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Question 96
Innovation and Utilisation of Dams and Reservoirs
Innovations dans l'utilisation des barrages et réservoirs

Risques et sûreté des barrages d'altitude pour la production de neige artificielle / Mountain reservoirs for producing artificial snow: related risks and safety

Paul ROYET

Marika BOUTRY, Laurent PEYRAS, Dominique LAIGLE, Sébastien MERCKLE, Guillaume PITON, Alain RECKING, Guillaume STOLTZ, Davide PATROCCO, Roberto DEL VESCO, Giulia BODRATO, Paolo ROPELE, Franco COLLE

Cfbr comité français des barrages et réservoirs

REGIONE PIEMONTE

irstea

Région Autonome Vallée d'Aoste
Regione Autonoma Valle d'Aosta

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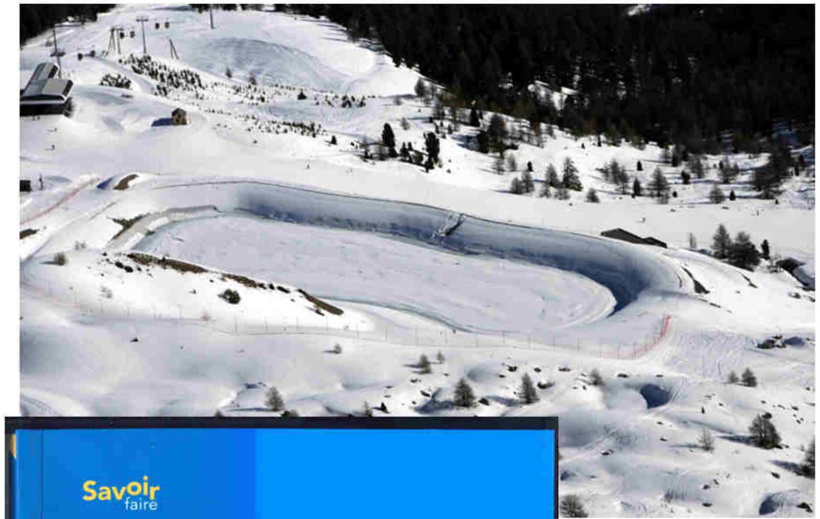
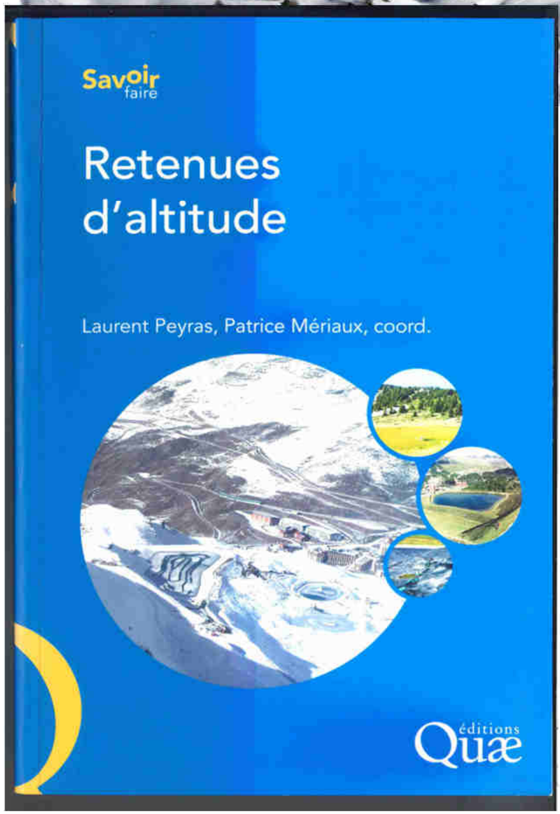
Introduction: specific context of those dams

