Ageing Concrete Dams
Part I
ICOLD Bulletin
#198

Erik Nordström - Vattenfall R&D - SWEDEN

International Commission On Large Dams

The International Commission on Large Dams – ICOLD – utgör ett forum för att främja utbyte av kunskap och erfarenhet inom planering, projektering, byggande, skötsel och underhåll av höga dammar.
ICOLD grundades 1928 och har ca 100 medlemsländer och ca 6000 individuella medlemmar.
De aktiviteter som i huvudsak bedrivs är:

- Tekniska kommittéer som ger ut mellan 2 till 10 bulletiner per år.
- Vart tredje år hålls en kongress där fyra ämnen behandlas (mellan 200 och 300 uppsatser).
- Symposier
- Föreläsningar

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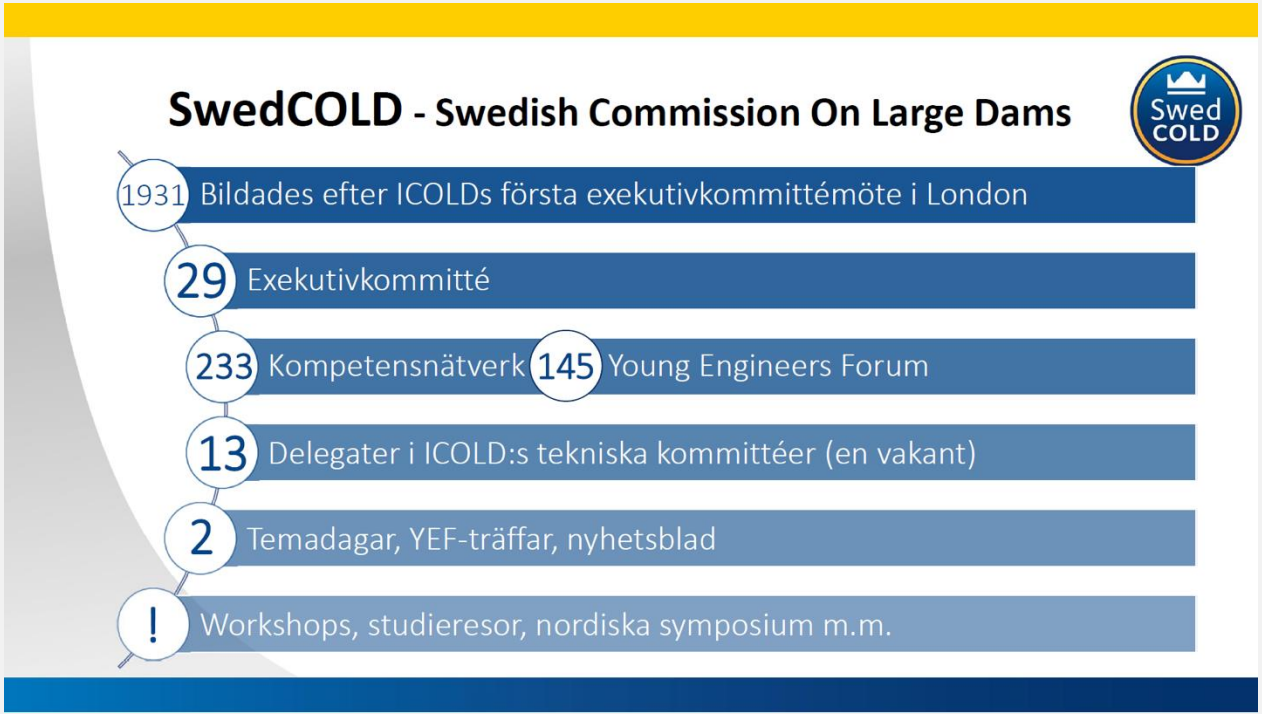
Swedish Commission on Large Dams



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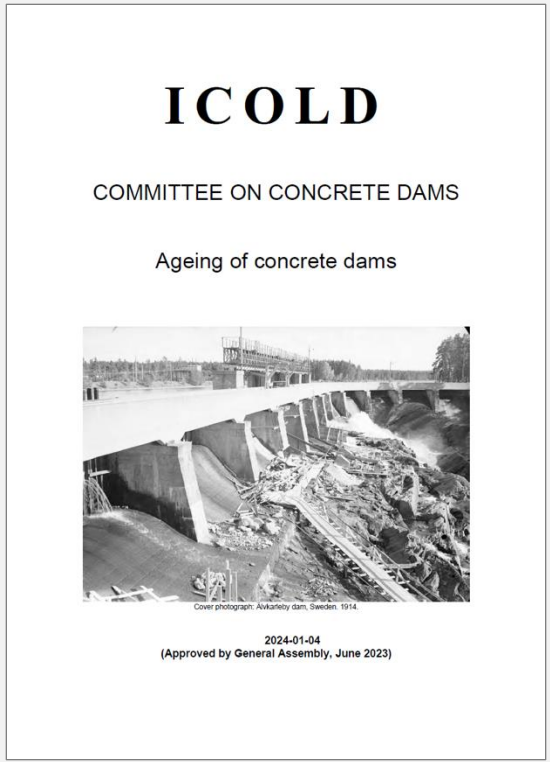
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COMMITTEE ON CONCRETE DAMS

Ageing of concrete dams

Cover photograph: Älvkarleby dam, Sweden, 1914.

