Beauharnois dam

Proposition of a potential benchmark case for ICOLD BW 2021 (Slovenia): AAR affected dam

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HYDRO-QUÉBEC PRODUCTION
DIRECTION DAMS AND INFRASTRUCTURES EXPERTISE

Past ICOLD AAR benchmarks workshops

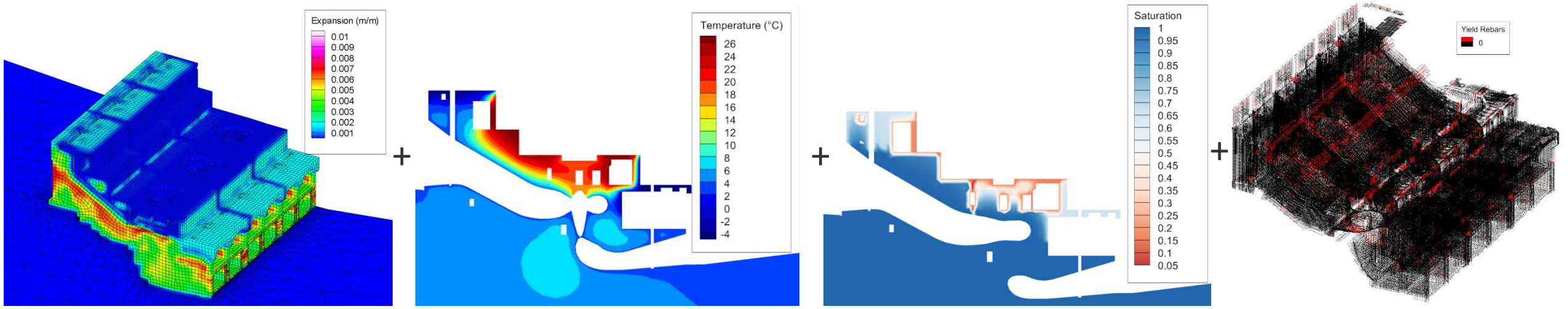
- 2011 - Valencia, Spain
  - Case: Kariba dam (arch dam)
  - Exercise: Determining the adequate swelling law and parameters which allow the best identification with both horizontal and vertical movements of the dam vs time.
  - Number of participants: 9
  - Only one participant presented damage plots
- 2005 - Wuhan, China
  - Case: Poglia dam (hollow gravity dam)
  - Exercise: Structural behaviour of a large hollow gravity dam, with special reference to the ultimate strength against the hydrostatic load
  - Number of participants: 2
- 2001 - Salzburg, Austria
  - Case: Pian Telessio dam (arch dam)
  - Exercise: Forecast on stress-strain state generate by AAR
  - Number of participants:

After 10 years: What is the added value of formulating a new case?

- Presentation at the RILEM comitee revealed that a new benchmark case would be of interest;
- Evolution in the FE software industry (inclusion of damage and swelling laws) opens up perspectives to have a number of participants:
  - Merlin, Diana, Code_Aster, Atena, Grizzly, etc.
- The case should be formulated in a way that there is a number of steps to achieve with feedback and comparison with others before the workshop;
- Curve fitting of displacements is not enough for dam owners: damage plots, crack opening, seepage analysis, uplift pressure and potential failure modes should be given. Ideally safety factors would be nice to compute, but this is still a complex task with AAR affected dams;

After 10 years: What is the added value of formulating a new case?

- The benchmark will be used to discuss the type of physics required to correctly simulate AAR :
  - Creep, saturation, thermal effects, presence of reinforcements, uplift pressure evolution, two-way coupling, etc.



