ICOLD
INTERNATIONAL
COMMISSION ON
LARGE DAMS

ICOLD-BW 9th-11th September 2019 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 behavior of Pine Flat concrete gravity dam using microplane damage-plasticity model

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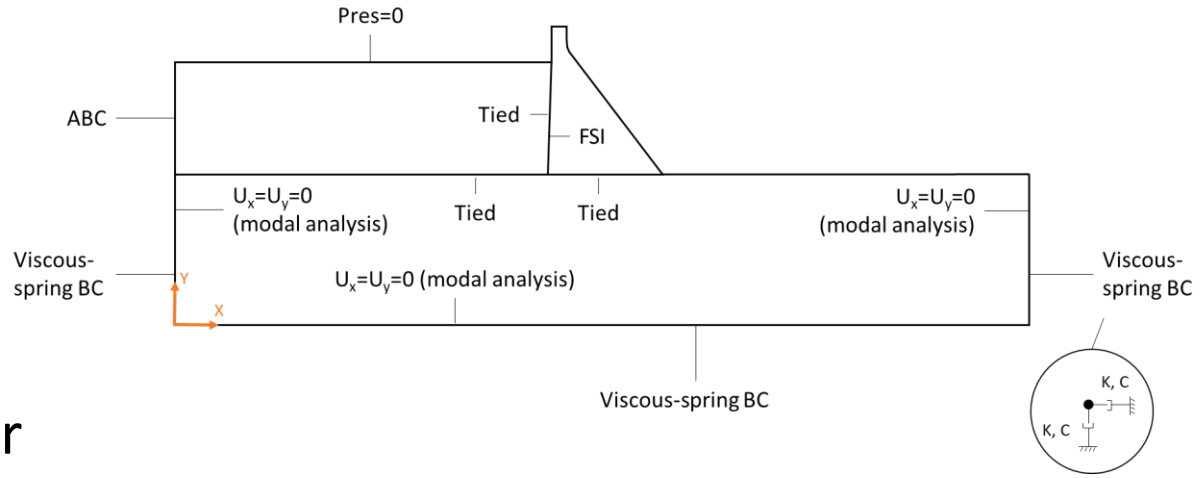
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES
EPFL

Introduction

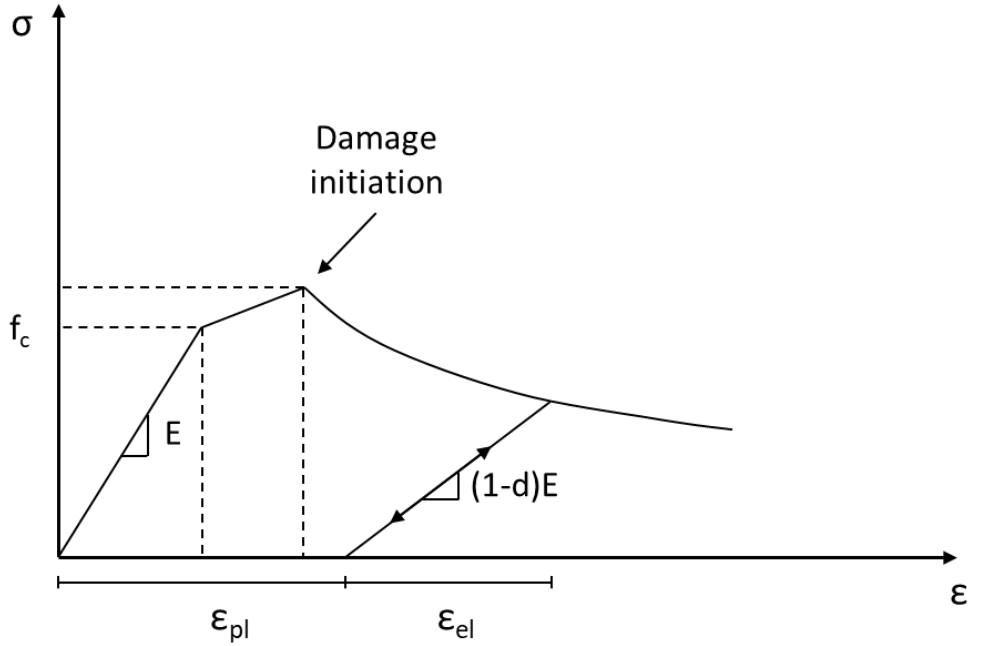
- Numerical modeling:
  - FE code ANSYS Mechanical-APDL
  - 2D Plane strain elements
  - FSI: Acoustic-Structural coupling
  - Reservoir: inviscid and compressible behavior
  - No seismic waves absorption by the reservoir bottom sediment
- Dynamic analysis with concrete non-linear properties:
  - **Damage-plasticity model based on microplane formulation***