2024-01-04
(Approved by General Assembly, June 2023)

Table of Contents

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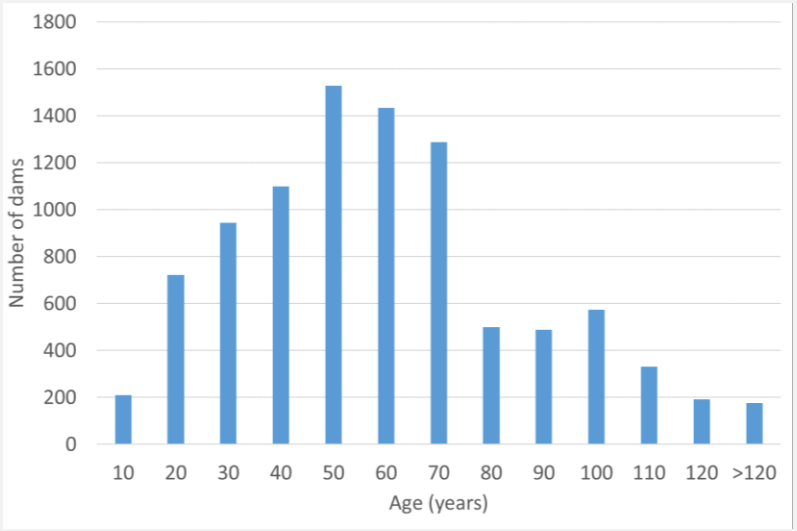
Ch 1 – Introduction

Scope of bulletin

- Compile current knowledge on management of ageing concrete dams and hydropower concrete structures
- Specific focus on degrading processes
- Ageing effect on properties and potential impact on dam behaviour is to be described.
- A general system for management is presented



- World Register of Dams
- ~ 10.000 concrete dams (explicitly denominated as)
- Average age 55 years

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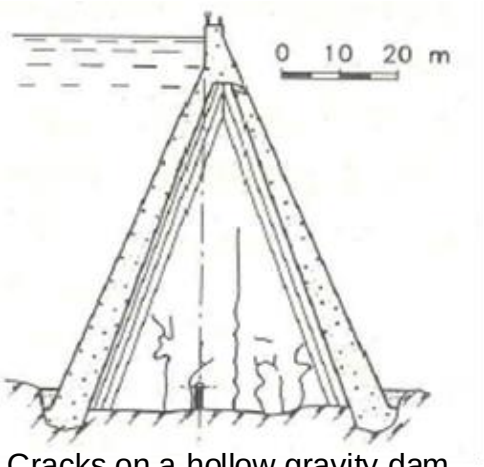
Ch 2 – Ageing in general

- Dam design quality:
  - geological evaluation of dam site and stability of reservoir area
  - hydraulic design of the dam outlets
  - evaluation of loads acting on the dam (thermal, creep, uplift press.)
  - construction details (upstream face, joints, drains, grout curtains)

- Materials and construction technology quality :
  - concrete components materials
  - concrete mix design
  - construction technology (mixing and casting)

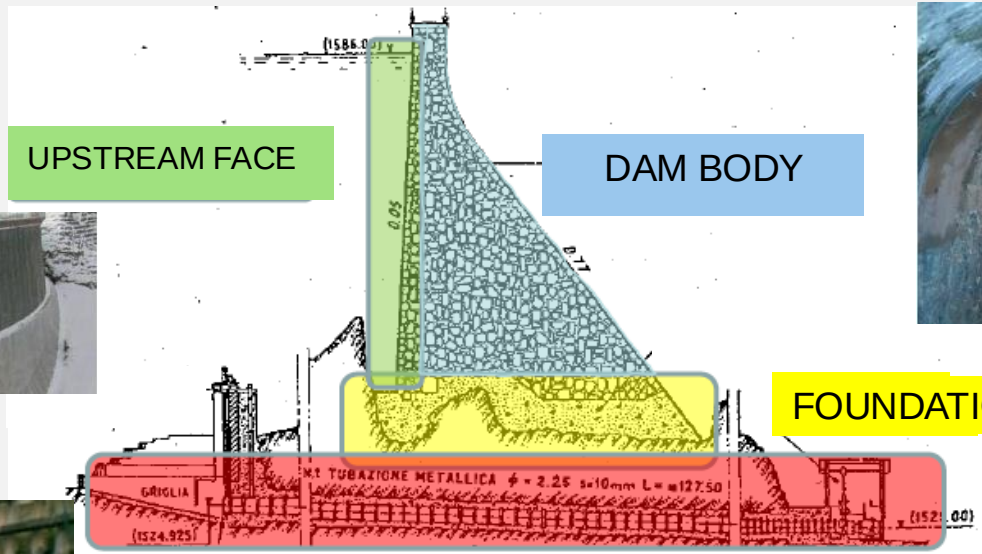
- Concrete deterioration processes:
  - chemical reactions (aggressive waters, expansive reactions etc.)
  - physical phenomena (freezing/thawing cycles, erosions etc.)

