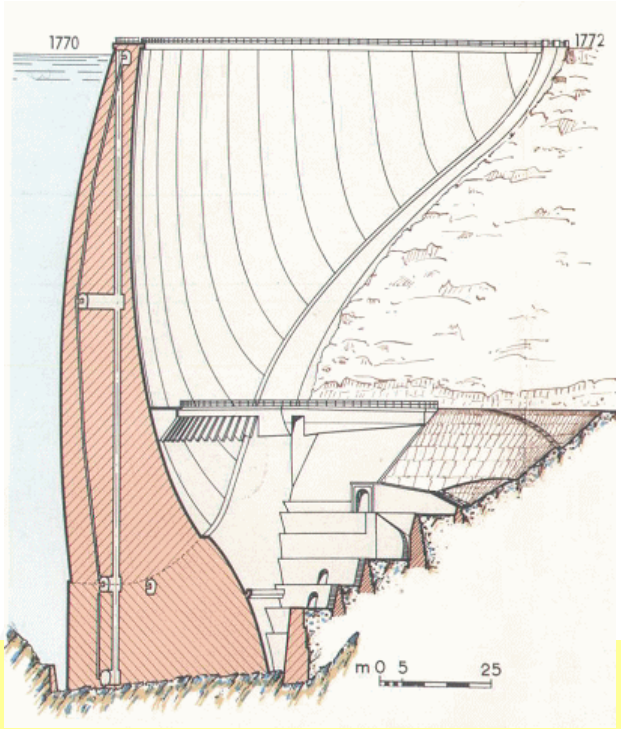
2nd-3rd October 2013

# The rehabilitation of Beauregard Dam:
## *the contribution of the numerical modeling*

**A. Frigerio, G. Mazzà**

# General data of Beauregard dam




- Arch-gravity dam 132m high
- Crest length 408m
- 45.6m thick at the foundation level and 5m thick at the crest level.
- Maximum operating level 1770m a.s.l.
- Total reservoir volume 70 $Mm^3$
- Annual power production 286,410 GWh
- Maximum discharge capacity of the intake tunnel 16.5 $m^3/s$.

# Evidences of problems during the first fillings and operation

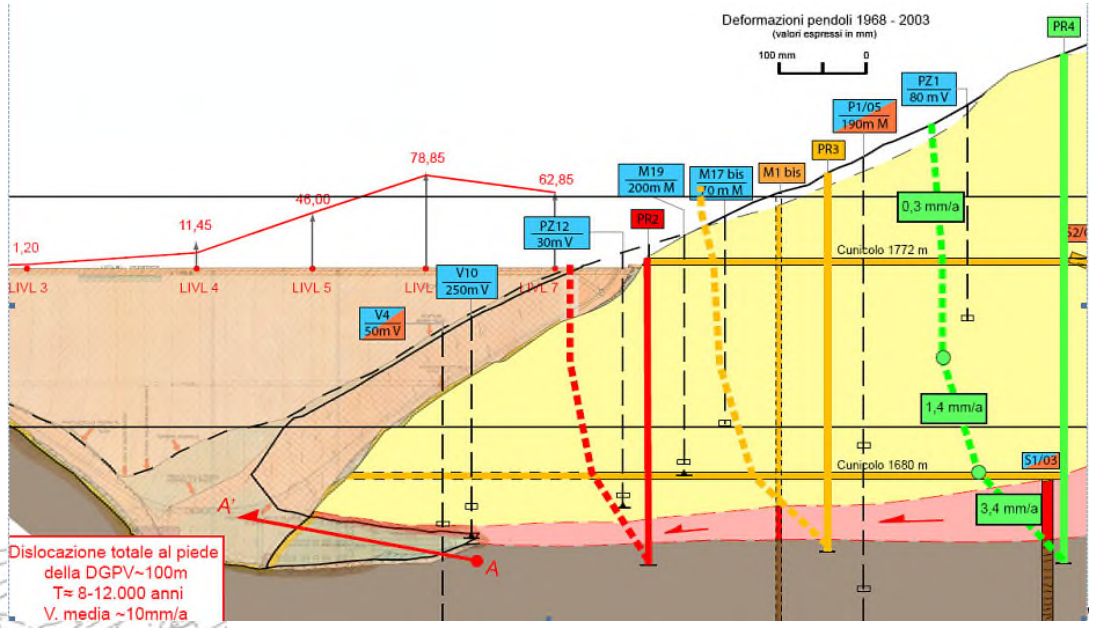

- The filling of the reservoir was undertaken in stages between 1958 and 1968.
- The readings of the instrumentation installed on the left slope abutment confirmed a clear relationship between reservoir level and rate of movement of the Deep Seated Gravitational Slope Deformation (DSGSD).
- The dam was also observed to deflect upstream with cracks appearing on the downstream face and openings of some upstream vertical joints.
- As a consequence, in 1969 the operational reservoir level was lowered down to 1710m a.s.l., as enforced by the Italian Dam Authorities, corresponding to a reservoir volume of 6.8 $Mm^3$ (about 1/10 of the design reservoir volume).

