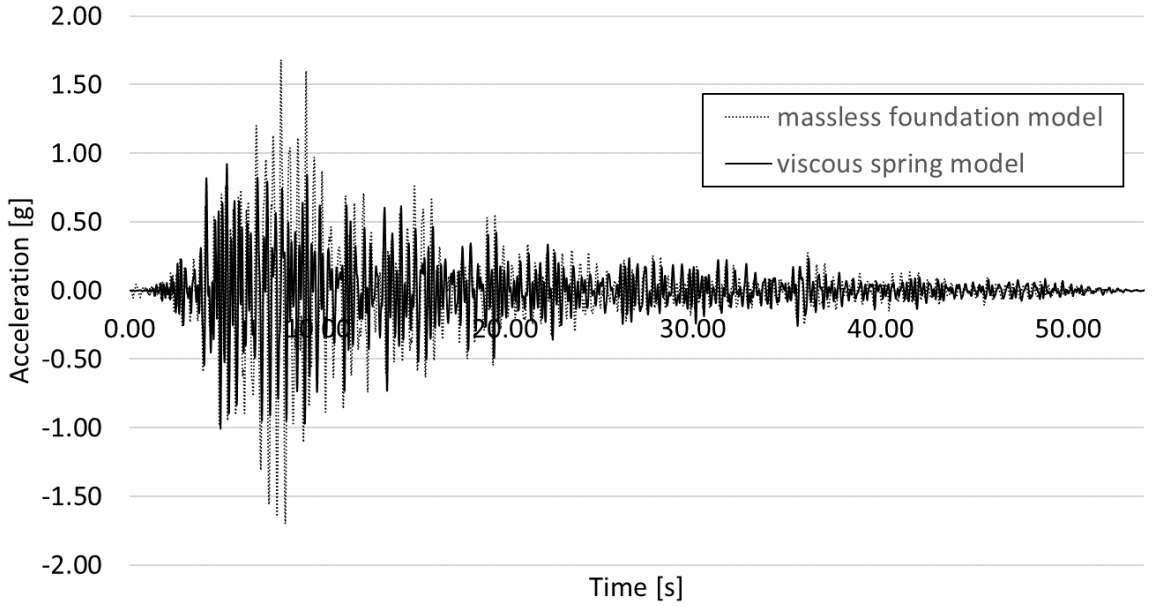
- Modal analysis: natural frequencies for winter and summer reservoir levels
- Fourier frequency decomposition: assessment of the structural vulnerabilty



Results of the transient structural analysis

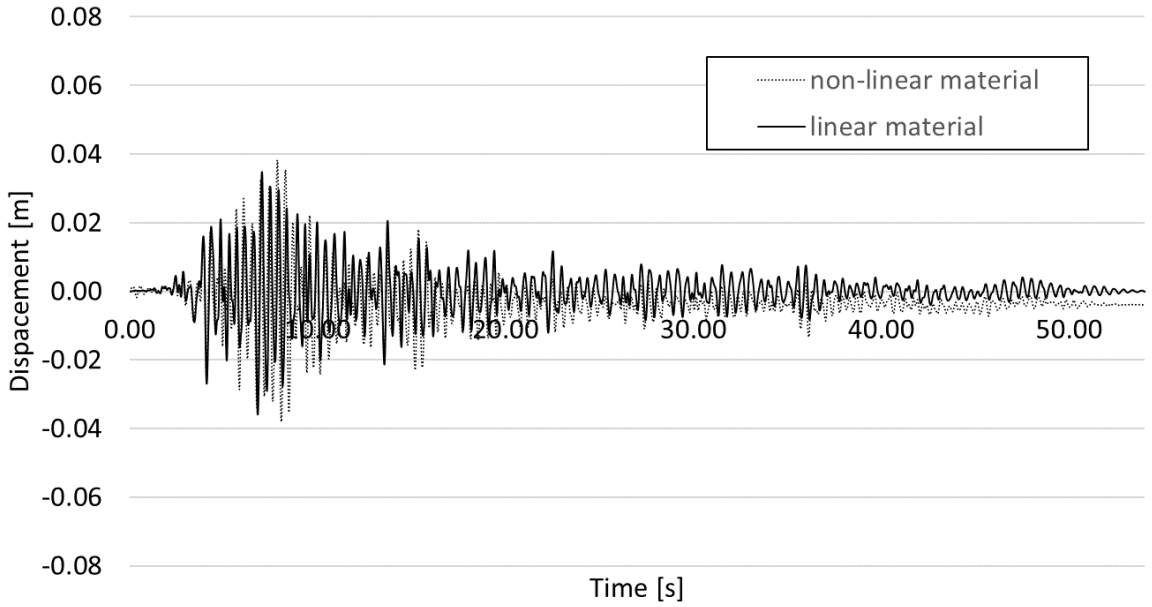
- Massless foundation vs. viscous spring model: clear tendency for the first to reach higher peak values

