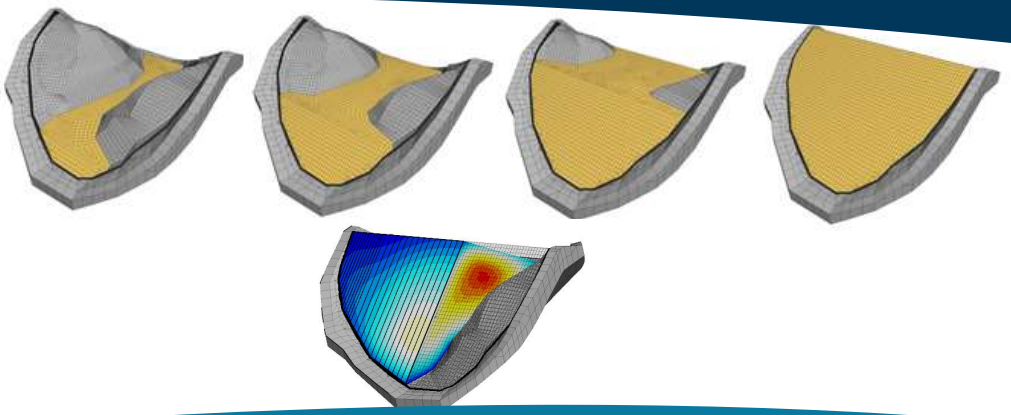
# Numerical analysis fo the Nam Ngum 3 CFRD

## How to reduce the risk of extensive cracking of the concrete face?

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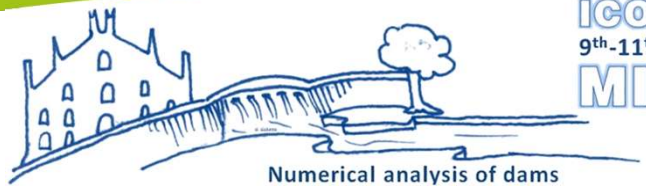


ICOLD-BW
9th-11th September 2019
MILANO

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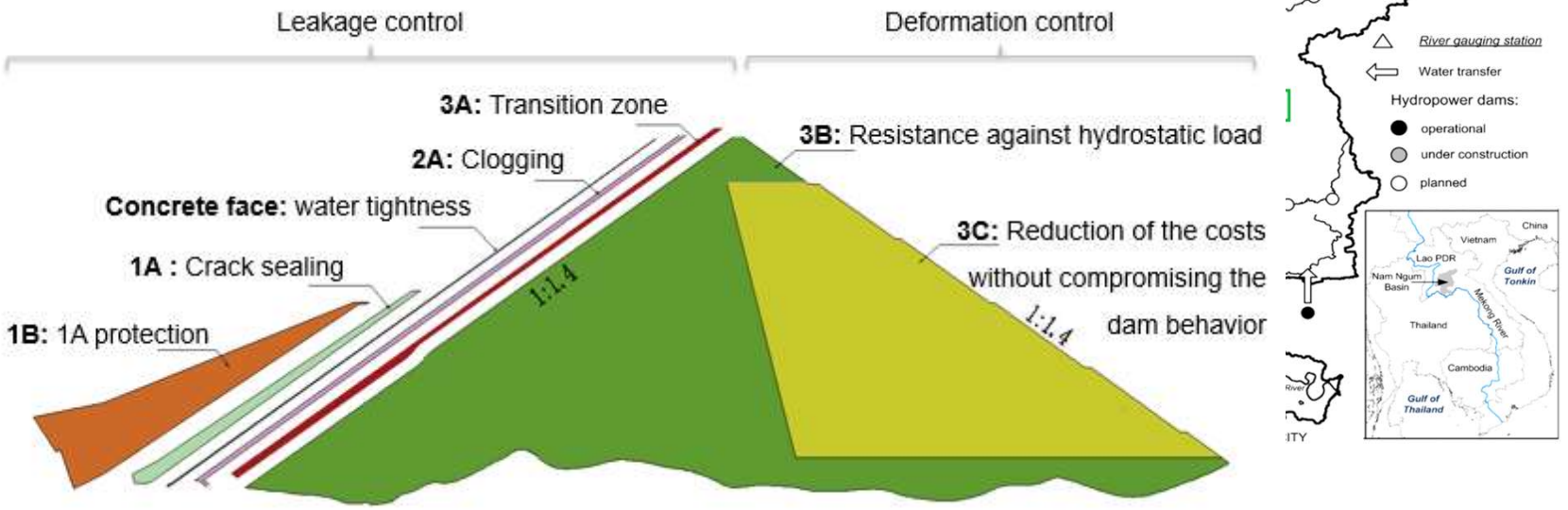
# Nam Ngum 3 dam

