

Validation of Non-linear FEA Methods for Concrete Dams

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Mark Schultz, SE, GE
Supervising Engineer
CA Division of Safety of Dams



Overview

- **Professor Chopra's Influence on Seismic Analysis of Concrete Dams**
- **Application of Design Ground Motion**
- **Two Case Studies - System Response to EQ**
- **Nonlinear Materials & Interface Contacts**



Idealized 3D Dynamic System

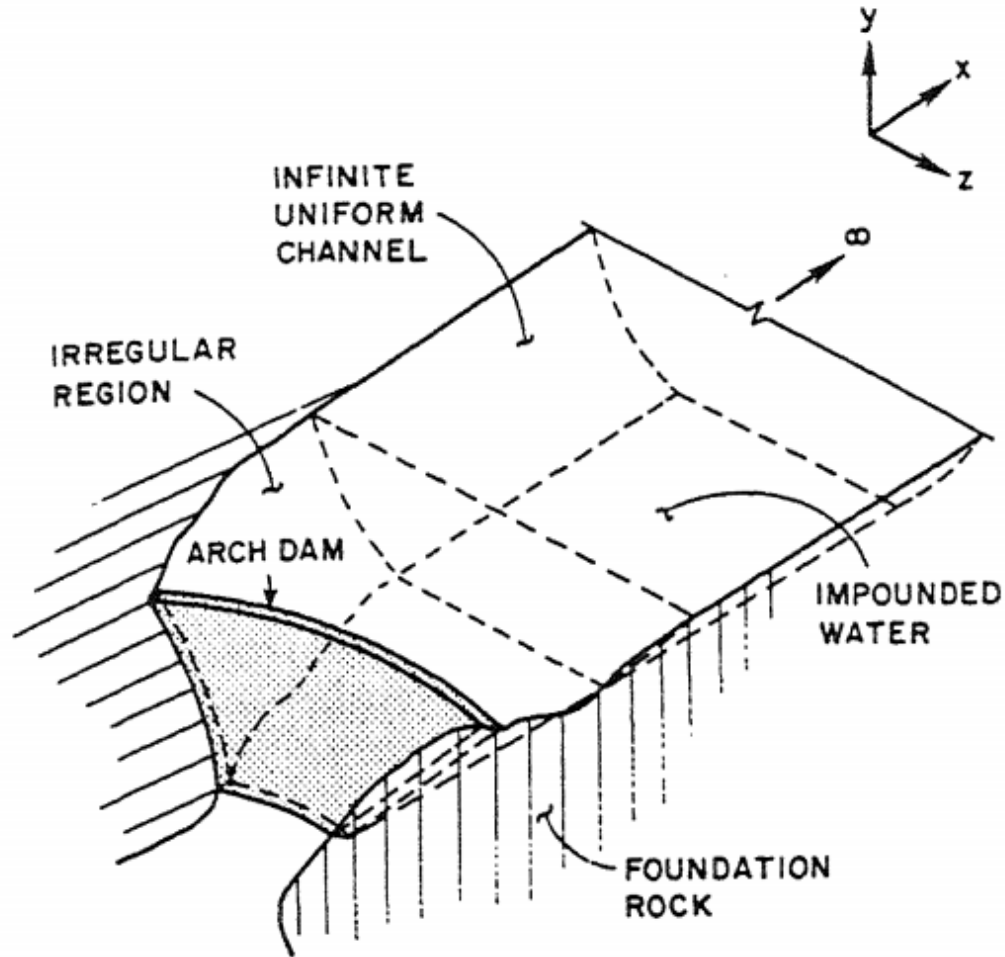


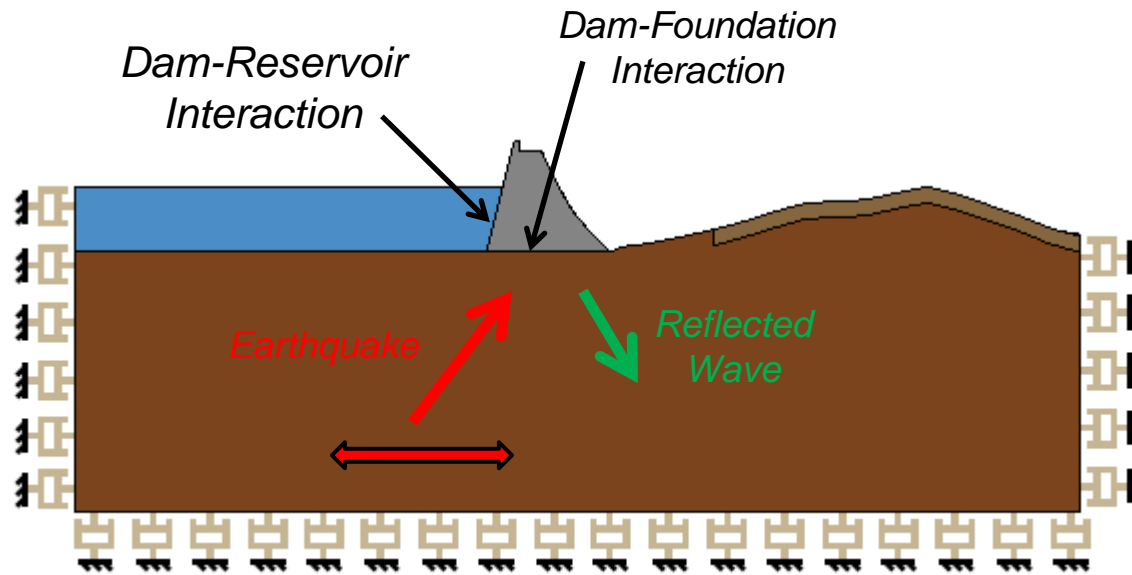
Figure 9. Arch dam-water-foundation rock system (Fok and Chopra 1985).

Research Deliverables

- **Theoretical Basis of Analyses**
- **Dam-specific FEA Software**
 - EAGD 2D-84
 - ADAP-88 (Interaction between Monoliths)
 - EACD 3D-96 (Updated 2008)
 - SCADA (Smearred-Crack Approach)
- **Chart & Equation Methods**