**Zreid I., Kaliske M. (2018). A gradient enhanced plasticity-damage microplane model for concrete. Computational Mechanics, Vol. 62(15).*

Damage-plasticity model based on microplane formulation*

- Different damage initiation criteria and damage evolution laws:
  - **Brittle behavior** of concrete in tension (softening starts directly after the elastic limit)
  - **Hardening before softening** in compression
- Cyclic loading conditions:
  - Stiffness lost during cracking recovers due to crack closure during transition from tension to compression
  - Damage sustained under compression remains upon transition to tension state



- Local dam failure: DMG=1
- Failure of the dam body: subsequent large ε

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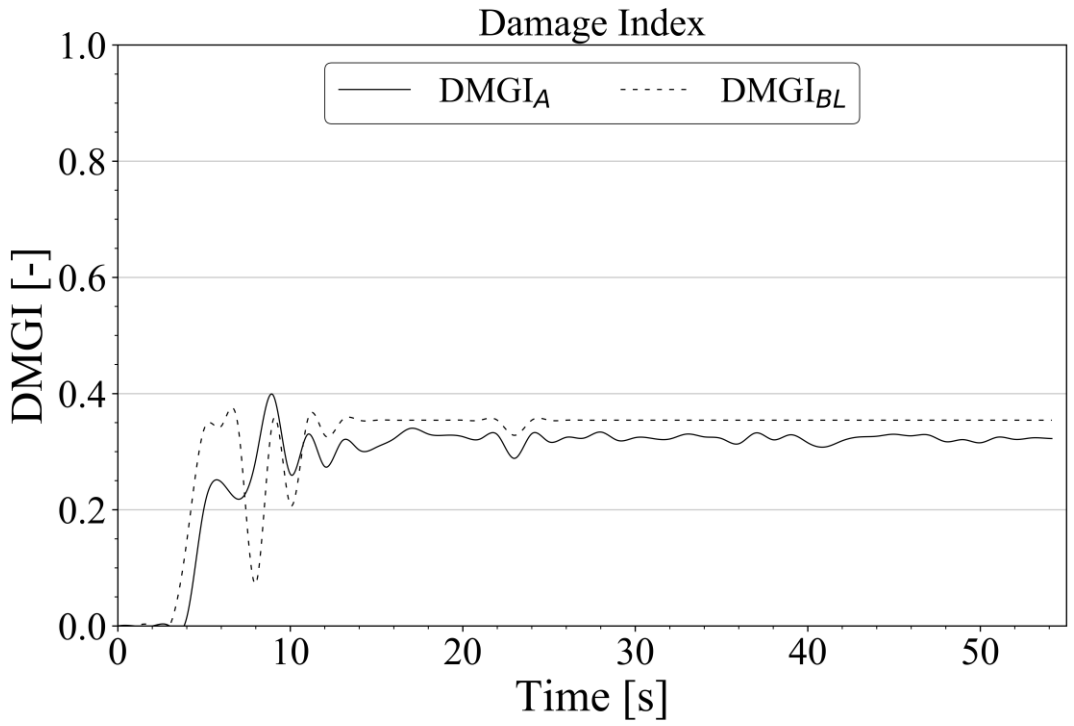
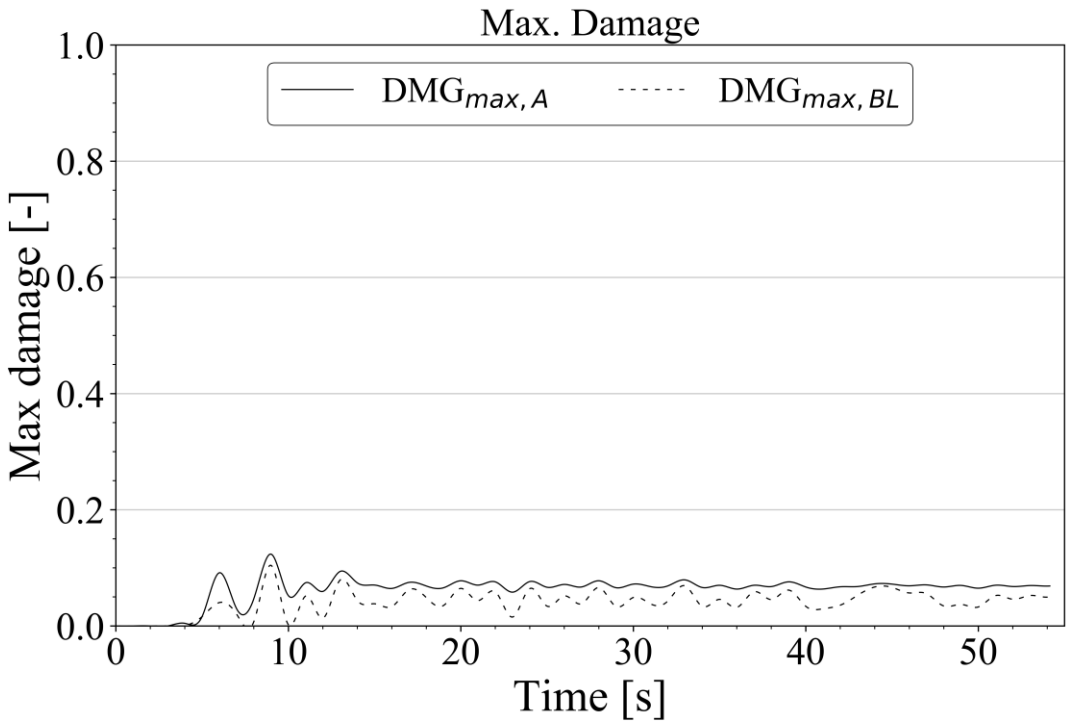
Results