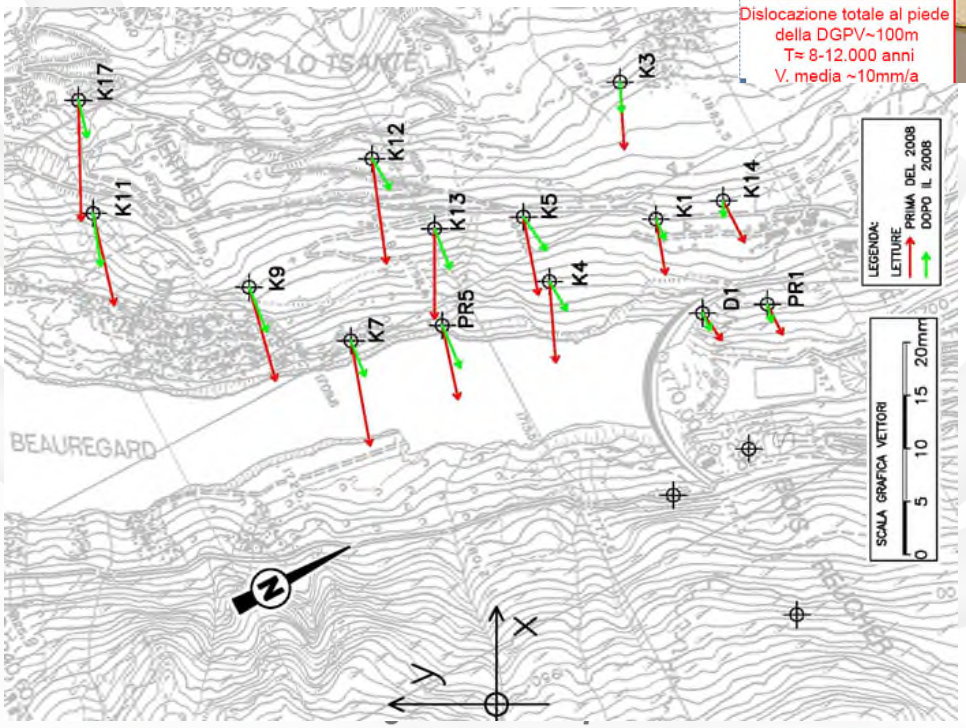
# Geological and geotechnical investigations and studies

- The continuous monitoring and investigations of the dam behavior carried by the former owner (ENEL up to 2000) have been enforced by the new owner (CVA – Compagnia Valdostana delle Acque) with the aim to find a long lasting solution of the problem.
- In order to gain a thorough understanding of the left slope conditions and of its interaction with the dam, since 2002 CVA initiated a series of further investigations and studies:
  - ✓ geological, geomorphological, geophysical, hydrogeological, and geotechnical studies
  - ✓ in situ and laboratory testing
  - ✓ additional monitoring instrumentation installed along the left slope and on the dam
  - ✓ systematic interpretation of performance monitoring data
  - ✓ numerical modeling of both slope and dam response

