

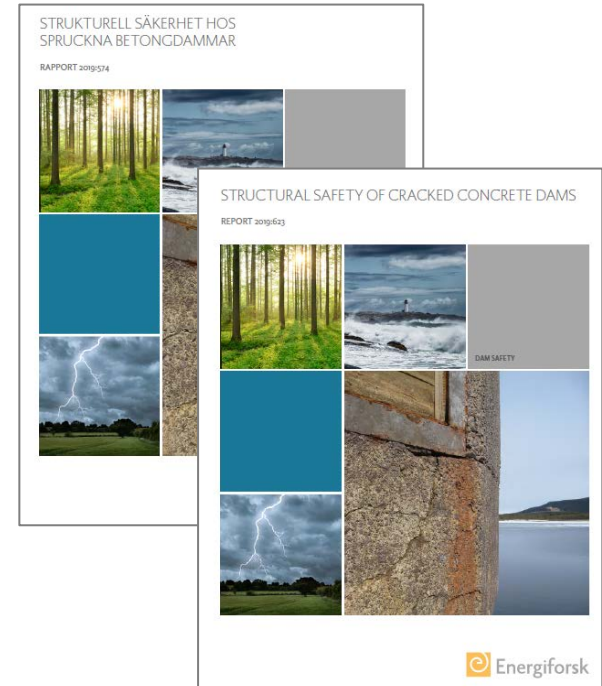


# Guideline for structural safety in cracked concrete dams

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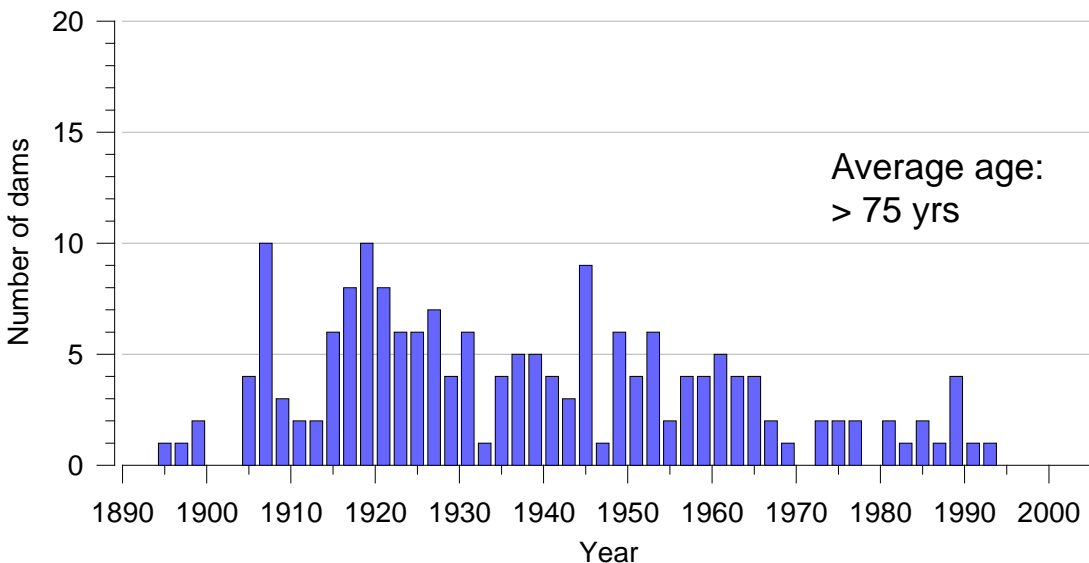
# Pre-Background

- Continuation of a DSIG-project by Charlwood and Tarbox (2014).
- Originally a request for tender from DSIG
- Joint offer from SWECO and ÅF (today AFRY).
- Project put on ice due to lack of funding
- Decision from Energiforsk to do a Swedish version
- Translated to English and now in-kind in other CEATI/DSIG-projects



# Background

- Demography of concrete dams in Sweden
- Inspections – how to document and evaluate cracks?
- Impact of cracks on dam safety and structural capacity ?



