Road Map for Advanced Structural Analysis of Concrete Dams

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Outline

Introduction

Road Map
  Overview
  Example

Summary
Outline

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Summary
Motivation

- Engineer, Analyst use of numerical methods for advanced structural analysis of concrete dams

- Reduction of modeling uncertainty, ability to perform desired level of sophistication modeling and simulation

- Expert analysis system, a synergy of expert analysts and expert numerical modeling tools, for advanced structural analysis of concrete dams
Advanced Analysis of Concrete Dams

- Verification and Validation (V&V)

- Prediction of behavior of the concrete dams under conditions for which the model has not been validated.

- Verification provides evidence that the model is solved correctly. Mathematics issue.

- Validation provides evidence that the correct model is solved. Physics issue.

- Goal: Predict and Inform, instead of just force fitting
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Road Map for Advanced Analysis of Concrete Dams

A Formal Process for

- Education and training of expert analysts
- Development of numerical analysis program
- Verification of numerical analysis program
- Validation of numerical analysis program
- Development of concrete dam models
- Concrete dam model verification
Road Map Components

- Real Object: Dam, reservoir, foundation system
- Conceptual Model: Dimensions, loads, properties
- Mathematical Model: System of differential equations
- Computational Model: Solution method - numerical
- Software Quality Assurance (QA)
- Interpretation of Results and Reporting

Model Calibration

Model Validation

Solution Results
Road Map Activities

- Numerical program
  Quality Assurance: Verification and Validation
  Repeatability of analysis results using the same program
  Reproducibility of analysis results using different program

- Numerical Model
  Identify sources of modeling errors (simplifications)
  Identify sources of numerical errors

- Engineer, modeler, numerical analyst
  Numerical modeling expertise
  Numerical results interpretation expertise

- Interpretation of numerical analysis results
  Design
  Regulation
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Road Map, Example

Pine Flat Dam in California

- Model verification, components, full model
  Dynamic wave propagation through rock only
  Eigen-analysis of dam structure, with/without reservoir
  Dynamic response of dam structure, with/without reservoir
  Dynamic response of reservoir/fluid
  Constitutive integrations for material response

- Model validation, components, full model
  Seismic wave propagation through the rock
  Constitutive modeling of rock, concrete, interfaces, joints
  Reservoir, fluid dynamics
  Seismic response of a concrete dam
Road Map, Workshop

Yang et al. (2019)
Salamon et al. (2019)

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Concrete Dam – Rock – Reservoir Model

- Model components: concrete dam, rock, reservoir
- Verification and Validation of each component, model
Input Pulse Wave, at Depth, Only Rock

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Pulse Wave at Surface

Non-reflective BC

Free field BC
Numerical Damping Effects, $\ddot{u}_{\text{hor}}^{\text{top}}$
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Road Map for Advanced Structural Analysis of Concrete Dams
Summary

Road map: Formal process to ensure quality of results

Numerical modeling to predict and inform, rather than fit

Education and Training is the key!