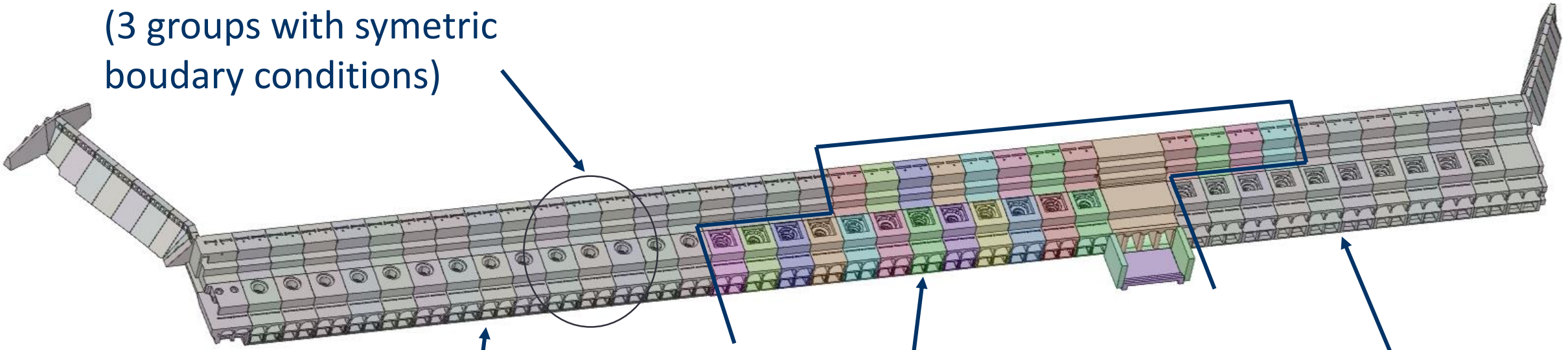
Chemical reaction | Temperature | Saturation | Reinforcement

Theme formulation

- Contributors will be given
  - Measured data for 85 years (air temperature, water level, displacements, hygral conditions)
  - CAD geometry model and FE mesh
  - Material properties
  - Reinforcements
- All types of models are welcome to use (thermal analogy, poroelasticity, multi-physic, chemo-mechanical model) from the simplest to the most complex ones.
- For all cases, the formulators will provide excel templates that the contributors should use for submittal of their results

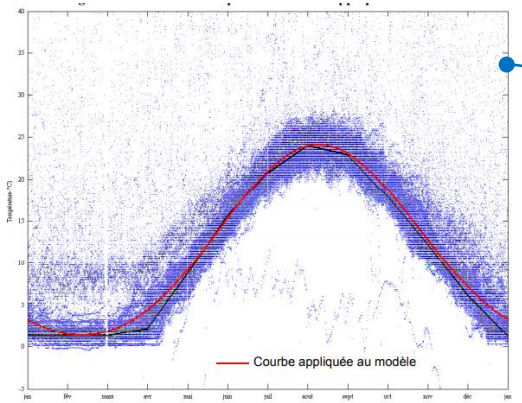
Theme formulation

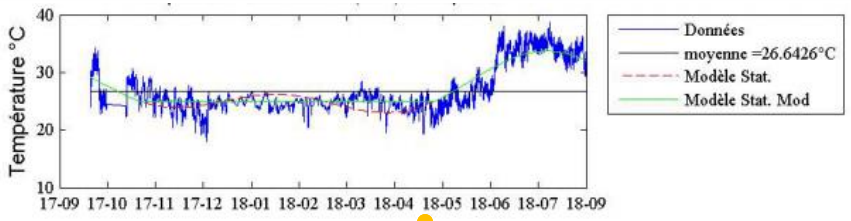
To be realistic in the context of a benchmark, analysis of this section (3 groups with symetric boudary conditions)