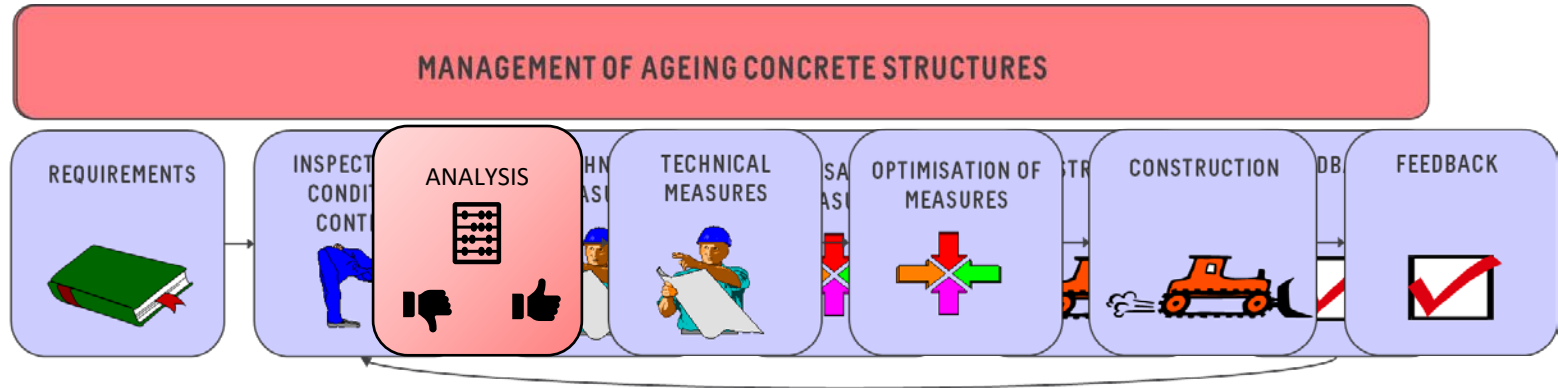
# Outline of the guideline

- Management of existing concrete dams
- Assessment
- Analyses
- Measures
- Case studies



