The Impact of Earthquake Ground Motion on Design and Evaluation of Concrete Dams:
How Earthquake Ground Motions Affect the Design Compared to Other Parameters

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Design Earthquakes and Associated Ground Motions for Dams

1. Seismic source characterization
2. Ground motion characterization (GMPEs)
3. Seismic hazard analysis to obtain MCE and uniform probability ground motion (UHS)
4. Selection of controlling earthquakes and ground motions
5. Selection and modification of acceleration time series

From EC 1120-2-6000

Figure 3-22: Development of equal-hazard response spectrum from probabilistic seismic hazard analysis for response spectral values
Typical Failure Modes of Gravity Dams
Sensitivity to Ground Motion

- Rock site with $V_{s30} > 2000$ m/s
- Effects of canyon topography
- Selection of acc. time series
  - Is primarily based on spectral shape
- Database to provide mean and standard deviation for other important parameters such as:
  - Arias Intensity
  - Duration
  - PGV, PGD, PGA*PGD/PGV^2
  - ....
Permanent Sliding Displacement
Sensitivity to Ground Motion and Modeling Parameters
Seismic Sources

1. Subduction Interface
2. Subduction Intraslab
3. Active Crustal Faults
4. Shallow Background
Controlling Crustal Faults

Cimandari

Rajamandala

Lembang
Seismic Fragility Analysis
Including Random and Uncertainty Variabilities

- Dam-water-foundation model
- Water with radiation damping
- Foundation with inertia and damping
- Sliding surfaces with failure criterion

- Nonlinear piers
- Gates with trunnion anchors
- Concrete cracking
- Rebar yielding and rupturing
Earthquake Records from PEER Database

Target: M6.5 MCE at 14 km
Horizontal Components of 30 Selected Acceleration Time Series
Examples of Predicted Failure Modes
Results of Seismic Fragility
Composite and Random Variability Fragility Curves

\[ A_m = 0.4 \text{g} \]
\[ \beta_c = 0.62 \]
\[ \beta_r = 0.28 \]
\[ \beta_u = \sqrt{(0.62)^2 - (0.28)^2} = 0.55 \]

<table>
<thead>
<tr>
<th>( A_m )</th>
<th>Median capacity in terms of PGA</th>
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<tbody>
<tr>
<td>( \beta_r )</td>
<td>Logarithmic standard deviation associated with randomness</td>
</tr>
<tr>
<td>( \beta_u )</td>
<td>Logarithmic standard deviation associated with uncertainty</td>
</tr>
<tr>
<td>( \beta_c )</td>
<td>Logarithmic standard deviation associated with randomness and uncertainty</td>
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