# The gravitational landslide affecting Beauregard arch dam

**Displacement vectors measured from the surface targets located on the left slope**



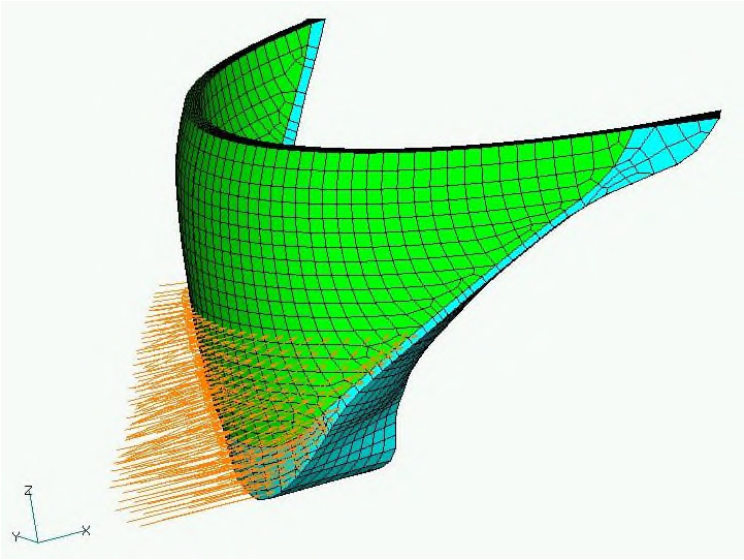



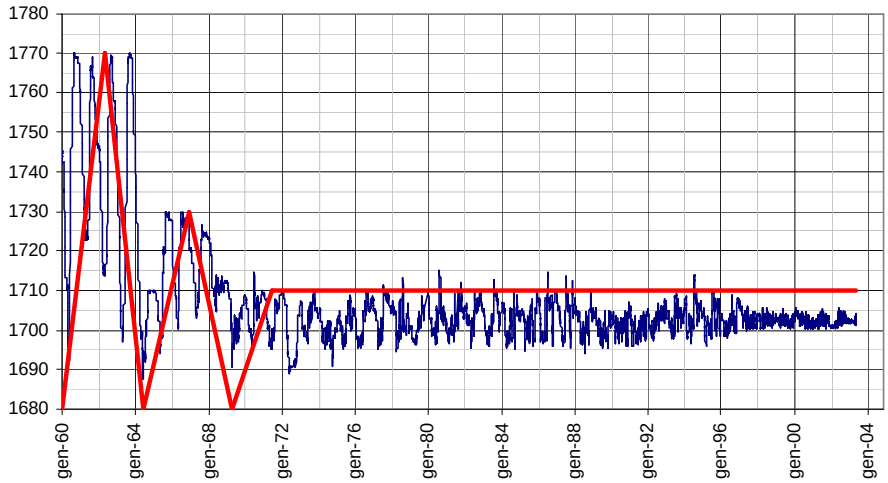

**P-wave velocity tomography which identifies a shear surface of the active portion of the DSGSD that is laying tangentially to the dam toe**

# Numerical modelling to support the interpretation of the dam behavior

**The aims of the numerical model were:**

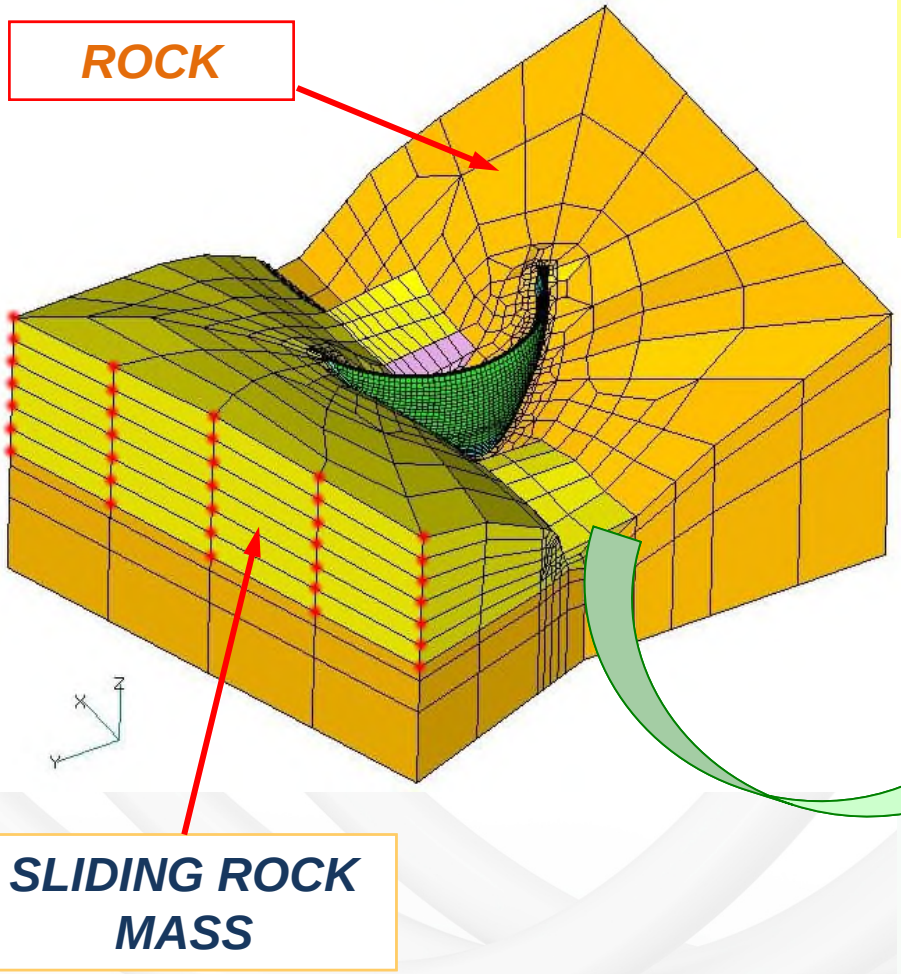
- ✓ **Interpretation of the dam behavior experienced since its first fillings**
- ✓ **Calibration of the mechanical parameters of the dam-rock system in terms of comparison between the observed dam behavior and model results**
- ✓ **Forecast of the future dam behavior at short-middle term adopting the calibrated model**
- ✓ **Support to the designer in the analysis of possible technical solutions to guarantee the long term operation of the dam**