Commercial Nonlinear Software

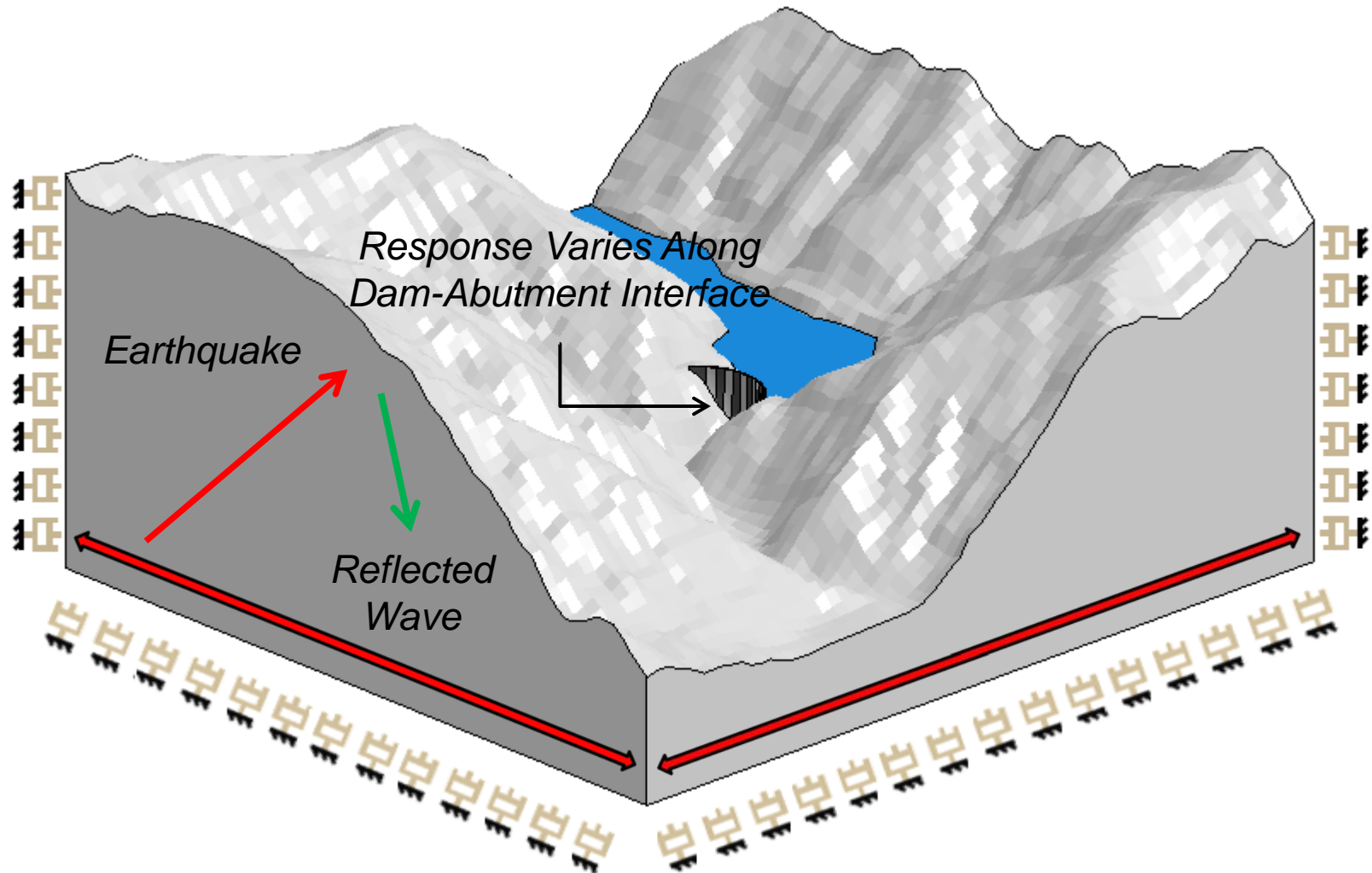


Absorbing Boundaries

- Simulate unbounded domain
- Absorb reflected wave

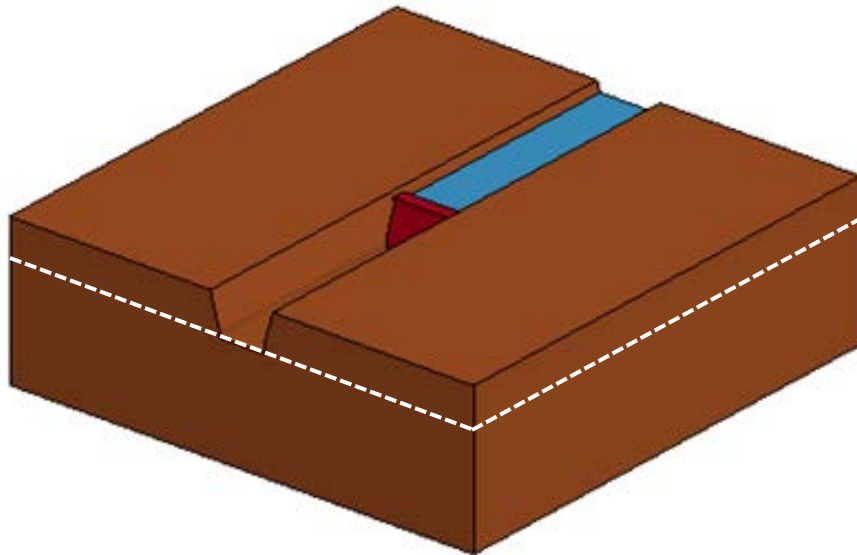
- Mass Foundation w/ Wave Propagation
- Spatially Varied Ground Motion
- Unbounded Domains – Nonreflecting Boundaries
- Reservoir Hydrodynamics & Water Compressibility
- Interface Contacts
 - Dam-Foundation
 - Dam-Reservoir
 - Monolith-Monolith
- Material Softening & Load Redistribution