- Damage Index (DMGI) and Max. Damage (DMG_{max}) time evolution
- TAFT Record





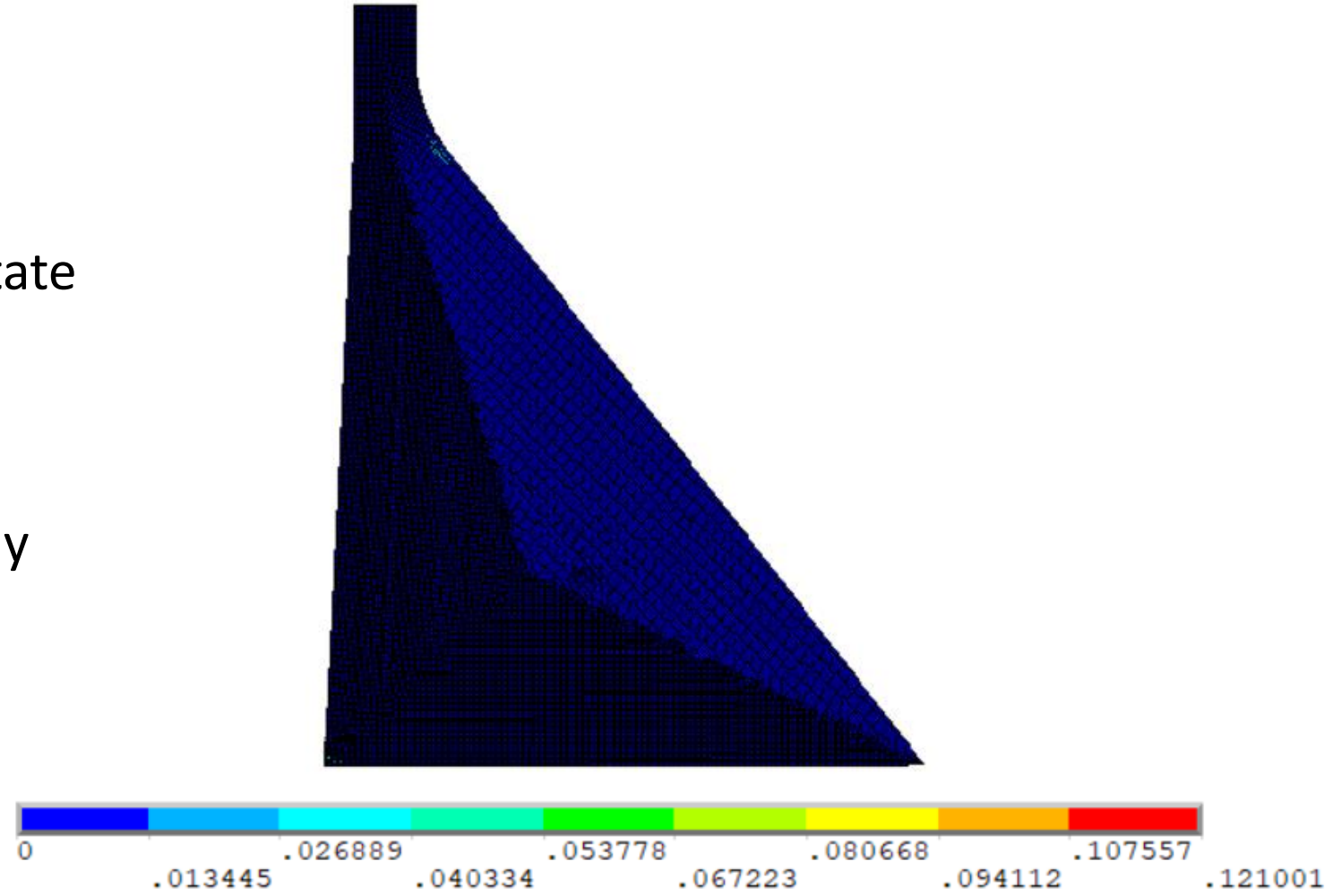
Results

- Damage (DMG)
- TAFT Record
- t = 54 [s]
- Damage only in tension state

→ No local dam failure