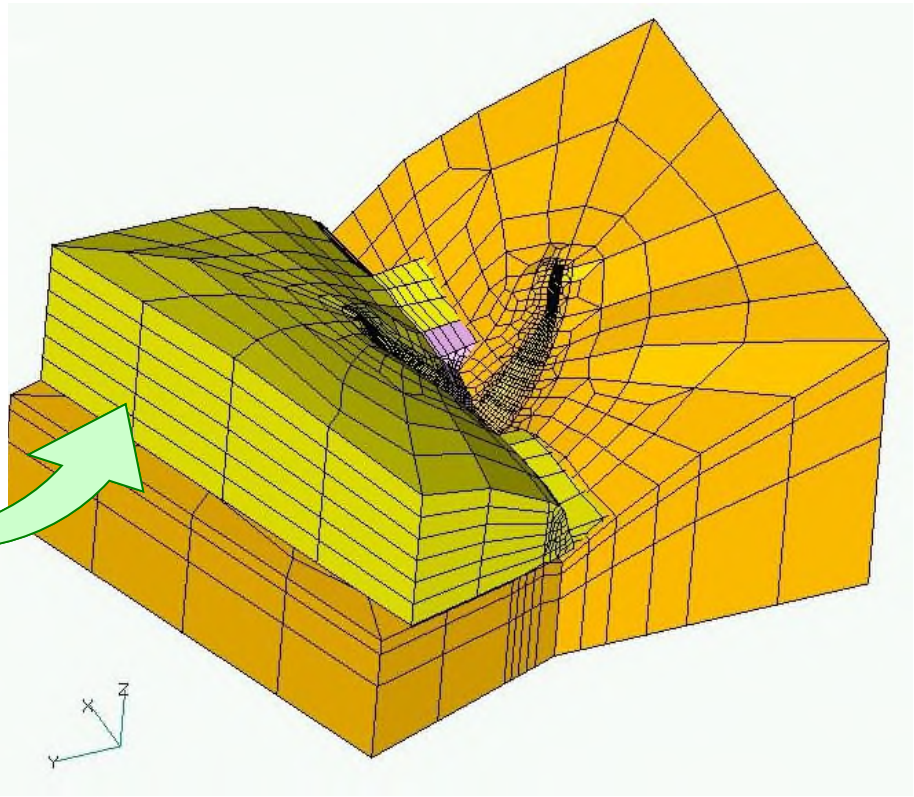




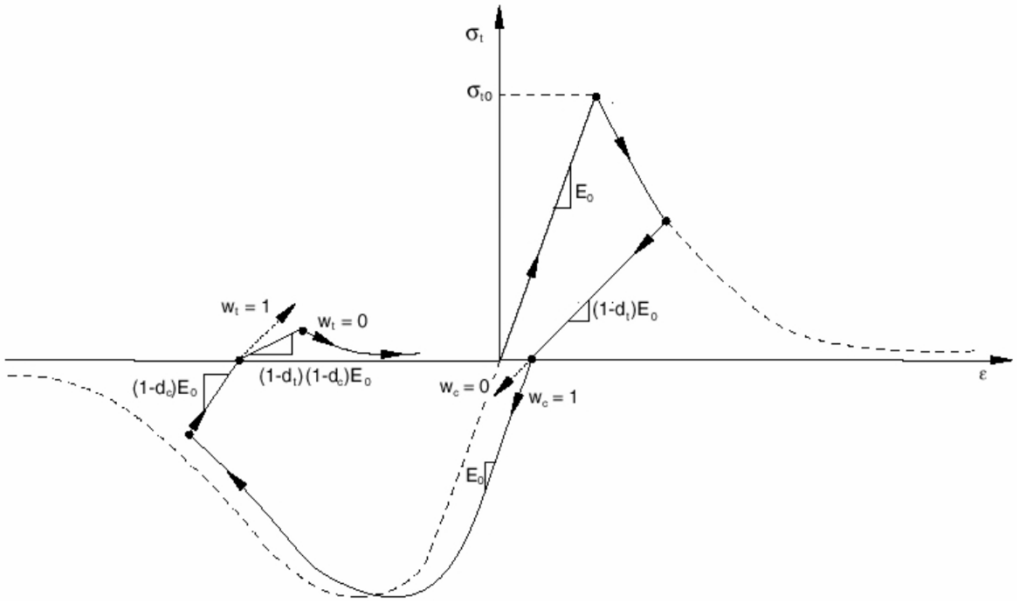
# Numerical modelling to support the interpretation of the dam behavior