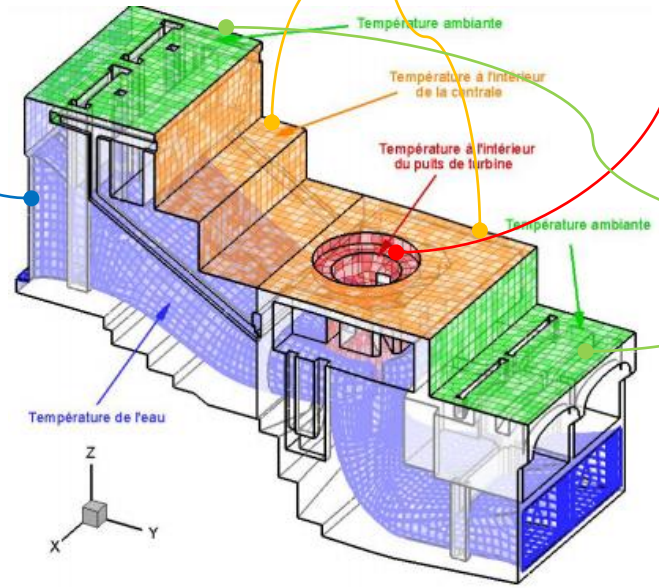


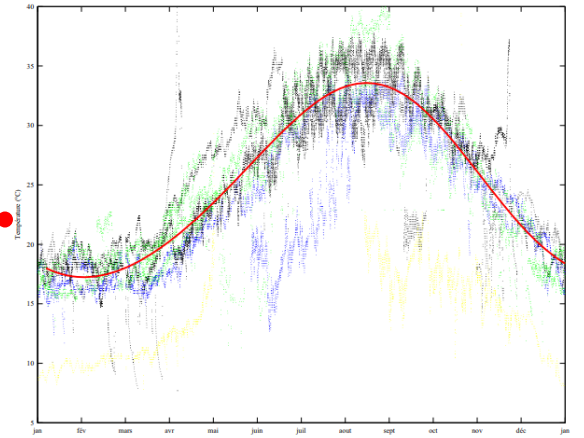
Boundary conditions

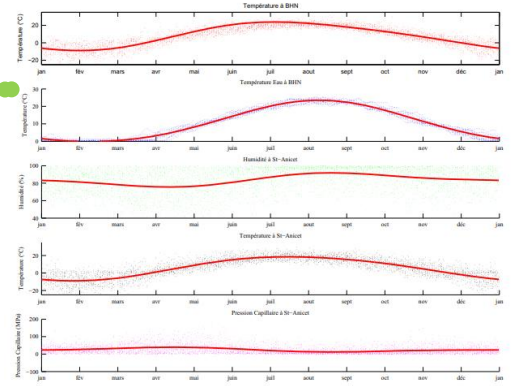
The formulators will provide common set of basic boundary conditions