- Quality of maintenance work



Cracks on a hollow gravity dam due to thermal stresses

Ch 2 – Ageing in general

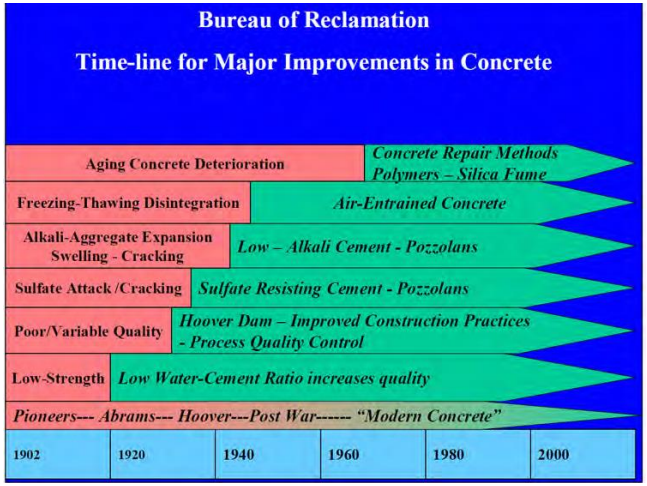


According to the Italian experience on the repair interventions of > 200 dams, dam ageing concerned:

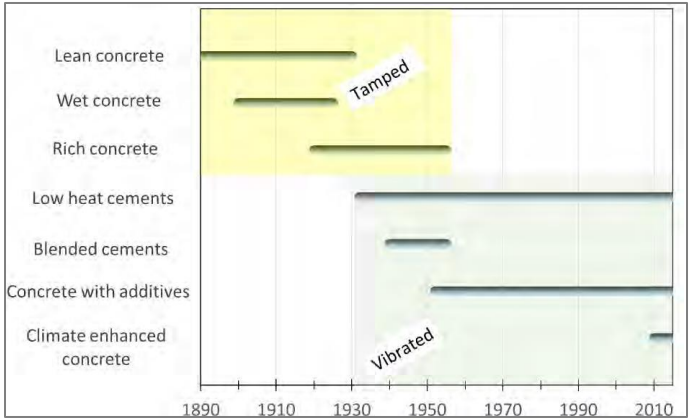
Upstream face	33%	**Dam body**	23%
Outlets	28%	**Foundations**	16%