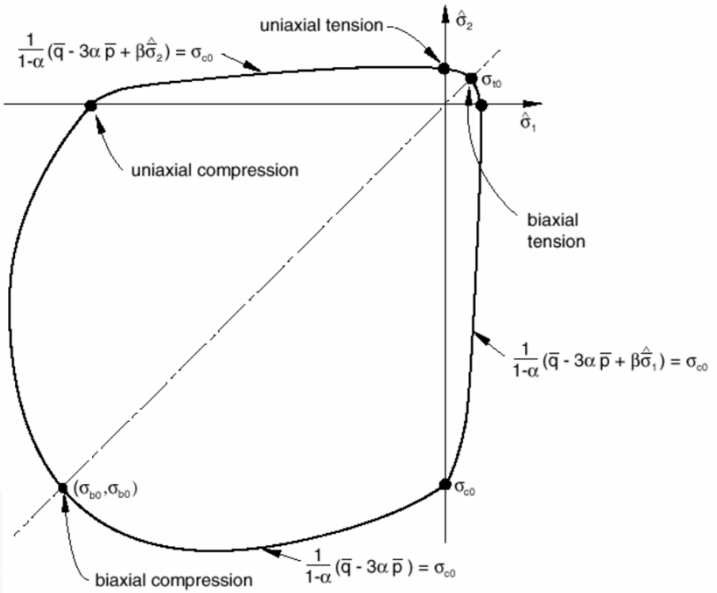
**Displacements measured with the monitoring system installed in the sliding rock mass have been imposed at the nodes marked in red**



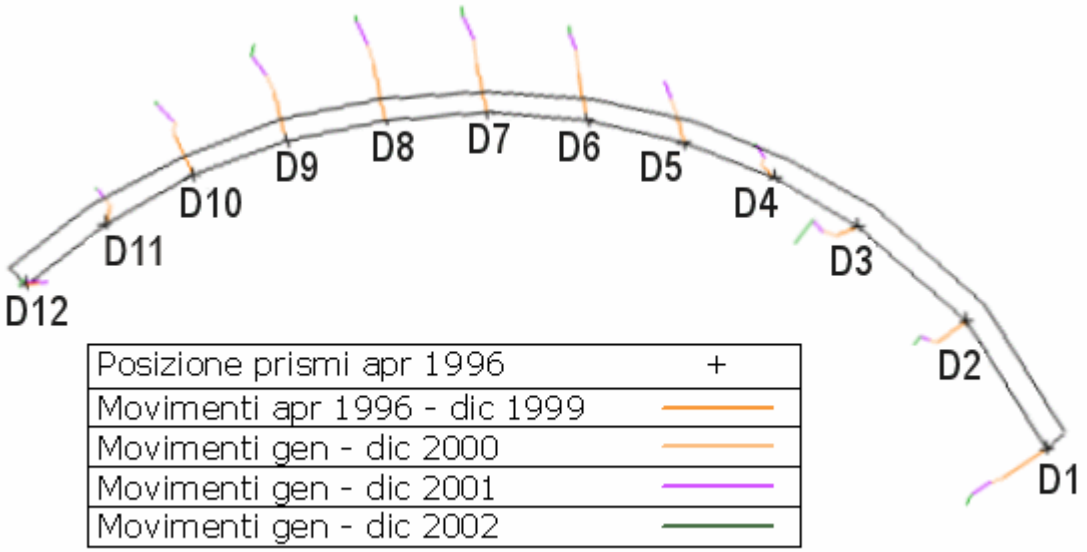
# Numerical modelling to support the interpretation of the dam behavior