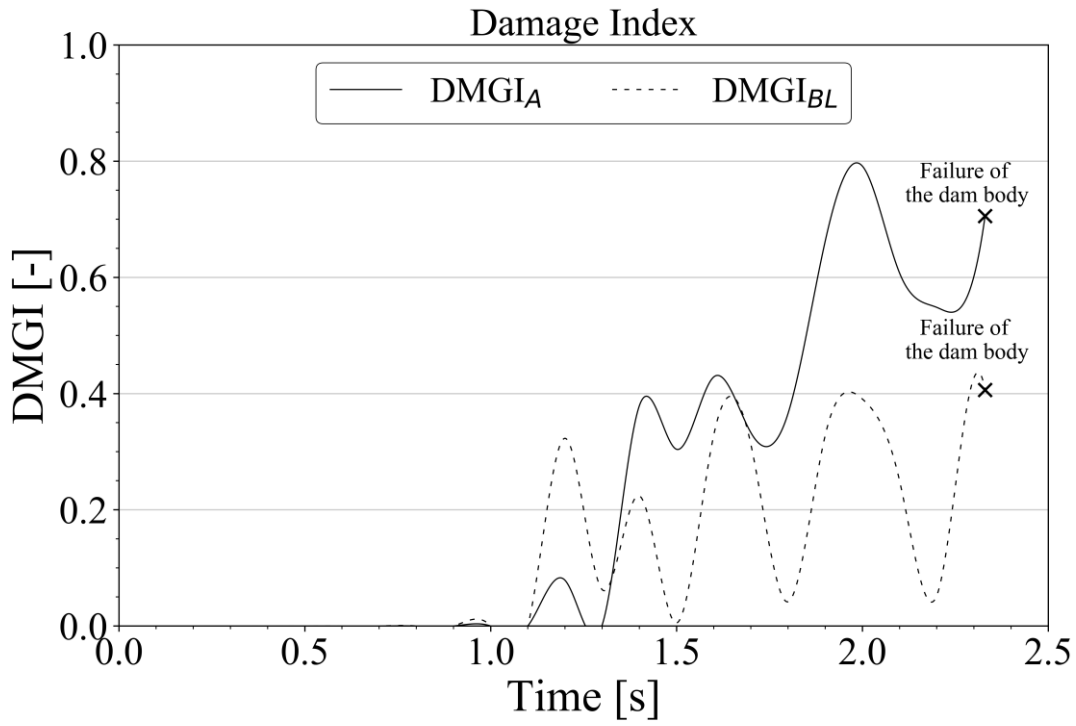
→ No failure of the dam body

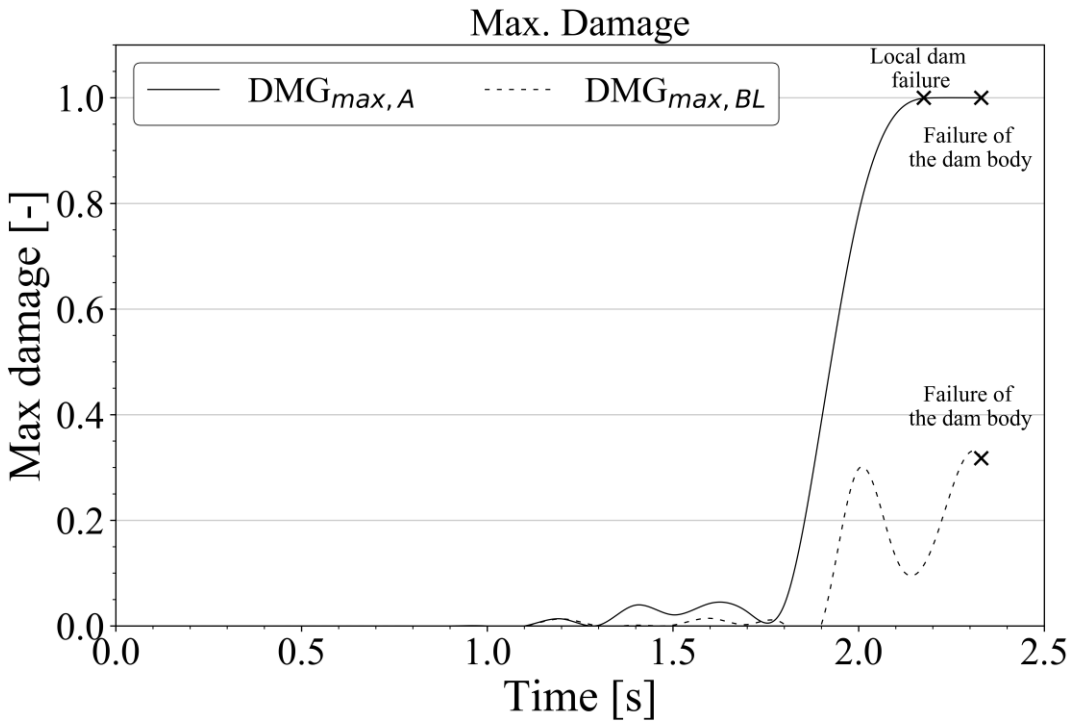
→ $DMG_{max,A}$ = 0.0688



Results

- Damage Index (DMGI) and Max. Damage (DMG_{max}) time evolution
- ETAF sollicitation