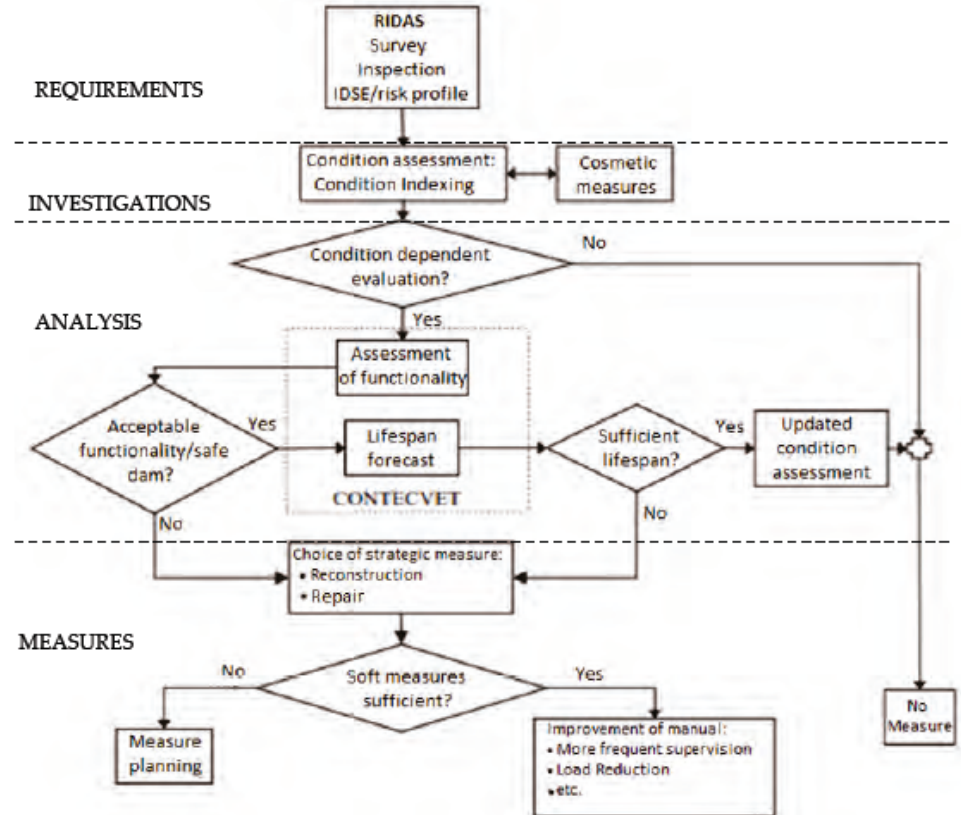
# Management of existing concrete dams

- General process for existing dams



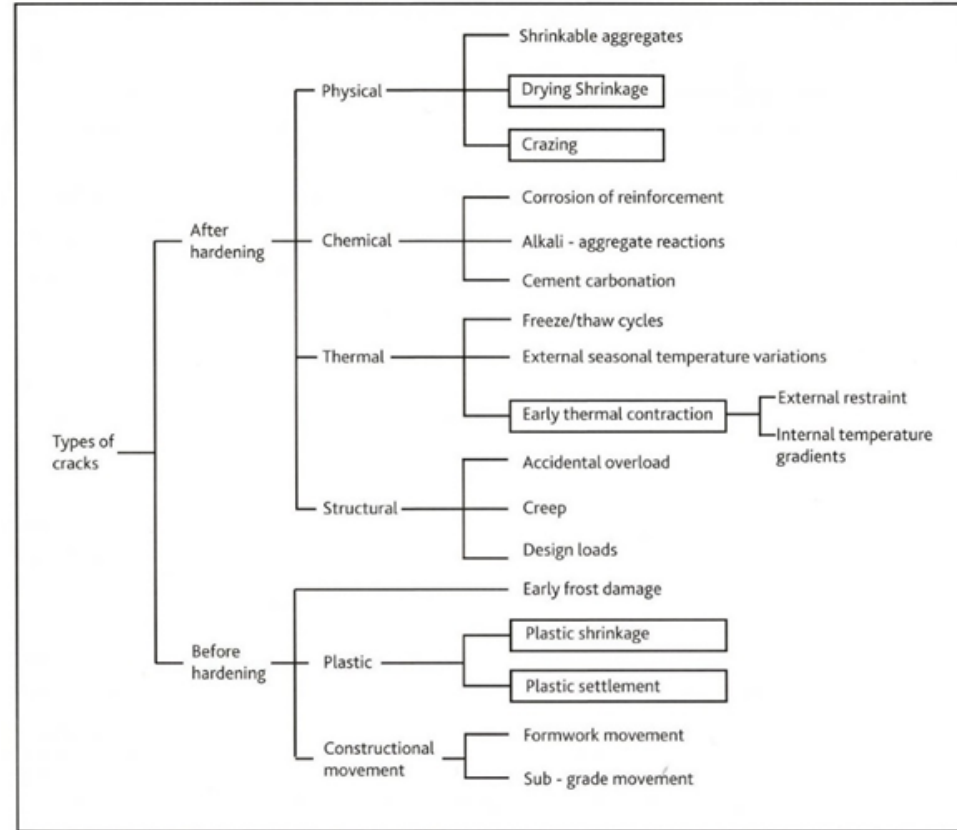
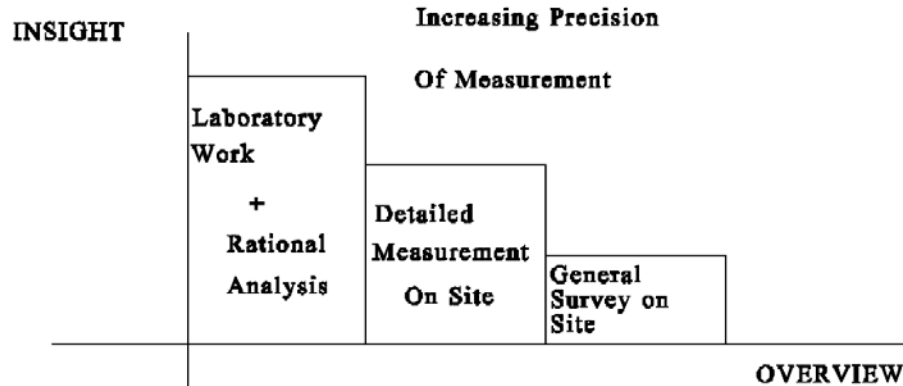
# Management of existing concrete dams