## DAM DESCRIPTION




- Dam zoning
  - 3B fresh gneiss (70%), 3C moderately weathered gneiss (90%)
  - Maximum particle size: 800mm (~lift thickness)



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# Nam Ngum 3 dam

## CONCRETE FACE LAYOUT

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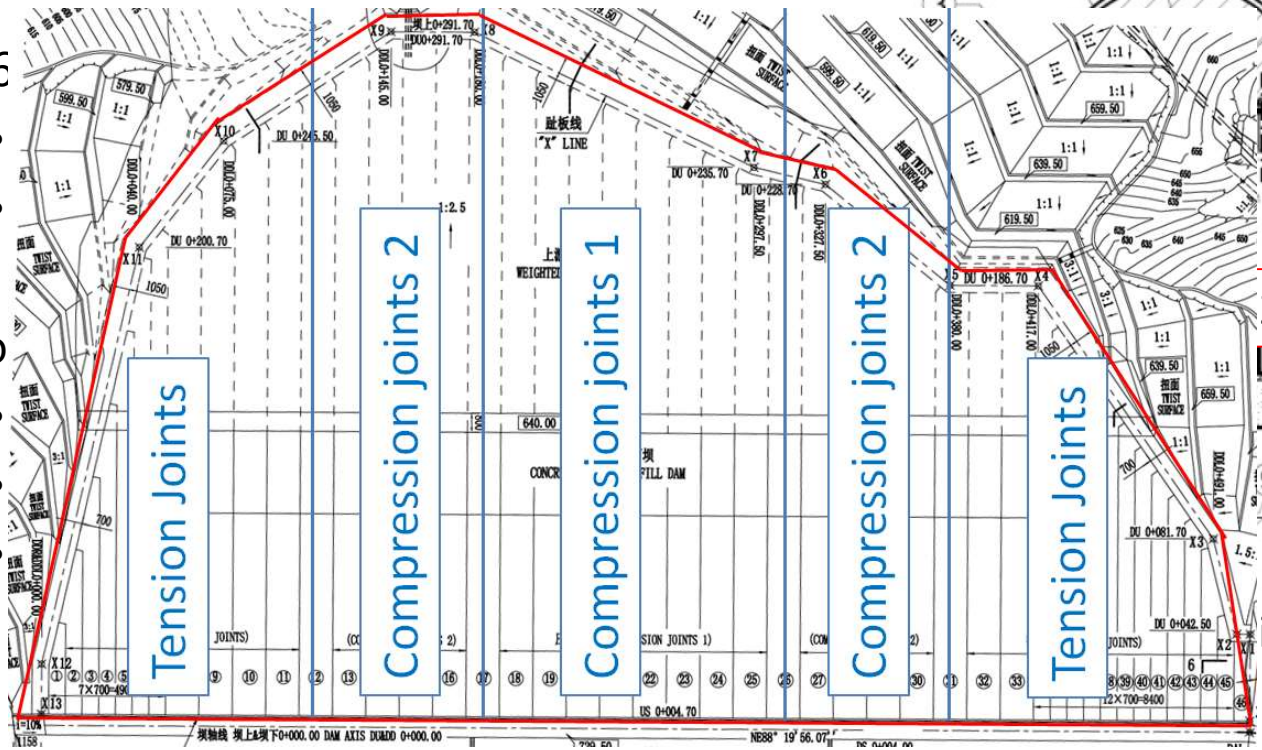
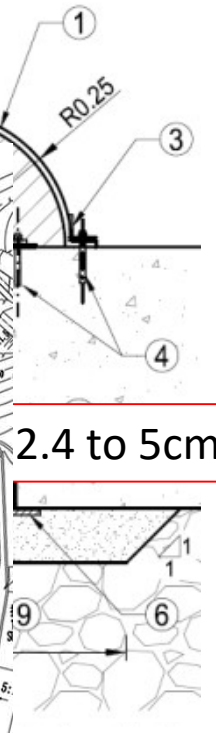