Non-uniform Ground Motion

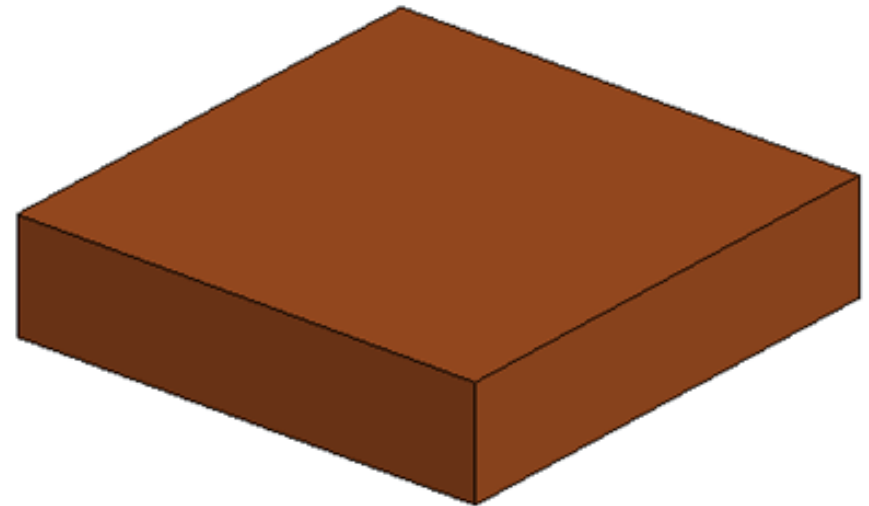


Application of Ground Motion

Input Design Motion (GMPE) Based on Level Terrain



Full Model