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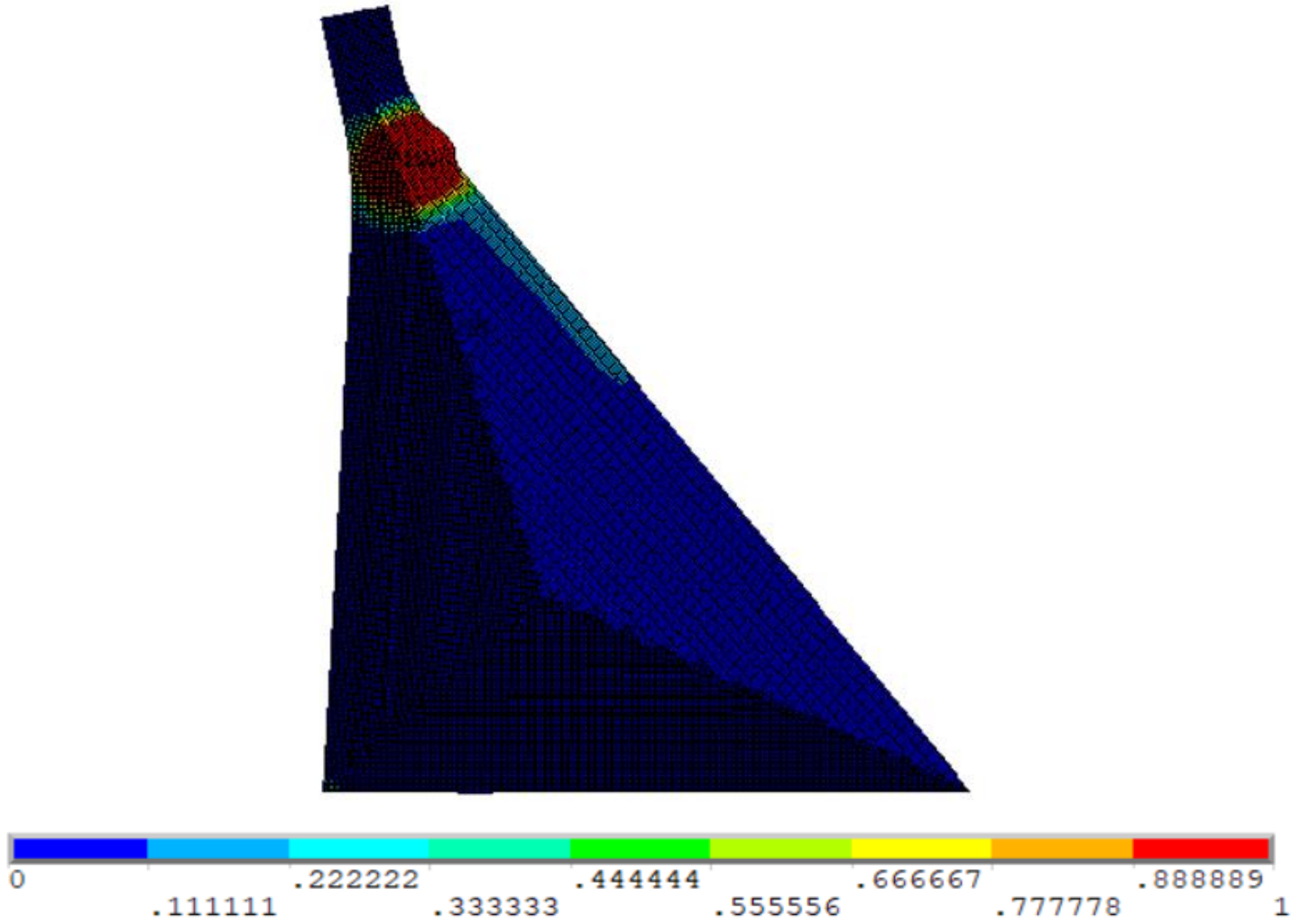
Results

- Damage (DMG)
- ETAF sollicitation
- t = 2.33 [s]
- Damage only in tension state

→ Local dam failure at t = 2.17 [s]

→ Failure of the dam body (large deformations) at t = 2.33 [s]

→ $DMG_{max,A} = 1$



Final remarks

- Lessons learned:
  - Results show the ability of the numerical model to:
    - Reproduce adequately dynamic properties of reservoir-dam-foundation system
    - Conduct linear and nonlinear analysis
  - Damage-plasticity model based on microplane formulation:
    - Ability to represent:
      - cyclic loading conditions
      - subsequent failure of the dam body
    - Limitation: fracture energy
- Issues to be addressed in future investigations
  - Interfaces modeling (dam-foundation)
  - Fracture modeling in the dam body

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