Plane view of the concrete face



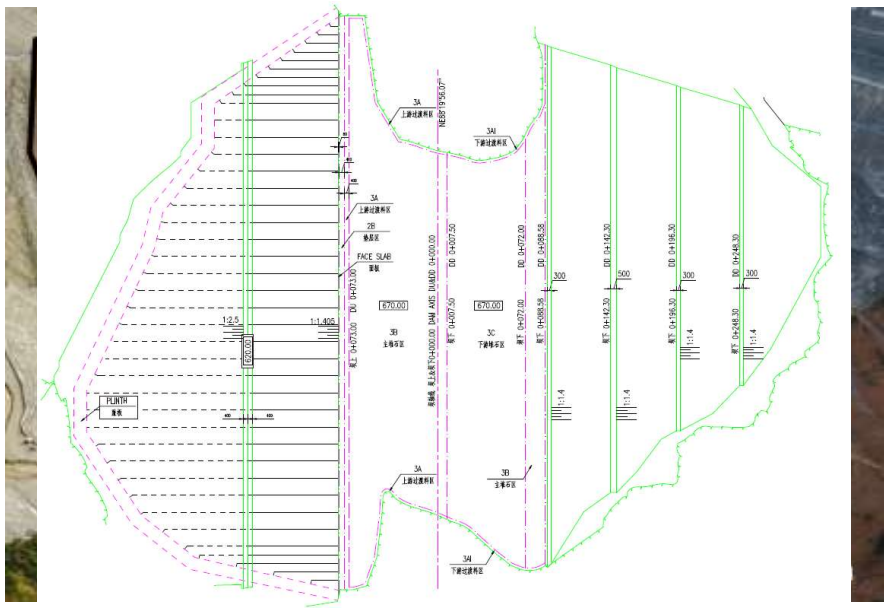

2.4 to 5cm thick

joint

# Nam Ngum 3 dam

## A VERY PECULIAR VALLEY SHAPE

- Concrete face constructed slightly upstream the narrowest part of the valley
  - Probably for rockfill volume saving
- High stiffness contrast between the side and the central part of rockfill
  - Behavior at the impounding?




Concrete face footprint

Cross section at El. 670

Cross section at El. 620



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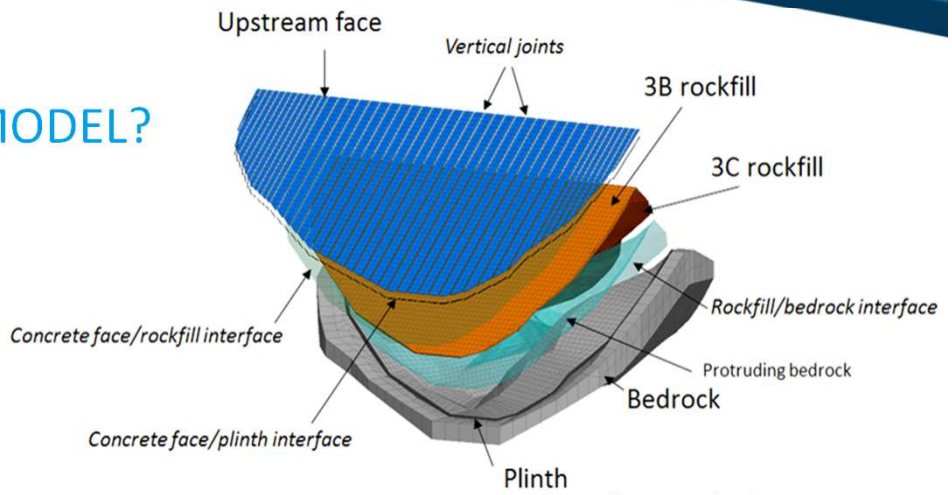
# Numerical model