- In Alpine area, increasing number of dams for producing artificial snow (about 150 only for France)
- Geological and geotechnical context usually complex
- Specific hazard linked to the mountain context: avalanches, earthquakes, debris flow, slope stability, freeze/thaw
- Stakes at risk in case of a rupture are usually important : ski resorts, intensive tourism in all seasons
- In return, a favorable economic context: necessary financial means available for construction and maintenance (investment cost up to 30€/stored cubic meter)

Main technical features





- Reservoir volume in the range 10 000 to 400 000 m^3, with a trend to increase for new projects
- Construction in excavation / embankment, with embankment maximum height up to 20m
- Rocky foundations; moraine and shale for the embankment
- Watertightness of the whole reservoir surface by means of a geomembrane (with all related issues)
- Some empiricism in the design, until the years 2000 (first guidelines issued in 2009, in French)

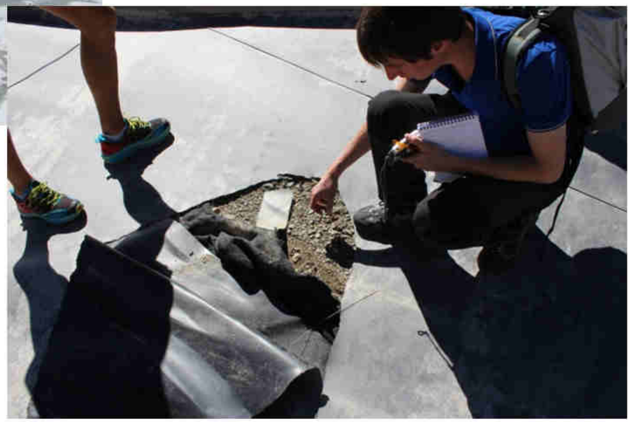
RISBA research project

3 research teams: Irstea (Fr), Valle d'Aosta Region (It) and Piemonte Region (It – project leader)

6 topics related to mountain reservoirs:

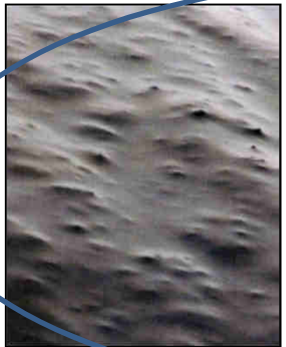
- **Resistance of GWD to puncture**
- Use of SAR technology for topographical survey
- **Simplified dynamic methods for justifying safety of the embankment**
- Control of sediment transport from u/s
- Dam break: modeling flow with erosion and sediment transport
- Simplified method for assessing and mapping stakes at risk, digitalization and GIS developments

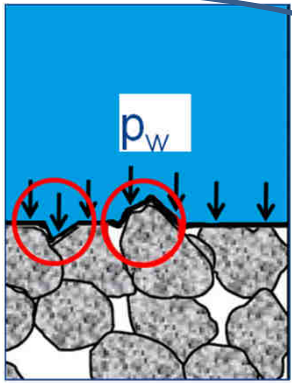
Geomembrane waterthightness devices – Context and lessons learnt (22 dams visited)



- 4 solutions for protection of the geomembrane:
  - No protection: 9% of cases
  - **Protection of the upper part of the inner slope (over a berm): 59%**
  - Protection of the entire slope: 5%
  - Protection on the total reservoir surface: 27%
- Main issues: slope stability, tearing or puncture of the membrane due to ice creeping, aggressive support layer or inadequate protection geotextile