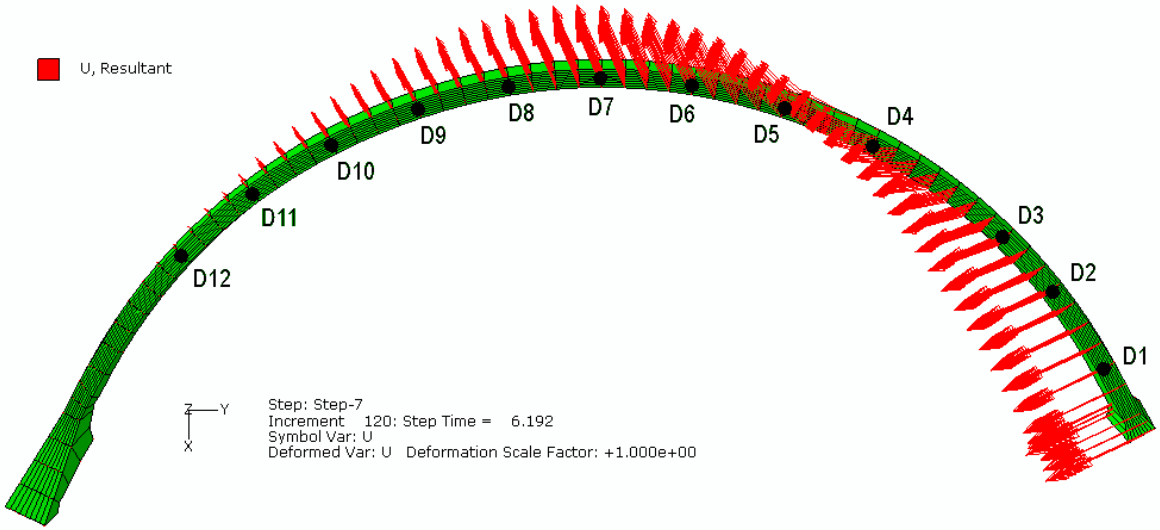




**The Concrete Damage Plasticity constitutive law (Fenves, 1998) has been assumed for concrete and pulvino of the dam.**
**The classic Mohr-Coulomb law has been assumed for the sliding rock mass.**

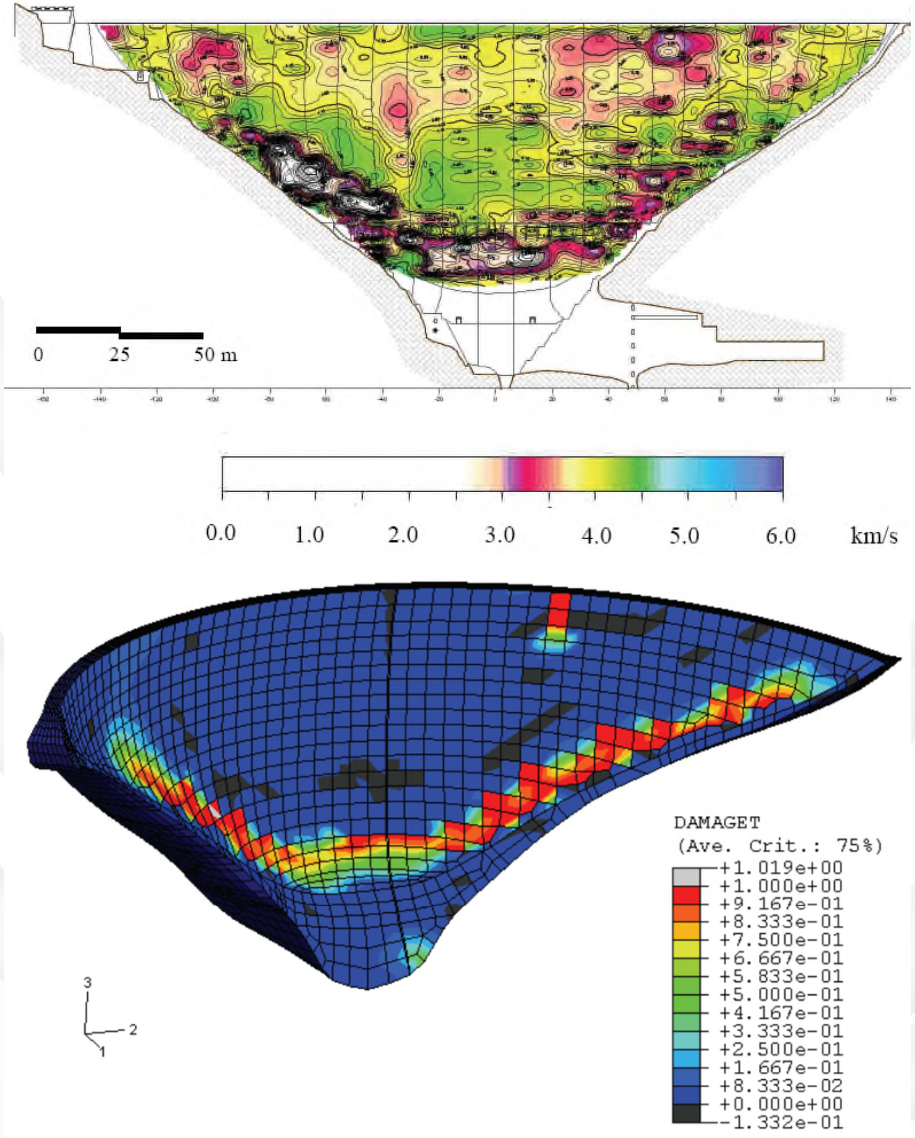
# Numerical modelling to support the interpretation of the dam behavior