## OWNER'S ENGINEER NUMERICAL MODEL?

- Existing Contractor's numerical model




FLAC 3D numerical model

- ARTELIA's verification model with major improvements
  - A more rational assessment of scale effect
  - A better simulation of rockfill / bedrock interface
  - Initial gap of compression joints taken into account
  - Delayed deformation based on international feedback and laboratory tests



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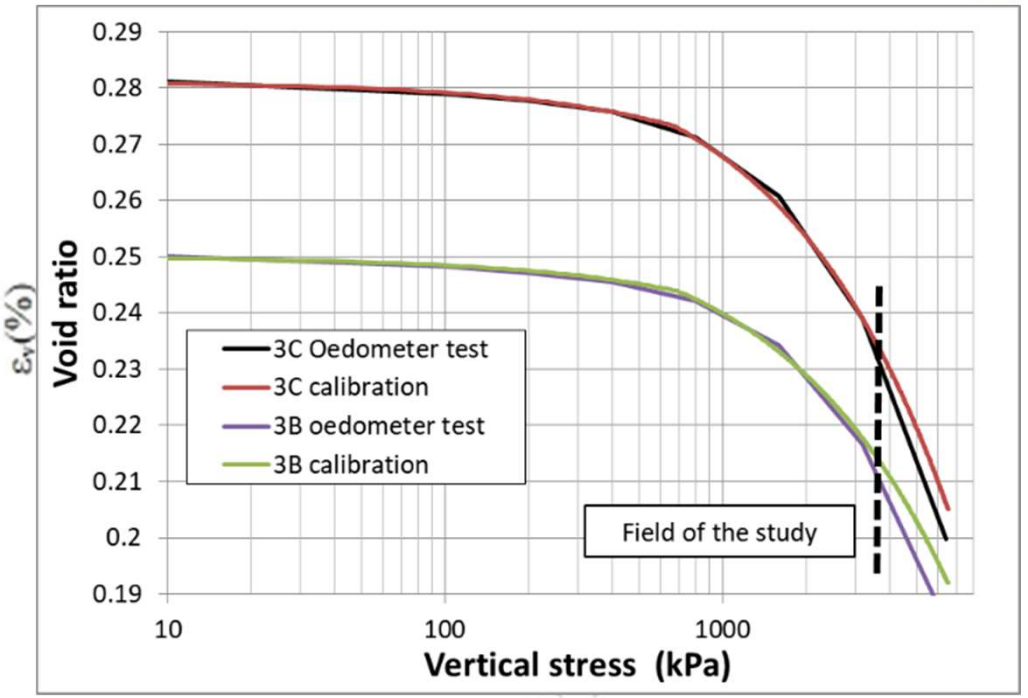
# Constitutive laws