- General process for existing dams



# Assessment

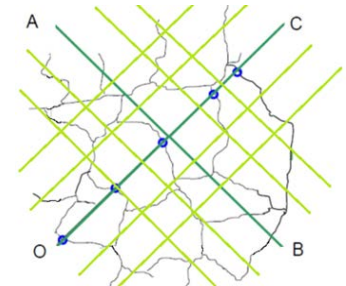
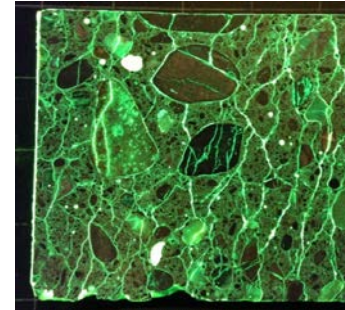
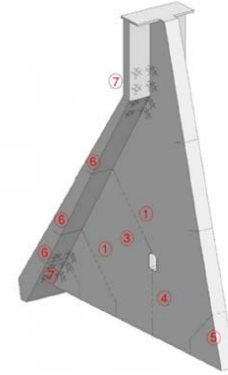
- Visual inspections
  - Preparations / Desktop study
  - Equipment
  - Different types of cracks/patterns
  - Mapping of cracks





# Assessment (cont.)

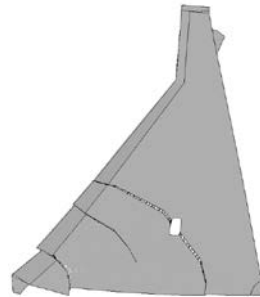
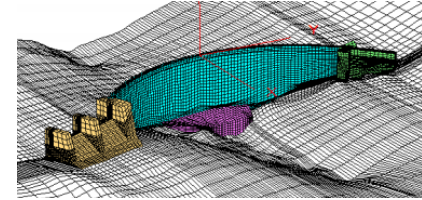
- In-depth inspections
  - *Determine crack reason*
  - *Collect data to status assessment, estimation of remaining service-life*
  - *Basis for planning of remedial works*
- Sampling and laboratory investigations
  - *Adapted to preliminary crack reason*
  - *How to get high quality cores*
- Measurements
  - *Temperature, humidity, crack width etc.etc.*





# Analyses

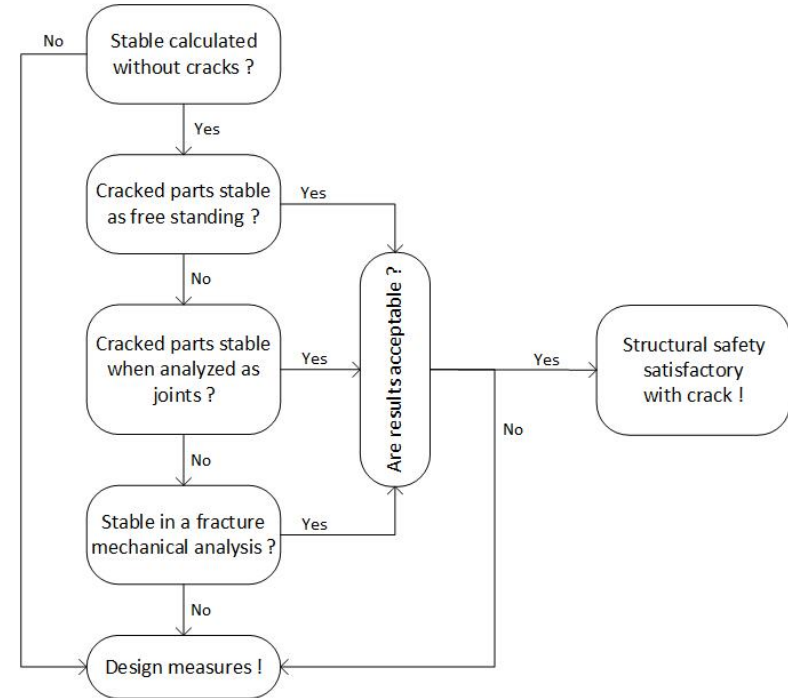
- Methods
  - *Conceptual models*
  - *Analytical calculations*
  - *Finite element calculations (linear elastic/non-linear)*
- Selection of method
- Simulation of different phenomena
- Modelling aspects
  - *Material models*
  - *Limitations*
  - *Boundary conditions etc.*
  - *Crack propagation etc.etc.*