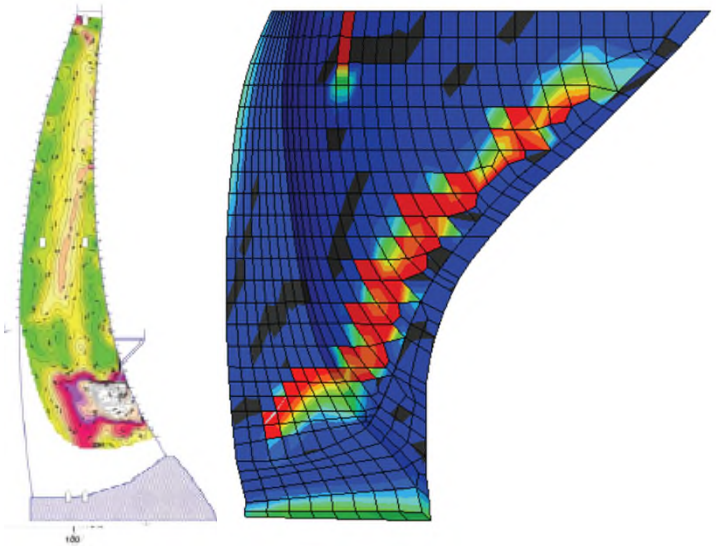



**Comparisons of measured and computed displacement drift at the dam crest**



# Numerical modelling to support the interpretation of the dam behavior

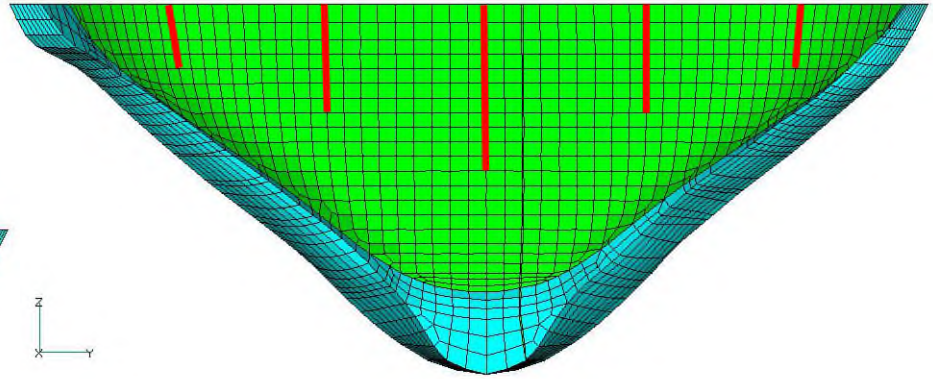


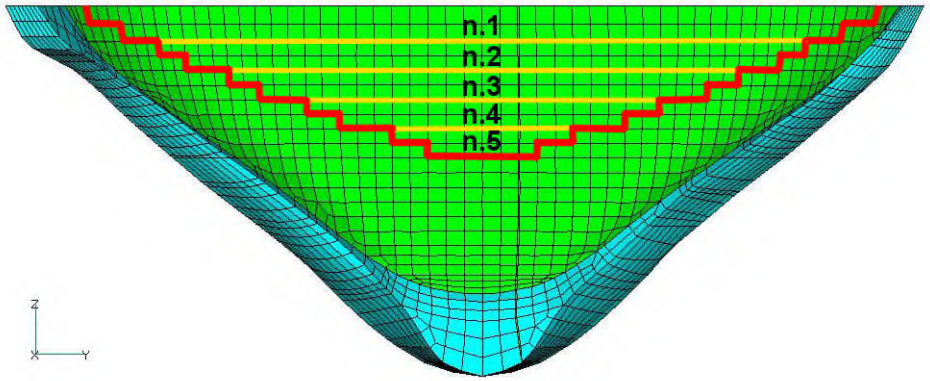
**Comparison between P-wave velocity tomography measured on the dam and the *damage index* computed by the numerical model on the downstream dam face and in the main vertical section**