## ROCKFILL

- 3B and 3C zones modeled (HSM)
- Shear + Volumetric hardening
- Consideration of a stress-dependent friction angle

$$\Phi = \Phi_0 - \Delta\phi \log\left(\frac{-\sigma_3}{p_{ref}}\right)$$

- Good calibration with laboratory tests




Triaxial - Dilatancy

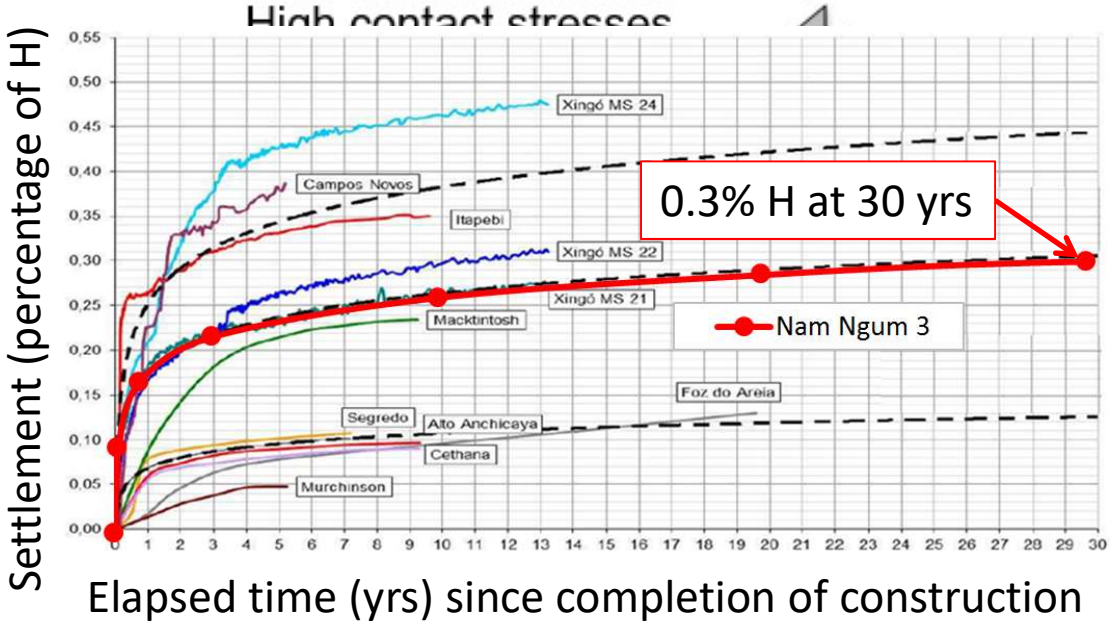
Triaxial - Shear

OEdometer

# Delayed deformation

## MAIN PRINCIPLES

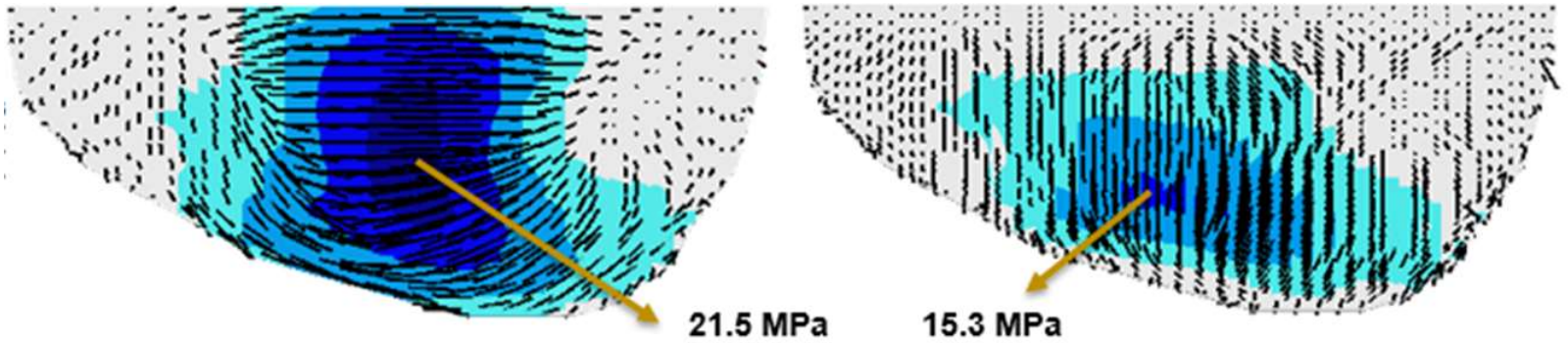
- Viscosity brought by
  - Saturation
  - Fine materials
- Average delayed settlement chosen for Nam Ngum 3 dam
  - Based on international feedback (CBDB)
  - Calibrated from laboratory test (stress dependency)
- Delayed deformation ~ stress relaxation in the model