Ch 3 – Development of concrete technology and materials

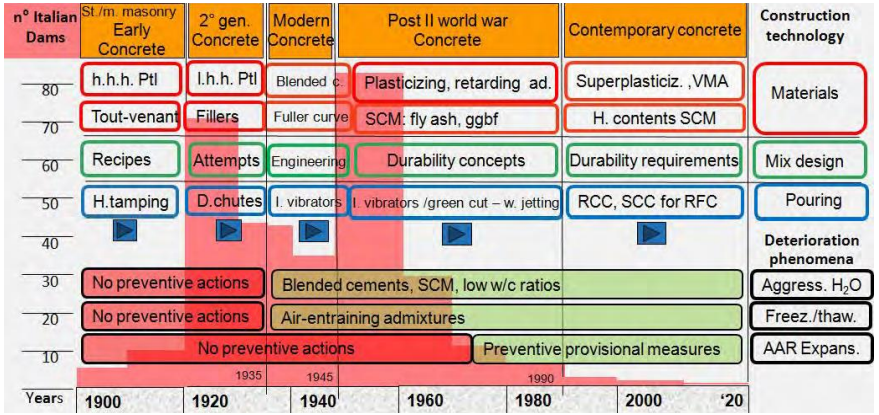
USA

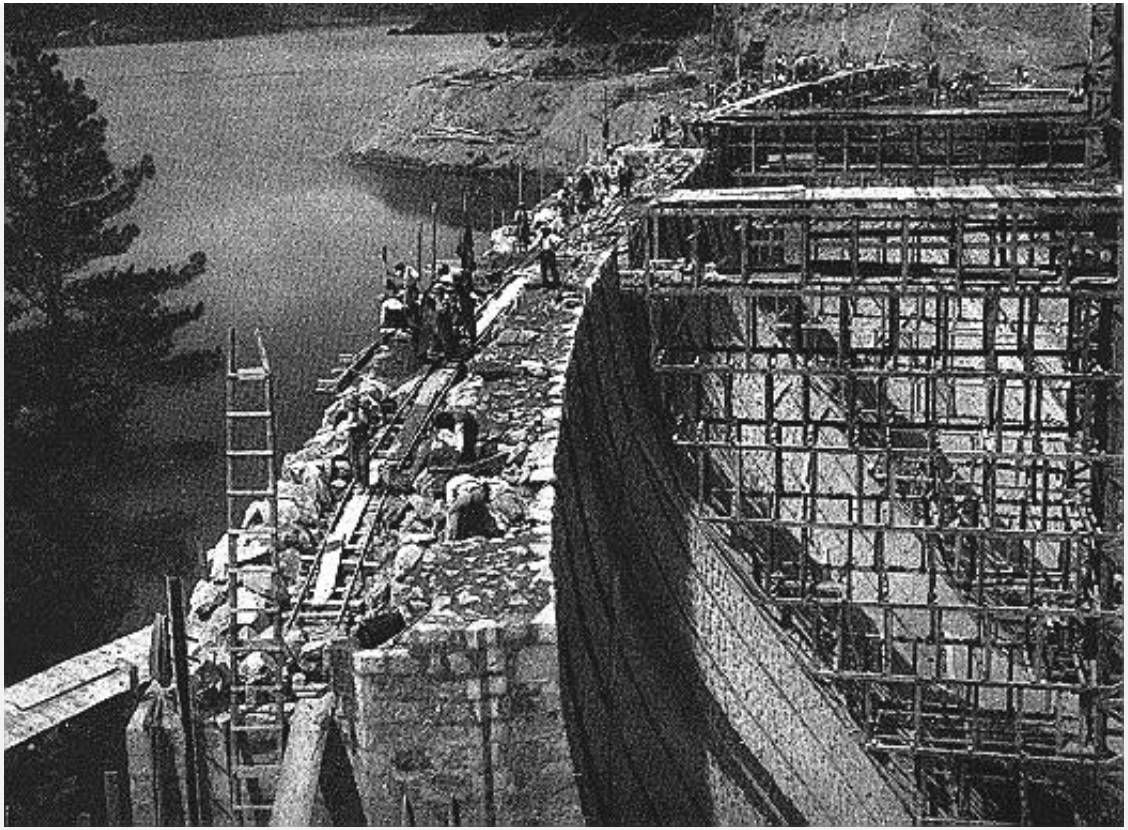


SWEDEN