# Dam rehabilitation: analysis of possible interventions

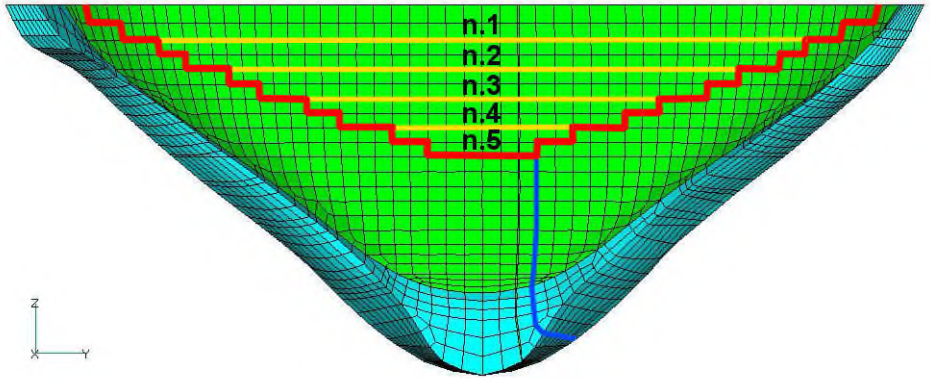
Diamond-wire cutting




Partial Demolition

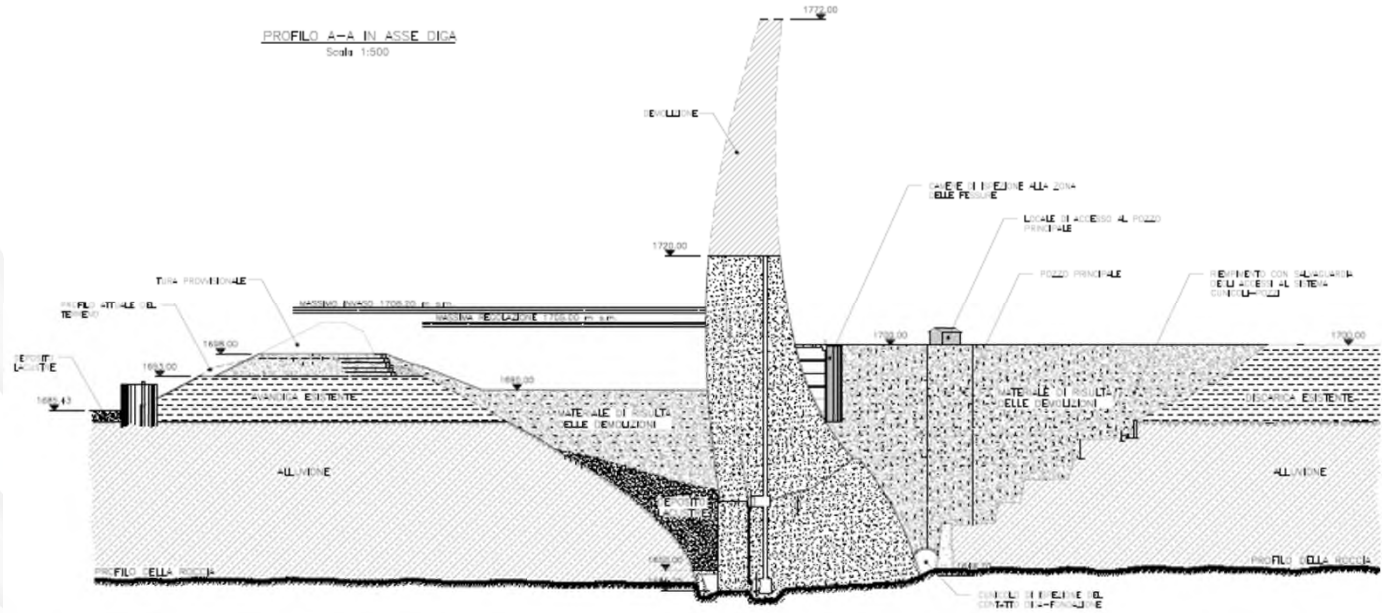



Partial Demolition
and vertical diamond-wire cutting



# Dam rehabilitation solutions

- **Estimated volume of demolished concrete, between elevations 1720-1772m asl: 150,000 $m^3$**
- **Methodology chosen for the demolition: blasting**
- **Demolished concrete will be used to fill the two volumes located at the upstream and downstream dam toes**




**The rehabilitation design has been carried out by the Studio Ing. Marcello of Milan.**

## Dam rehabilitation solutions

- **Improvement of the hydraulic scheme with the construction of a gated spillway and a discharge tunnel**
- **For the rehabilitation of the dam it was decided the progressive demolition by explosives of the upper part (52 m) of the dam**

**The demolition started in the spring of 2013 and it will end in 2014.**

**A video of one demolition step (6m high x 50m wide) will be showed.**

## Acknowledgements

**The Authors wish to express their thanking to CVA – Compagnia Valdostana delle Acque, and in particular to Dr. Lorenzo Artaz and Dr. Morena Colli, who have given the permission to present the communication.**

# THANK YOU FOR THE ATTENTION