# Results

## STRESSES IN CONCRETE FACE

- Clear beneficial effects of the compression joints
  - After 30 years of operation




Without compression joints

With compression joints

- → Extruded curb to be sawn at least behind the compression joints

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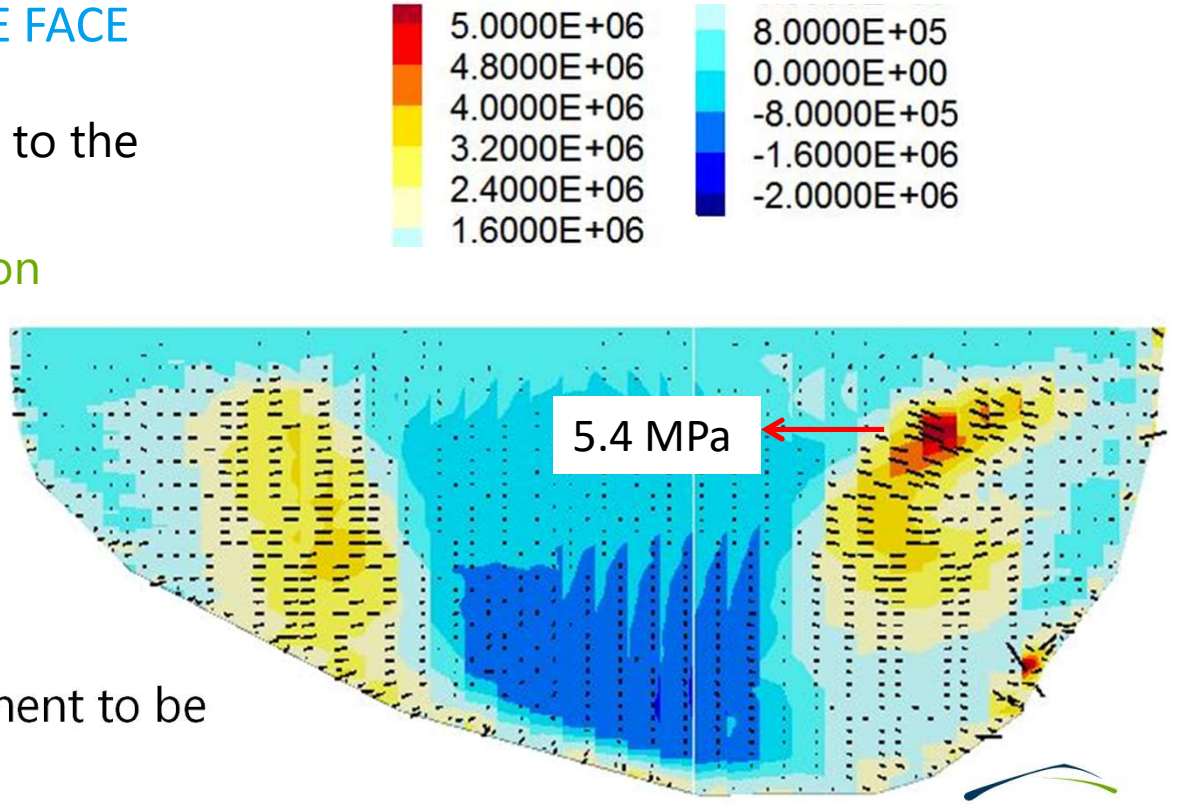
# Results