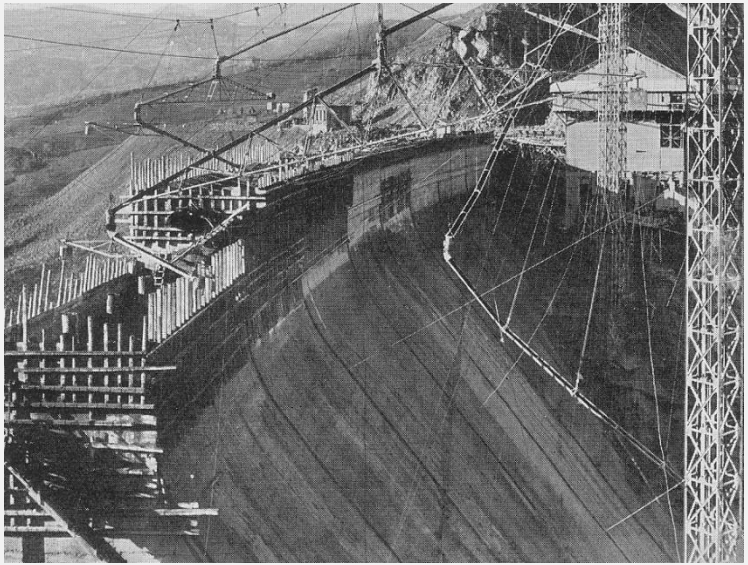


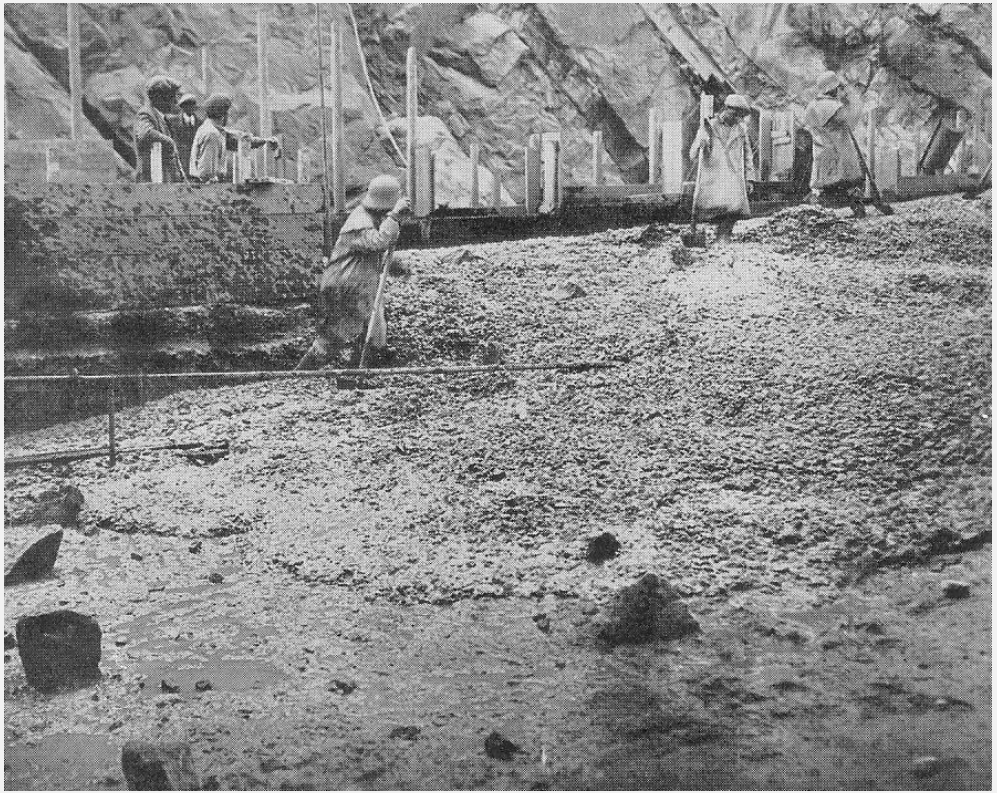
ITALY





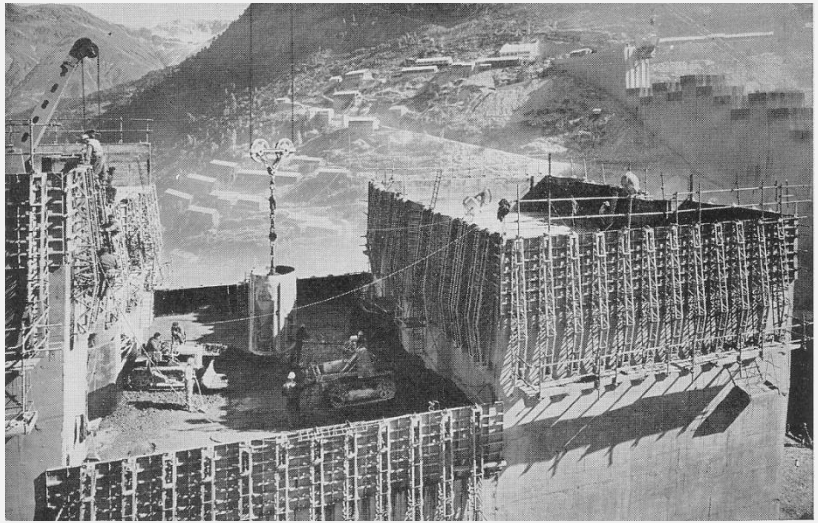
Early concrete - Hand tamping of concrete