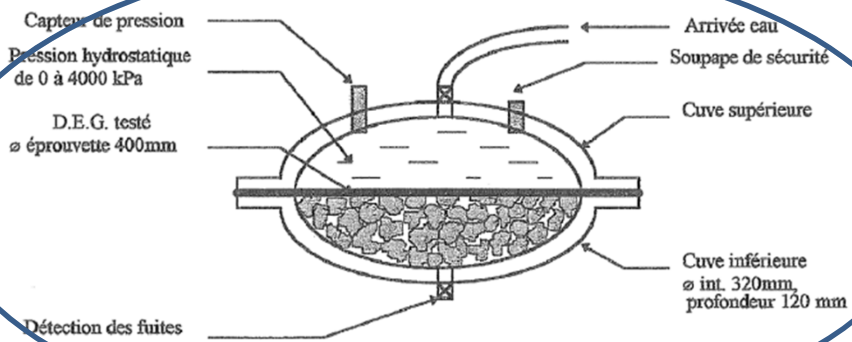
Geomembrane waterthightness device – Experimental approach



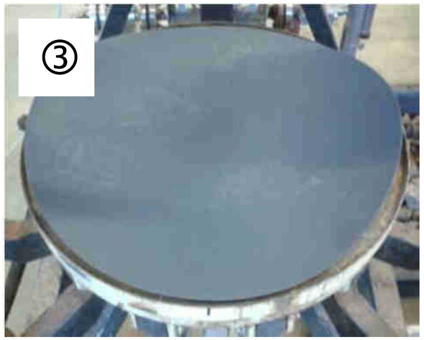


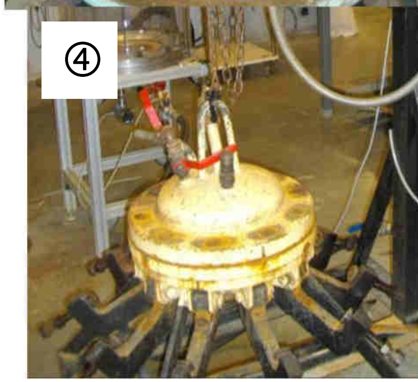
What we want to model

- Better define the performance of the GWD: Develop an experimental protocol of qualification and propose a quantitative criteria



The testing device





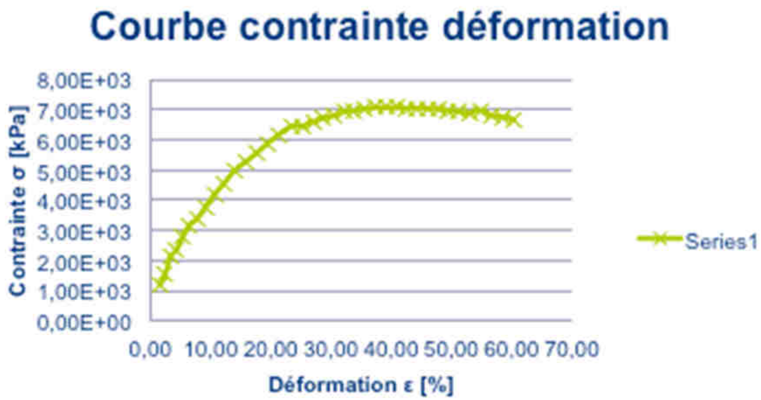
The 4 first steps of the test

Geomembrane waterthightness device – Experimental approach

The following steps of the test :

- •Dismounting the device
- •Visual observation of geomembrane and geotextile (preliminary analysis of GWD performance)

- •Burst test on the geomembrane



Comparison with the results on a "virgin" geomembrane (intrinsic resistance):

If the mechanical strength of the damaged geomembrane has dropped compared to the intrinsic resistance, GWD deemed unsatisfactory for the protection function of the membrane