Purpose	Analytical	FE	Non-linear FE	Other numerical
Stability (simple geometry)	x	x	x	x
Stability (complex geometry)		x	x	x
Stability (cracked, material failure etc.)			x	
Construction sequence (simple)		x	x	x
Construction sequence (property development)			x	
Prediction of surveillance data	x	x	x	
Prediction of surveillance data			x	
Definition of stress level	x	x	x	x
Definition of load-bearing capacity	x		x	
Prediction of impact from degradation	x	x	x	x
Simulation of impact from degradation development			x	

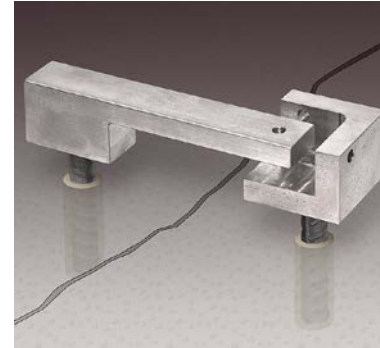
# Analyses (cont.)

- Material data
  - *Preferably measured*
- Validation of models
  - *Material model*
  - *Structural model*
  - *Convergence*
- Modelling the impact of a crack
- Acceptance criteria
  - *Current safety level ?*
  - *Further research needed !*



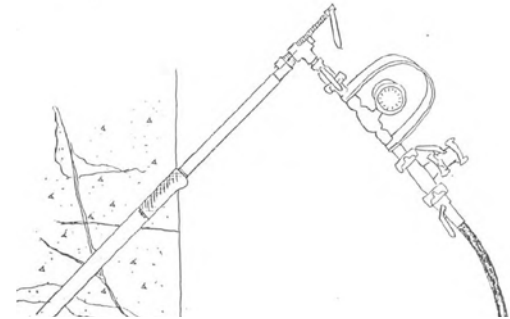
# Measures

- Emergency measures
  - *Reduce load or leakage*
  - *Increase stabilizing load*
  - *Preparedness plan*
- Monitoring
  - *Define crack status (active/passive)*
- Diminishing measures
  - *Surface protection*
  - *Climate protection*
  - *Slot cutting*



# Measures (cont.)

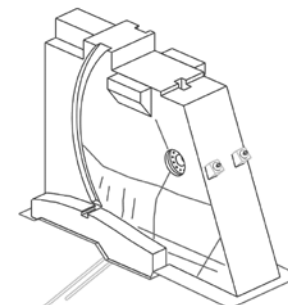
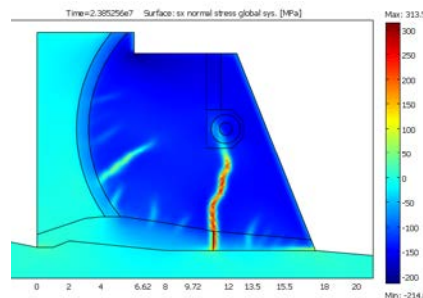
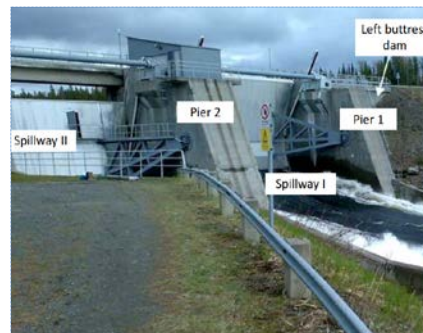
- Crack sealing
  - *Membranes*
  - *Crack grouting*
  - *Drill & plug*
  - *Expand and seal*
  - *Dry-pack*
- Structural reinforcement
  - *Reinforced overlays*
  - *Anchors / tendons*
  - *FRP composites*



# Case studies

- Twelve Swedish cases with cracked dams

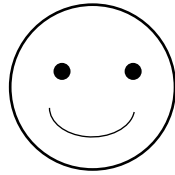
- Exemplify process:
  - *observation of cracks*
  - *analysis of crack reason*
  - *estimation of structural impact*
  - *comparison with monitoring*
  - *suggested measures*
  - *lessons-learned*



Thanks for your attention!



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