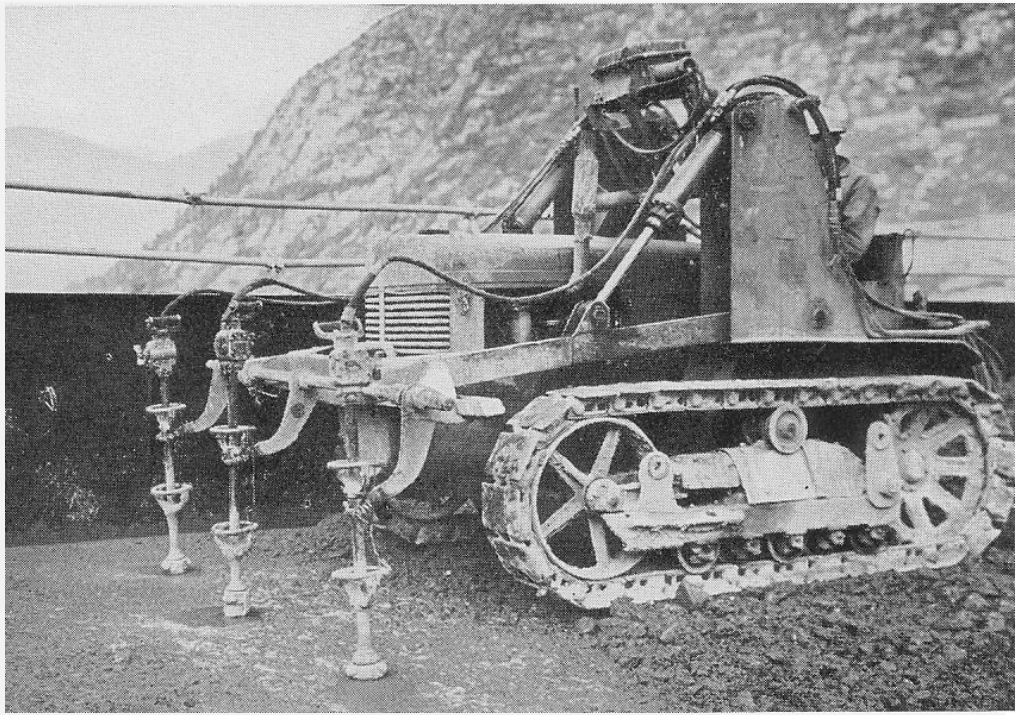




2nd generation concrete: flowing concrete distributed by chutes

Mario Berra (Independent consultant) and Roberto Saccone (Mapei), ITALY





Modern concrete - Concrete compaction by internal vibrators

Mario Berra (Independent consultant) and Roberto Saccone (Mapei), ITALY

Ch.4 – Ageing processes affecting concrete properties

4.1 – Degradation and influence of exposure type

4.2 – Ageing without ongoing degradation

4.3 – Leaching / Acid attack

4.4 – Expanding concrete

4.5 – Reinforcement corrosion

4.5 – Anchors

4.7 – Frost action

4.8 – Erosion

4.9 – Thermal effects

4.10 – Creep

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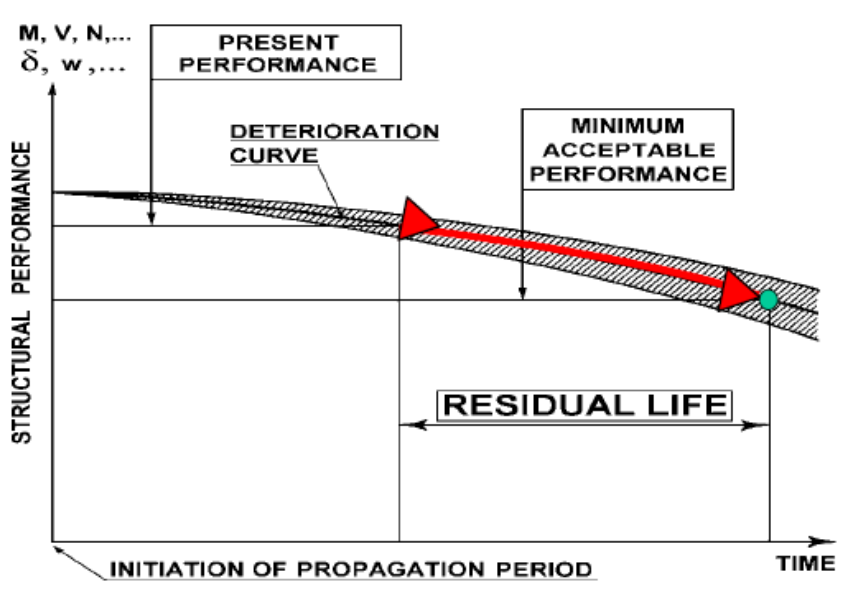
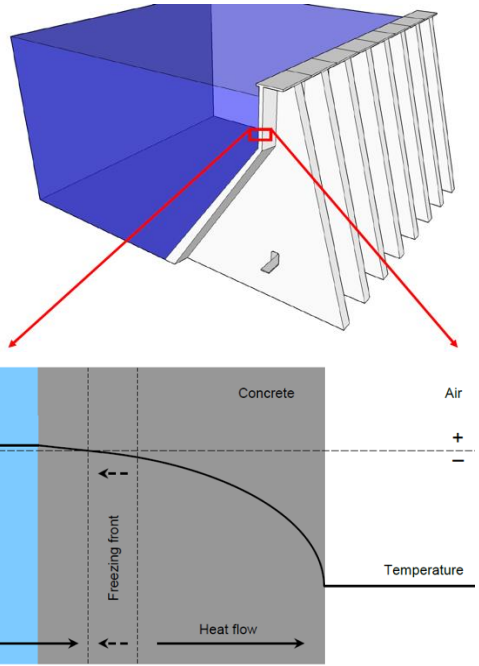
Ch.4 - Ageing processes affecting concrete properties

- Impact from degradation mechanisms on:
  - strength (compressive/tensile)
  - E-modulus
  - porosity
  - water-tightness, permeability
  - erosion resistance
  - geometrical shape
  - synergy effects from several mechanisms



Ch. 4.7 - Ageing from frost action (example)

- Freezing of water give an expansion of 9%
- Moisture state + air void system of the concrete rules the risk for frost damages
- Access to free water and exposure for low temperatures common for many hydropower dams