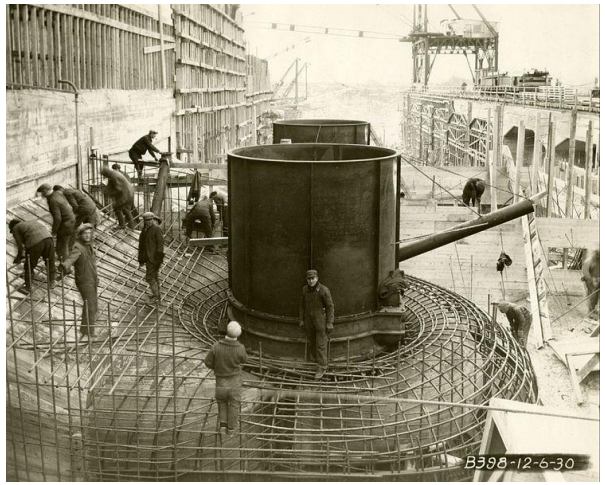


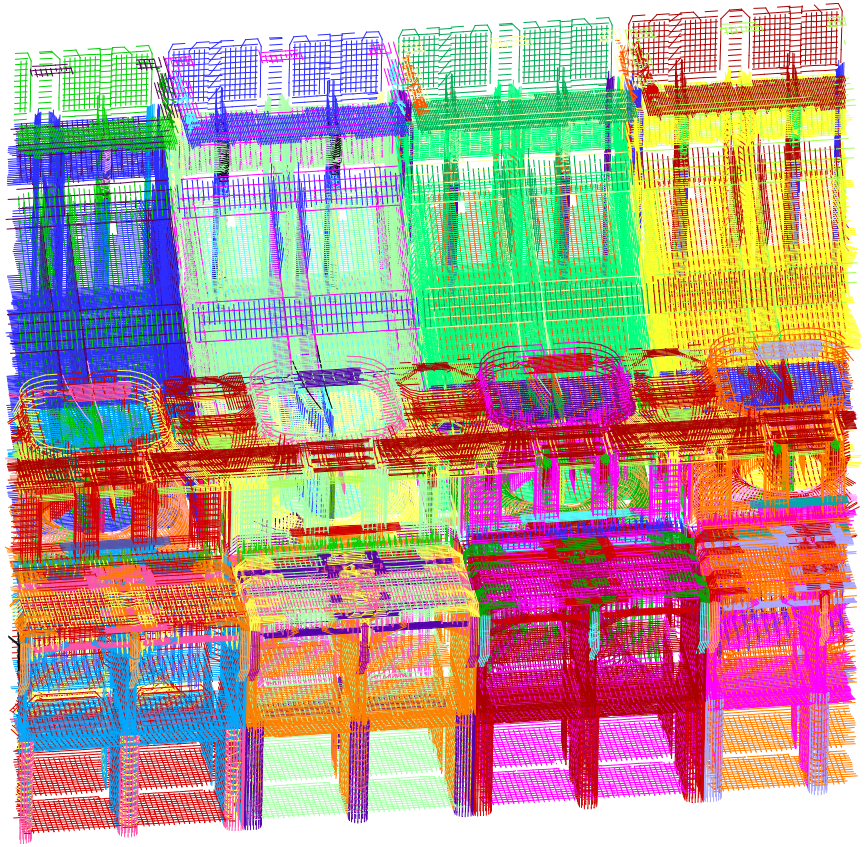


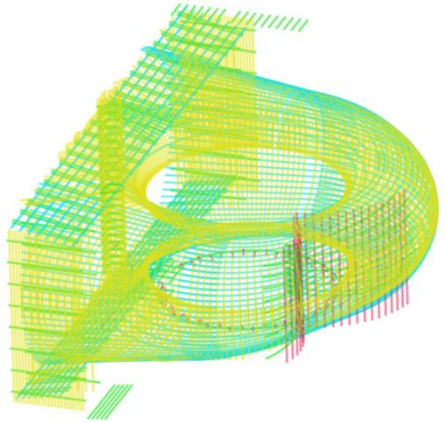


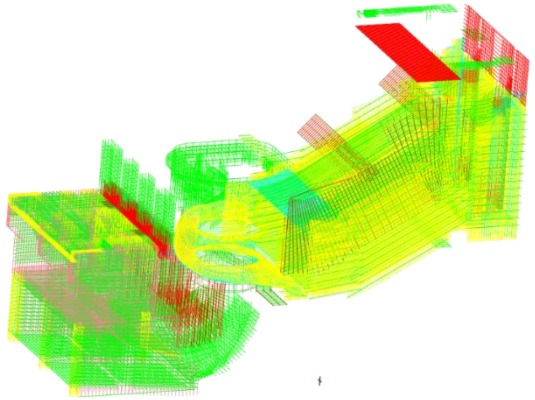
Consideration of reinforcement

The formulators will provide the reinforcement bars (discrete geometry, any modeling method is welcome)