## STRESSES IN CONCRETE FACE

- Diagonal tensile stresses due to the valley shape
  - After 30 years of operation




Tension principal stresses (Pa)

- → Structural rebar reinforcement to be provided



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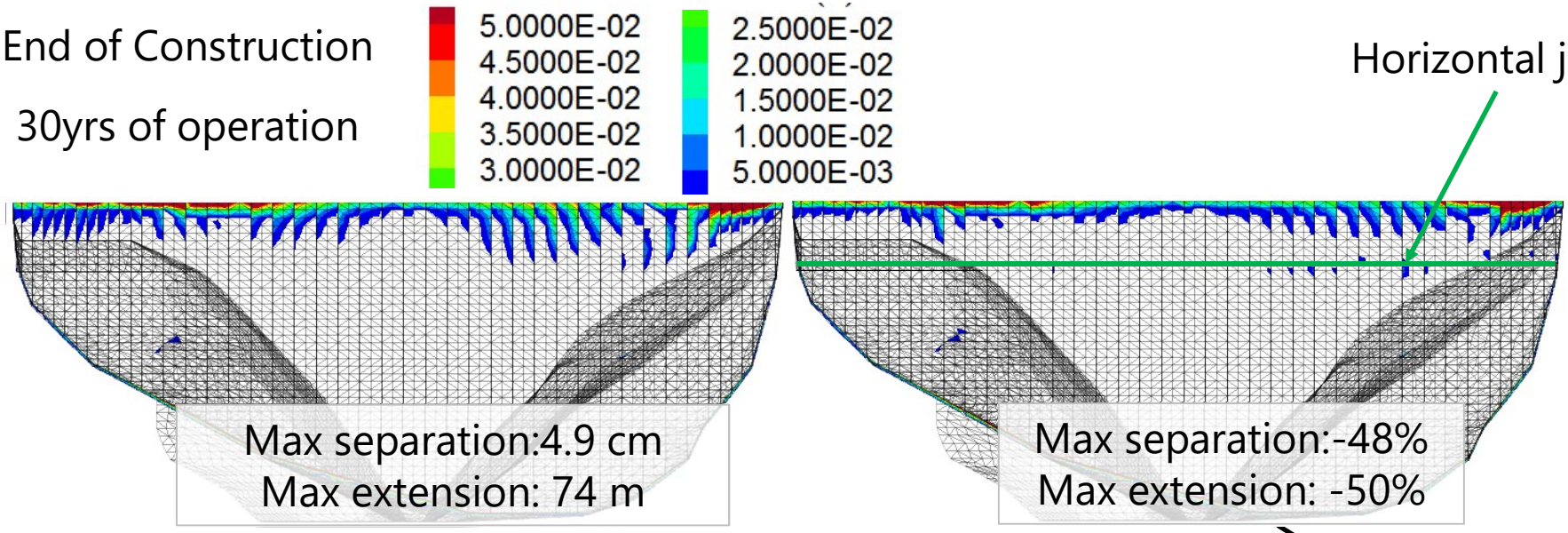
# Results

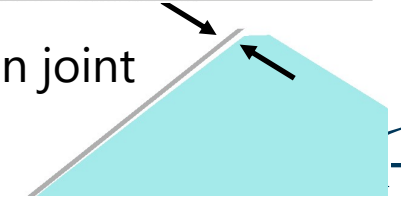
## DETACHMENT BETWEEN CONCRETE FACE AND ROCKFILL (M)