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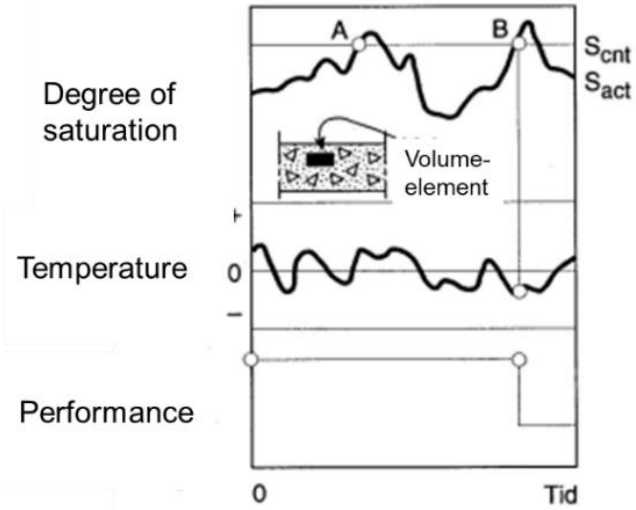
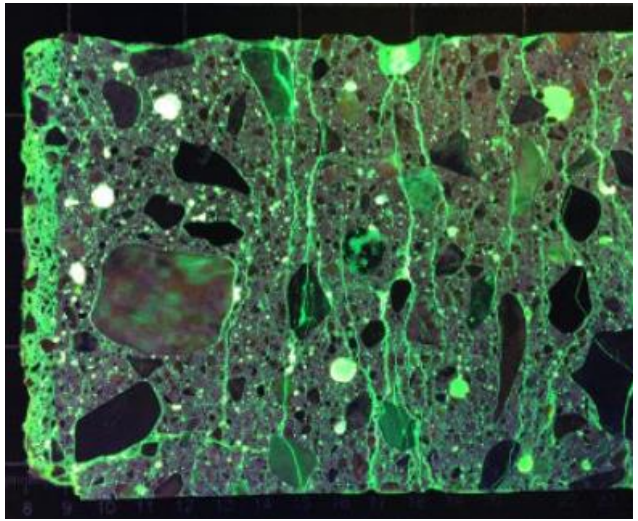
Ch. 4.7 - Ageing from frost action (example)



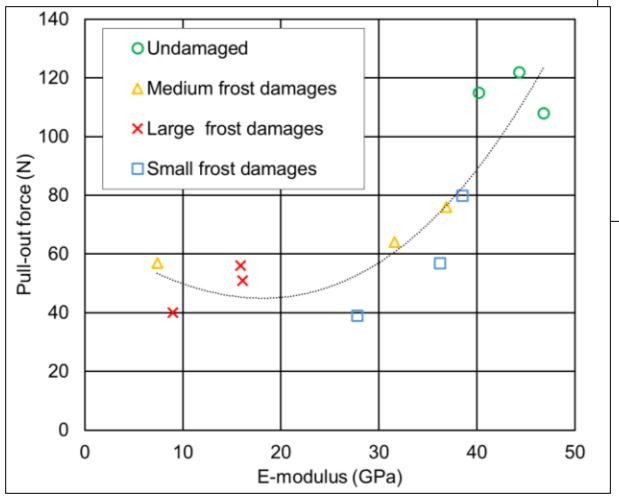


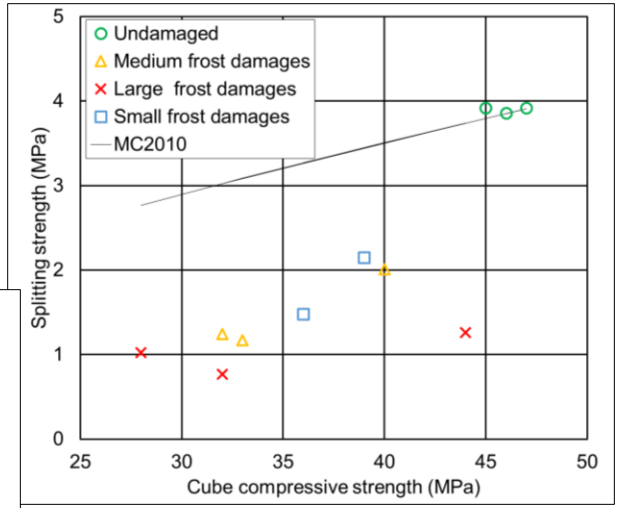
- S_{crit} for air entrained hydropower concrete typically 0.75 – 0.90

Ch. 4.7 - Ageing from frost action (example)

- Internal damage
- Strength loss in tension larger
- Lowered E-modulus
- Loss of bond to reinforcement

  loss of load-bearing capacity





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Chapter 5 – Management of existing concrete dams