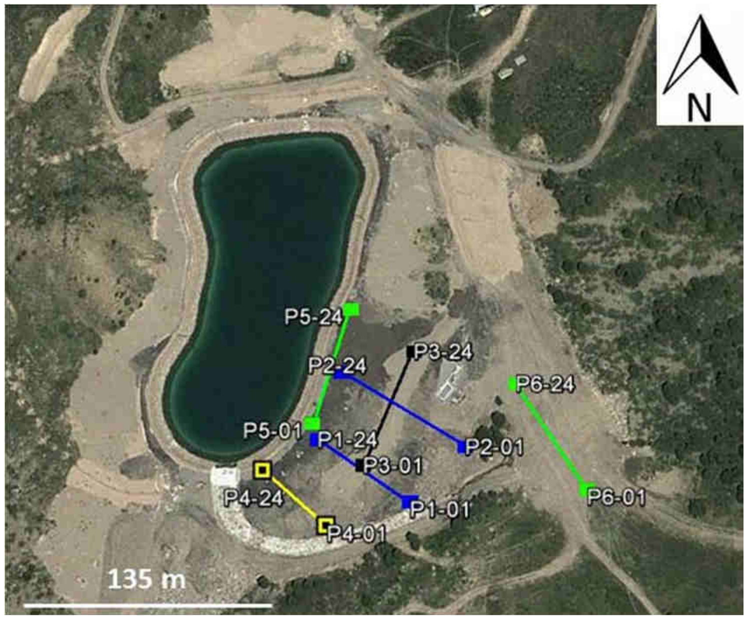
Seismic aspects – Context and method

More demanding regulations, with similarities in France and in Italy (eg.: for this category of dams, typically a_g = 2 to 3 m/s²)

As a consequence, seismic situation is often dimensioning when using pseudo-static approach (set of partial safety factors or global safety factor)

How to use simplified dynamic approaches? (performance criteria: admissible displacements)

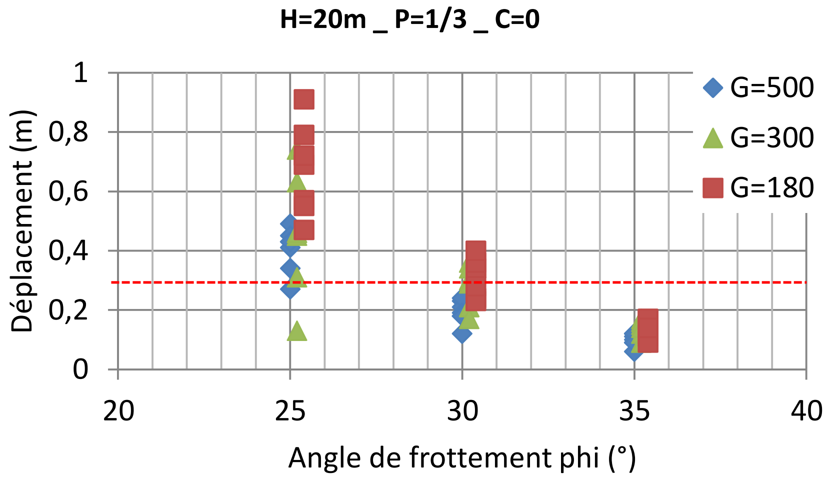
- Seed & Makdissi (failure circle SF=1 and use of abacus for displacement)
- Dynamic temporal approach with FEM modeling and Newmark analysis



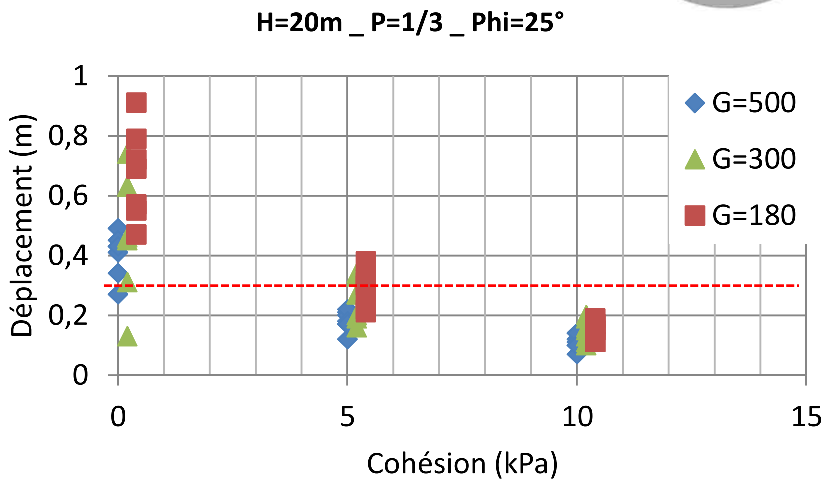
Comparison made by means of a parametric study (by varying geometric and mechanical characteristics of the embankment, Vs, and accelerographs: 11 + 33 + 231 calculations

