CHARACTERIZATION AND REPAIR OF INTERNAL EROSION IN SANDSTONE FOUNDATION

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INTERNAL EROSION IN DAM FOUNDATION

From the 2 hereunder failure paths of internal erosion:

1. 213 piping through the embankment
2. 44 piping through the foundation or of the embankment into the foundation

Internal erosion through foundation is less easy to characterize than through embankment
LESSONS LEARN FROM DAM ACCIDENTS

- BOUZAY (1895)
- TIGRA (1917)
- GLENO (1923)
- FLAGSTAFF (1963)
- FONTENELLE (1965)
- SISGA (1979)
- ITIYURO (1981)

Weathered Sandstone Foundations are most susceptible to internal erosion.
Emphasis is put on two investigation tests to characterize the susceptibility of the sandstone foundation to be eroded.

1. The drilling recording
2. The Water tests
Drilling
Recording

« DUR » = Hardness

\[ \text{Hardness} = \frac{P \times C}{V} \]

- \( P \): vertical pressure
- \( C \): torque
- \( V \): tool rate

Hardness of the rock is characterized by drill machine: F320 with tricone VH1 sand + gravel + cemented gravel
cemented clayey marl
Remolded gypseux
caliche
compact marl
decomposed marine argillaceous

Internal erosion in Sandstone Dam Foundations

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Water Critical Pressure

2 – Water Lugeon tests

2 new parameters:

- Critical pressure $P_c$
  - limit of linearity between pressure and discharge rate
- Opening ratio $K_f/K_o$
  - $K_o$: initial permeability
  - $K_f$: final permeability
Lessons from ITIYURO dam incident

Intake tower

Sinkholes

Outlet gallery
Lessons from ITIYURO dam

Leakages caused internal erosion in the sandstone foundation (>1000m³) Sinkholes occured in the rockfill crest and upstream face

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Application to ITIYURO dam

weak sandstones which suffered internal erosion have very low hardness values:

\[ \text{DUR} < 20. \]
Investigations of ITIYURO dam

- Weak sandstones areas suffering internal erosion have:
  - Low critical pressure $P_c < 0.4$ MPa
  - Lugeon Permeability $K > 15$ Lugeon

Initial permeability

Critical pressure (100 kPa)
Correlation between $P_c$ and Cohesion

Critical pressure (100 kPa)

Cohesion (100 kPa)

Grès rosés supérieurs

Grès jaunatres et blanchatres

Grès blanchatres à passages rosés
Correlation between $P_c$ and porosity

Porosity

Critical pressure (100 kPa)

$y = 39.31x^{0.3838}$

$R^2 = 0.8625$

$y = 37.067x^{-0.4938}$

$R^2 = 0.9918$
Experience from other dam incidents

BORDE SECO suffered internal erosion
Diaphragm wall was required
### Criteria from dam incidents

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unity</th>
<th>STATISTICS</th>
<th>ITIYURO</th>
<th>BORDE SECO</th>
<th>LAS CUEVA</th>
<th>LA HONDA</th>
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<td>3</td>
<td>8</td>
<td>3</td>
<td>6</td>
<td>2</td>
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<tr>
<td>Dur</td>
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<td>0</td>
<td>20</td>
<td>0</td>
<td>10</td>
<td>0</td>
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</tbody>
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Observed limits between erodable and no-erodable rock

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Final assessment of criteria of area susceptible to be eroded

**PROPOSED CRITERIA**

- **Critical Pressure:** $P_c < 0.2 \, \text{MPa}$
- **Hardness:** $\text{Dur} < 10$
- **Opening Criterion:** $O_c > 3$
- **Initial Permeability:** $K_o > 15 \, \text{UL}$
CONCLUSION : PROPOSED DESIGN CRITERIA

New parameters are proposed from drilling recording and water tests to characterize the resistance to internal erosion of sandstone foundations.

Depth of diaphragm wall: depth where the pore pressure under the full reservoir is lower than the critical pressure and the opening criterion is lower than 2 and Dur > 20-30.