5.1 – Requirements

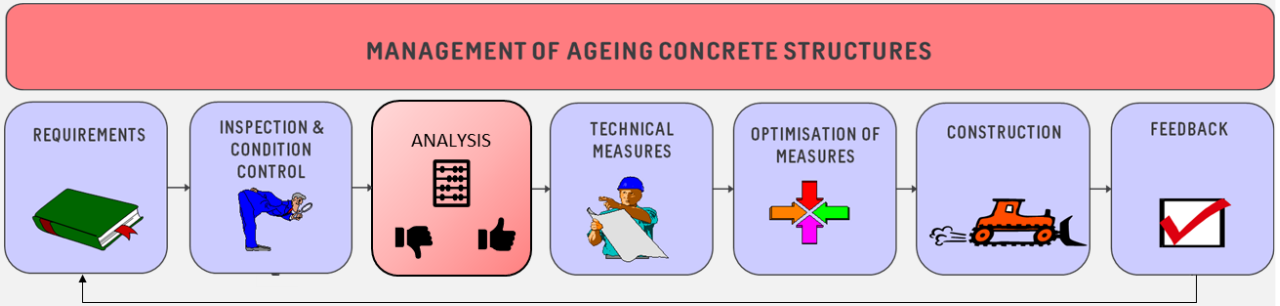
5.2 – Assessment

5.3 – Measures

5.4 – Selection and Optimization of Measures

5.5 – Design and construction

5.6 – Lessons learned



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Chapter 6 – Condition assessment of concrete dams *(place holder for part II)*

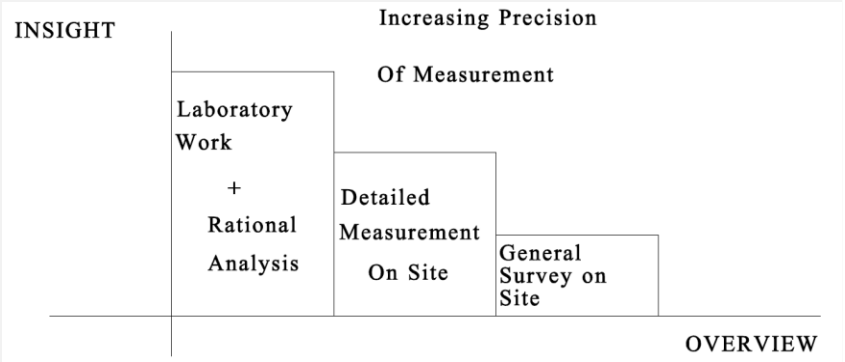
6.1 - Preparations

6.2 – Inspections
- 6.2.1 Visual inspections
- 6.2.2 In-depth inspections

6.3 - Monitoring, sampling & testing

6.4 - Analysis
- 6.4.1 Conceptual models
- 6.4.2 Analytical calculations
- 6.4.3 Numerical modelling
- 6.4.4 Verification, validation and acceptance criteria's

6.5 - Prediction of remaining service-life
- 6.5.1 Diagnosis
- 6.5.2 Prognosis

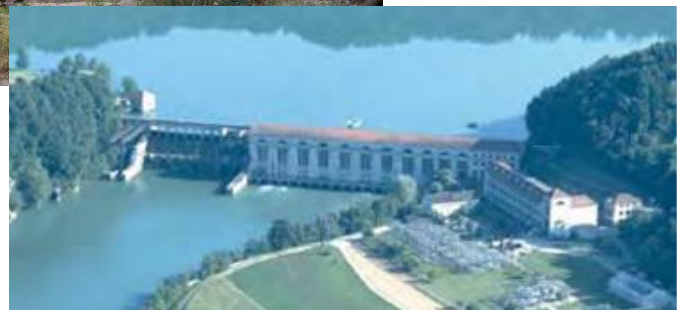


Chapter 7 – Case studies

- Spillway dam – Zambia - 1971

- Buttress dam/spillway – Australia - 1944

- HPP/gravity dam – Switzerland - 1920



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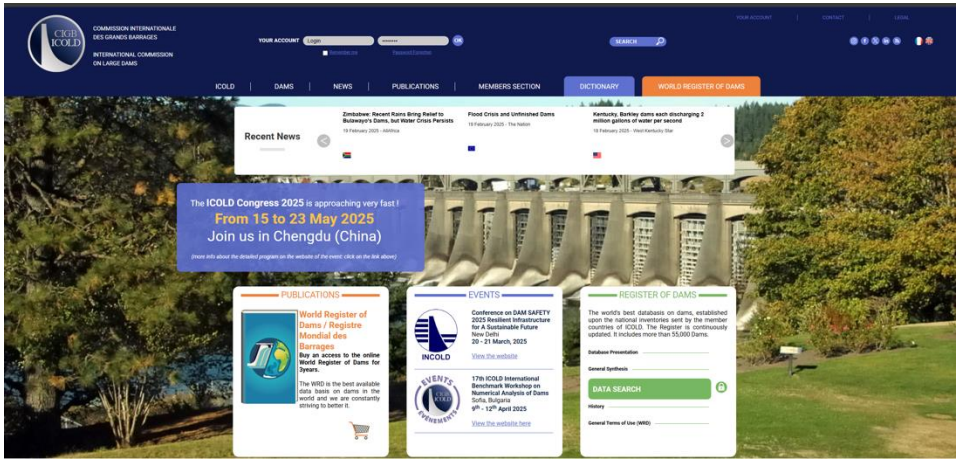
How to find the bulletin ?

- Translation to French ongoing
- Pre-print available on www.icold-cigb.org for members in SwedCOLD
- Final version can be purchased for 50-90 EUR (free for members)



Thanks for your attention !

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