And more in-depth study on a specific dam, after in-situ investigations (penetrometer and MASW)

Seismic aspects – Some results
Dynamic temporal approach



Influence of friction angle



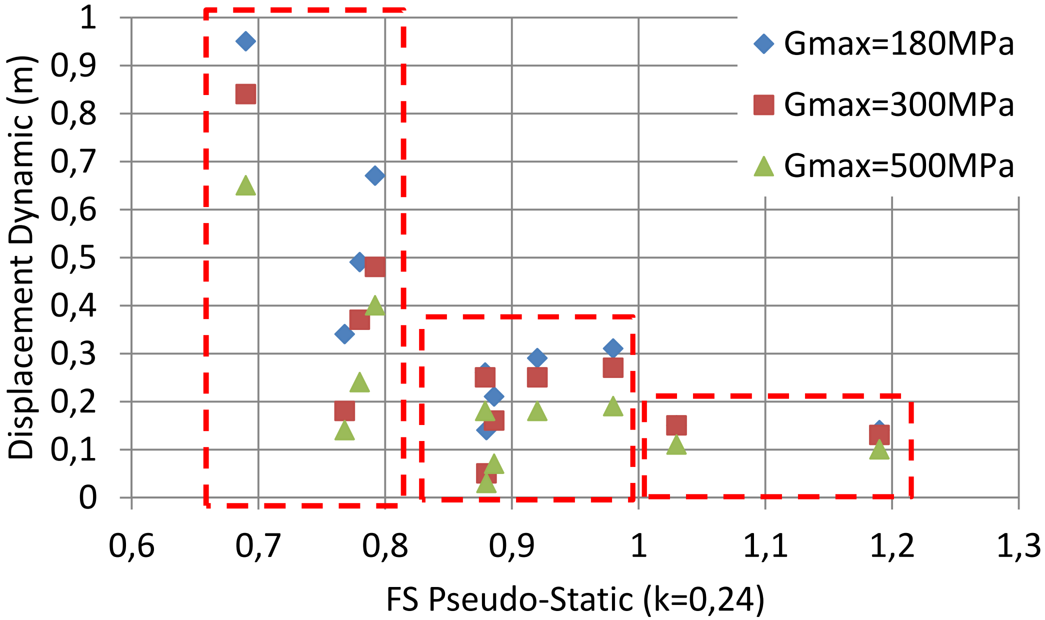
Influence of cohesion

The calculated displacement are reduced rather quickly when one deviates from poor values of {c' ; φ'} (pessimistic for the material usually used in the embankments)

The shear modulus at small strains (Gmax) has a significant impact RQ: This parameter can be measured in-situ, after construction. Importance of compaction

Performance criteria (here d<0.3m) are usually fulfilled

Seismic aspects – Some results
Comparison static / dynamic



Results pseudo-static	Results dynamic
FS > 1	Displacements: low (< 15 cm)
1 > FS > 0,8	Displacements: medium (< 30 cm)
0,8 > FS	Displacements: important

Contribution of dynamic methods to justifying the structural safety is essential for dams not meeting the usual criteria with static methods

See also comparison of results between Seed&Makdisi and dynamic temporal approaches

More details on RISBA research project

Printed Synthesis Report available for consultation on FrCOLD exhibition stand

Detailed reports available at: http://www.regione.piemonte.it/difesasuolo/risba/indexFr.htm