Theme D: Risk Analysis—assessment of reliability for concrete dams

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Theme formulators

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Background

- Risk assessment is increasingly used
- For structures it is well known that a larger factor of safety does not necessarily mean a smaller level of risk
- Reliability-based methodology, although used for structures in general, has yet limited application for dams
- Increasing numbers of publications
- ICOLD Benchmark Workshop 2015, Lausanne, sliding stability of earthfill dam
Background: Result of 2011 BW

Objective: to obtain relationships between water levels, factors of safety and probabilities of failure for sliding of a simple gravity dam

8 contributions

Significant differences among the results due to:

• Different decisions and choices
• select a crack opening and propagation criteria along the dam-foundation contact
• Definition of the factor of safety (ratio of forces or ratio of strength parameters).
• Selection of the characteristic value of shear strength (mean value from a data set vs. lower values as prudent estimates).
• Selection of statistical distributions used to describe random variables (normal, lognormal) and selection of reliability methods played also an important role on the results
Background: Probabilistic model code for concrete dams (PMCD)

Start in 2013 with funding from Swedish dam owners and authorities

Objective: Bring forth a reliability-based methodology for design and assessment of concrete dams founded on rock for conditions applicable in Nordic climate.

Same structure as the Probabilistic model code (JCSS, 2001)
“a first attempt to put together in a consistent way some of the rules, regulations and explanations necessary for design and assessment of concrete dams from a probabilistic point of view”.

The aim is for the methodology to be a framework for a systematic approach for reliability-based assessments.

Consists of
• basis of design; where basis of reliability based design is presented, limit states applicable to concrete dams and design situations as well as target reliability are defined
• load and resistance variables; where statistical distributions for relevant parameters are given and the background to the distribution is presented.
Aim of the theme

Objective: estimate probability of failure of an existing concrete dam using *Probabilistic model code for concrete dams*.

Test of the methodology at larger scale and to identify further needs to improve the document for future assessments.

The belief and hope of the authors of this proposal is that the *Probabilistic model code for concrete dams* can provide a framework for unified reliability calculations and thus increase the interest and confidence in risk analysis.
Problem description

- 25 m high gravity dam for hydro power, monolith width 12 m
- Inspection gallery in dam body, but no drain holes
- Location in Northern Sweden, subject to ice loads
- Volume of concrete 2870 m³, lever arm 12.74 m
- Jacking force 1080 kN/m from 6 anchors of 2160 kN/st, lever arm 16.5 m. Prestress loss 10%.
- Blasted rock surface. Granite foundation.
- Rock wedge volume 1376 m³.
- Rock joint with estimated $\phi_{res} = 32^\circ$, $i = 8^\circ$
Tasks (1/3)

1. Estimate the deterministic factor of safety for sliding considering 2 failure modes:
   (a) sliding along the dam-foundation contact,
   (b) sliding along an existing joint in the foundation.

For each failure mode, the factor of safety shall be calculated in 2 situations:
   (i) normal load case, and
   (ii) flood load case.
Tasks (2/3)

2. Define limit state functions for the 2 failure modes considered:
   (a) sliding along the concrete-rock contact and
   (b) sliding along a rock joint in the foundation.

3. Estimate the probability of failure for the 2 failure modes considered for
   i) a normal design situation and
   ii) for an exceptional design situation (flood).
   In total, 4 probabilities of failure have to be provided.

4. Present sensitivity values for all 4 cases.

Limit states and design situations as well as statistical distributions of input
variables are described in PMCD. Calculation could be done by tool of choice
(e.g. COMREL, @risk, FReET, Matlab....)
5. Estimate the system reliability of the monolith (for both limit states and both design situations).
6. Consider that two additional shear tests are performed on the concrete/rock contact to determine the basic friction angle. How does this change the failure probability of the normal design situation for sliding along the concrete-rock contact?
Statistical distribution related to flood event

Statistical distribution estimated based on:
Design flood, gate width and height, flow coefficient, crest length and crest length

- Gates are assumed available
- When flood arrives WL rises and
  - Water is discharged through gates
  - If WL continues to rise concrete dam will eventually be overtopped, discharge through gates and over concrete section
  - If WL continues to rise, earthfill dam will eventually be overtopped, discharge through gates, over concrete section and over earthfill dam
Statistical distribution related to flood event

\[ P(wl > \text{legal wl}) = 3 \cdot 10^{-3} \]
Wait for the results…