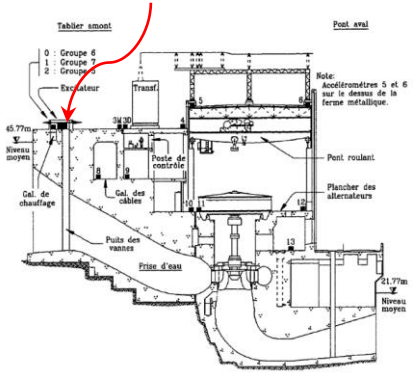


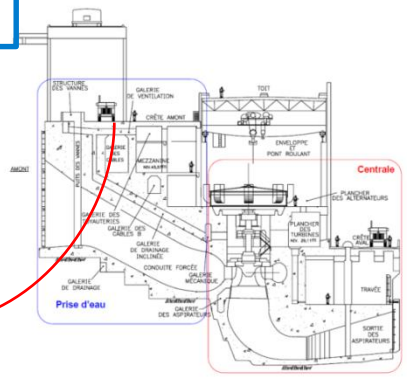


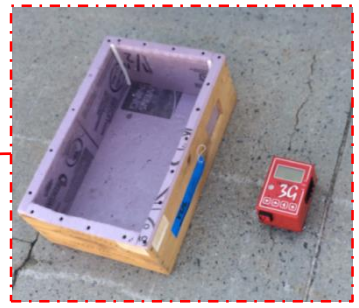
Model parameters and calibration

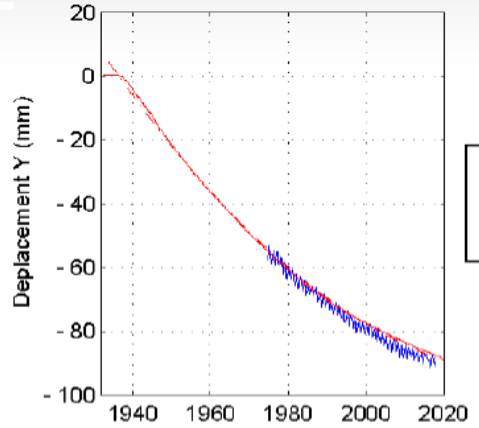
- Monitoring results will be available to calibrate the swelling kinetic (displacements and rates)
- Mechanical properties from:
  - Lab test (modulus, strength, …);
  - Ambient or vibration tests;
  - Slot testing.

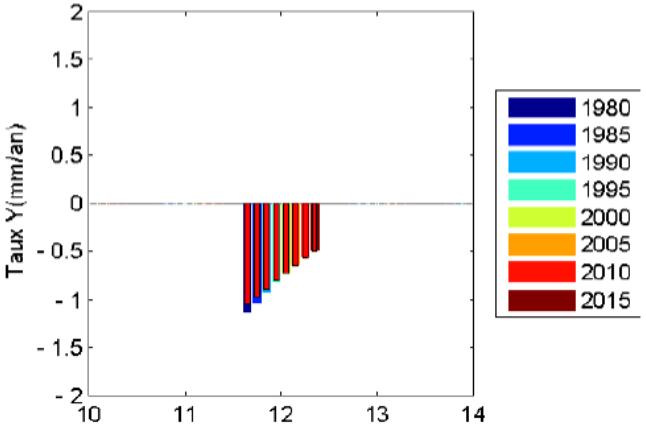
Depending on data availability (postponed by COVID)











Cases

The theme consists of four subcases and include calibration (covered by the instrumentation records) + Prediction of damage for a period of 50 years

- **Case A – Chemical reaction only**
- **Case B – Chemical reaction + Temperature effects**
- **Case C – Chemical reaction + Temperature effects + Hygral effects**
- **Case D – Chemical reaction + Temperature effects + Hygral effects + Reinforcement**

Tasks

- For each case, the contributors should perform:
  - Displacement calibration/prediction (50 years period)
  - Define damage level (crack opening) at two time points
  - Interpret the effect of physic consideration
  - Loading (integration in different cross sections) and sliding safety analysis at end of prediction period
  - For two different water levels, provide the displacement differences at a specific location at the end of the 50 year period to compare the difference in stiffness with an intact structure
- Plot different output variables:
  - Hygral and thermal distribution at specific locations, rebar state (damage, plasticity)

Expected outcomes

- Give a complete benchmark case for improving the validation in the V&V process applied to complex multiphysic AAR model;
- Improve our understanding on the effect of physic integration to model AAR on full scale problems;
- Highlight the development that has undergone within industry, academic and commercial softwares to model AAR and damage;
- Compare simple and complex models on a full scale problem;
- Discuss and evaluate methods to asses the performance criteria of AAR affected structures (failure modes, safety factors).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