End of Construction

30yrs of operation



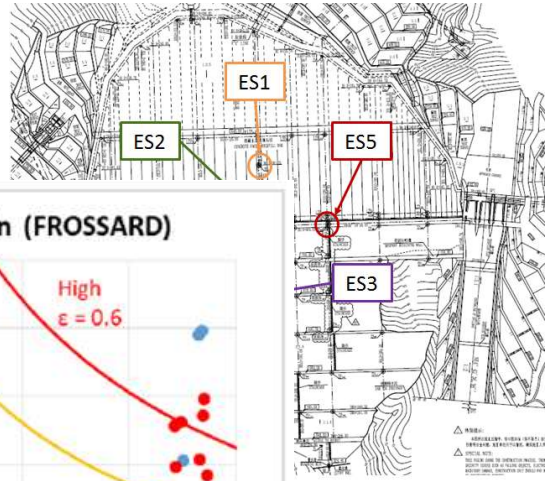

- Clear beneficial effects of a horizontal construction joint
- Anti-seismic provision (0.12g SEE)

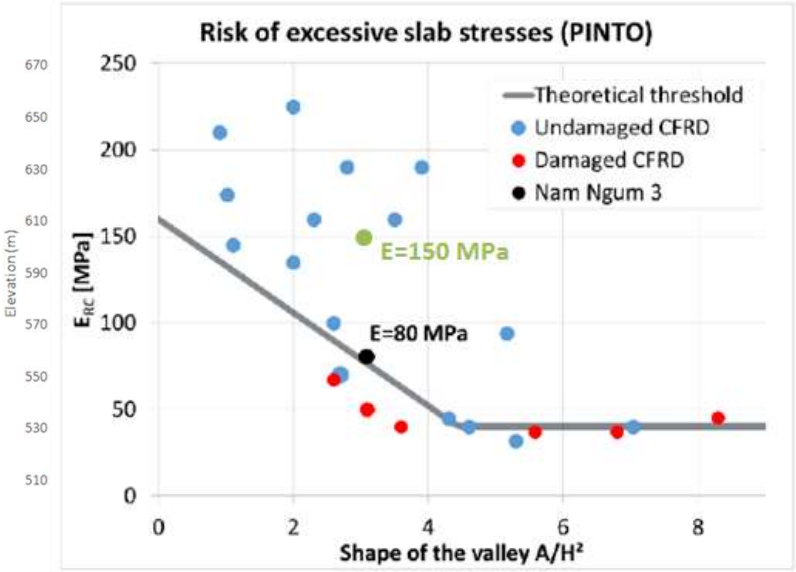


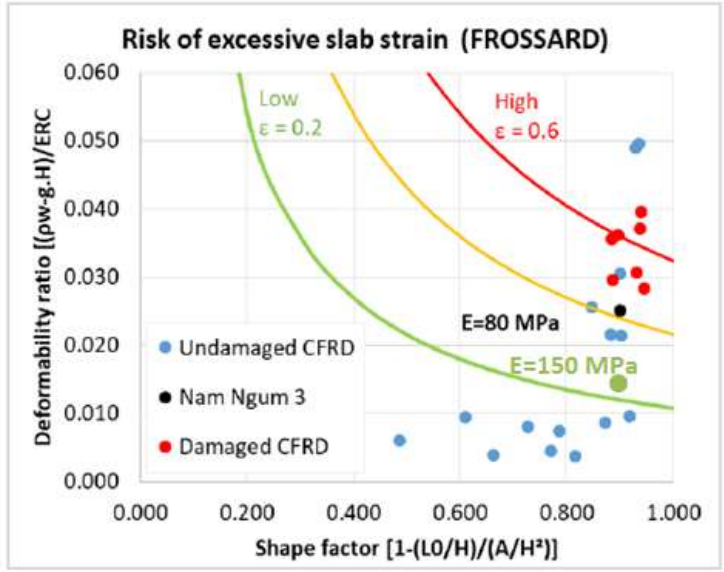
# Calibration on the monitoring data

## Reassuring behavior

- Decreased risk of cracking
- Increased risk of magnetic settlement gauges




- Apparent Young's modulus : 80 MPa expected, 150-180 MPa measured
- Compaction: 10 passes of 26t vibrating roller (almost twice as usual)
- 3C zone replaced by 3B very early in the construction
- Achieved porosity as per August 2019: 17.8% (vs 20% target)



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