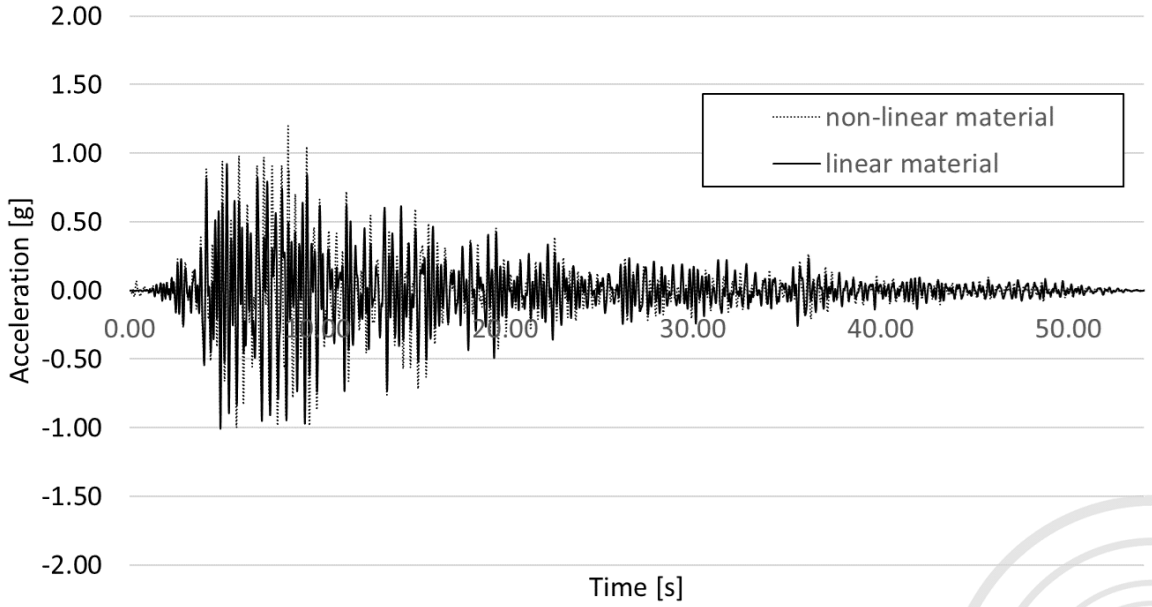




Results of the transient structural analysis

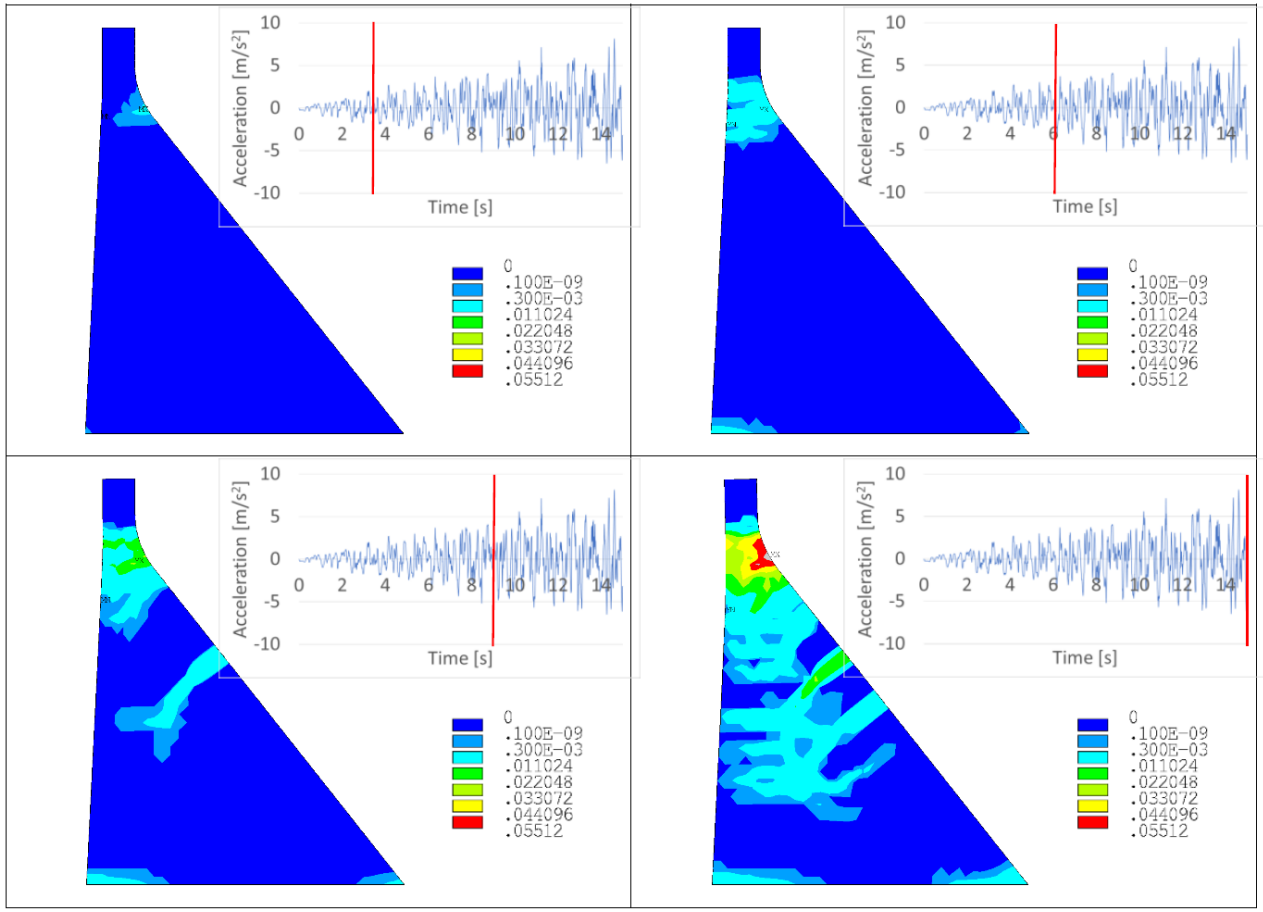
- Linear vs. non-linear model: comparable for the Taft-earthquake





Results of the endurance time analysis (ETA)

- Etaft loading: intensifying excitation
- Failure modes: non-linear model



Discussion and conclusion

- Massless foundation vs. viscous spring model
- Simplifications:
  - effective deconvoluted earthquake forces at the vertical side boundaries of the foundation are disregarded
  - shear wave reflections at boundaries are disregarded
- Further analyses:
  - Sensitivity analysis (uncertain material properties, damping etc.)
  - Calibration (displacements, temperature/pore water pressure distributions etc.)
  - Coupled hydraulic-mechanical simulations
  - Risk analysis (scattering of input/output, metamodel generation, reliability evaluation)