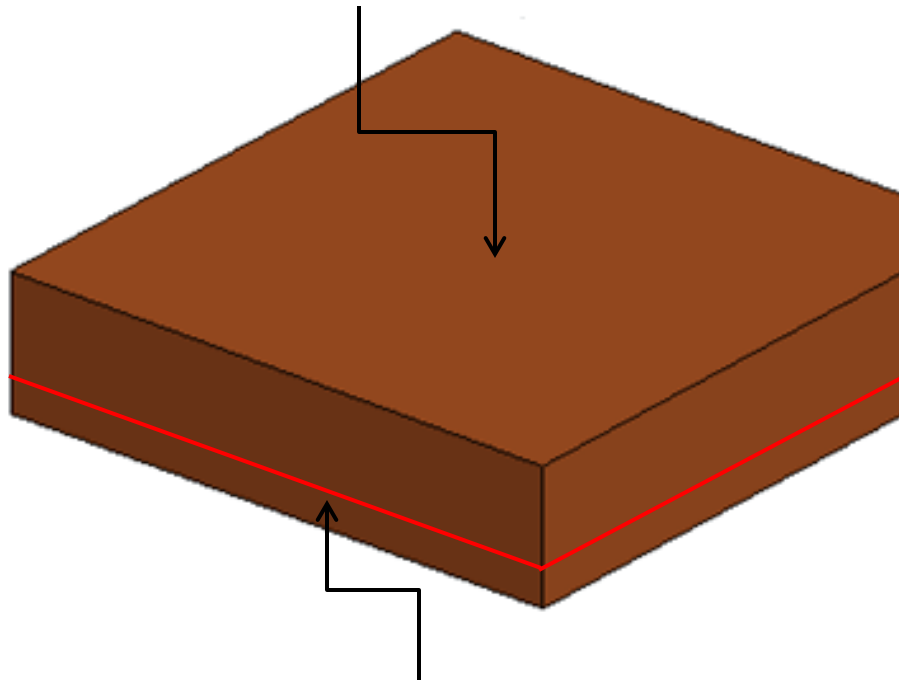


Free-Field Box Model

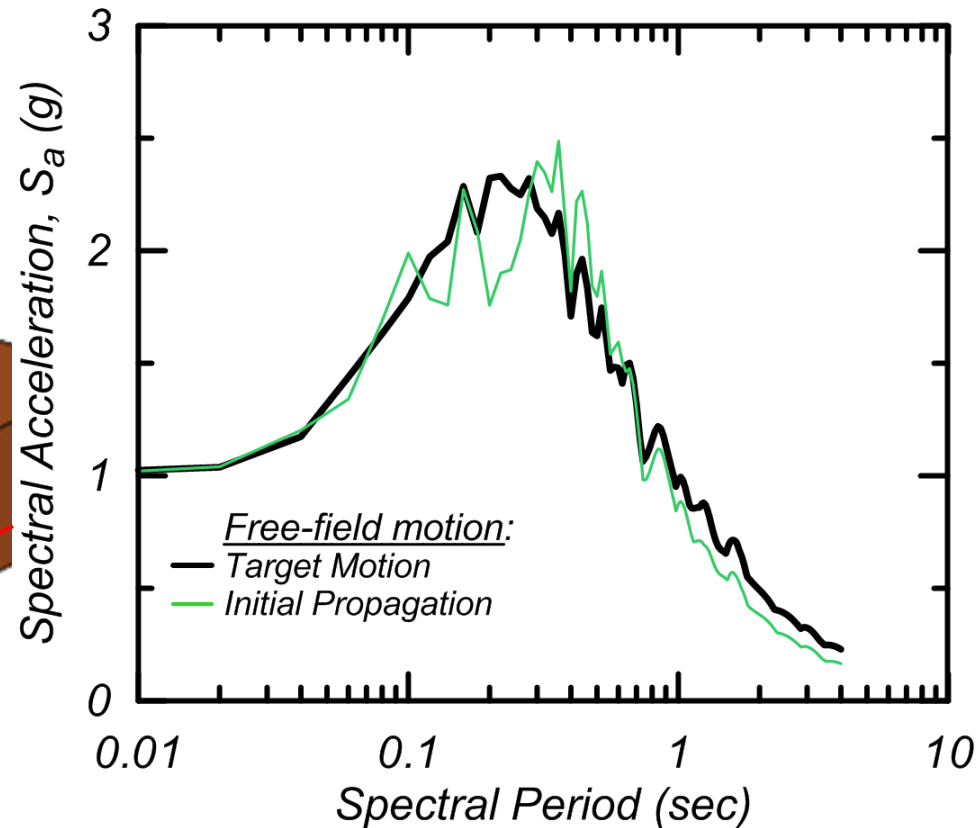
Frequency Domain Scaling

Free Field Model

Computed Free Field \neq Target Record



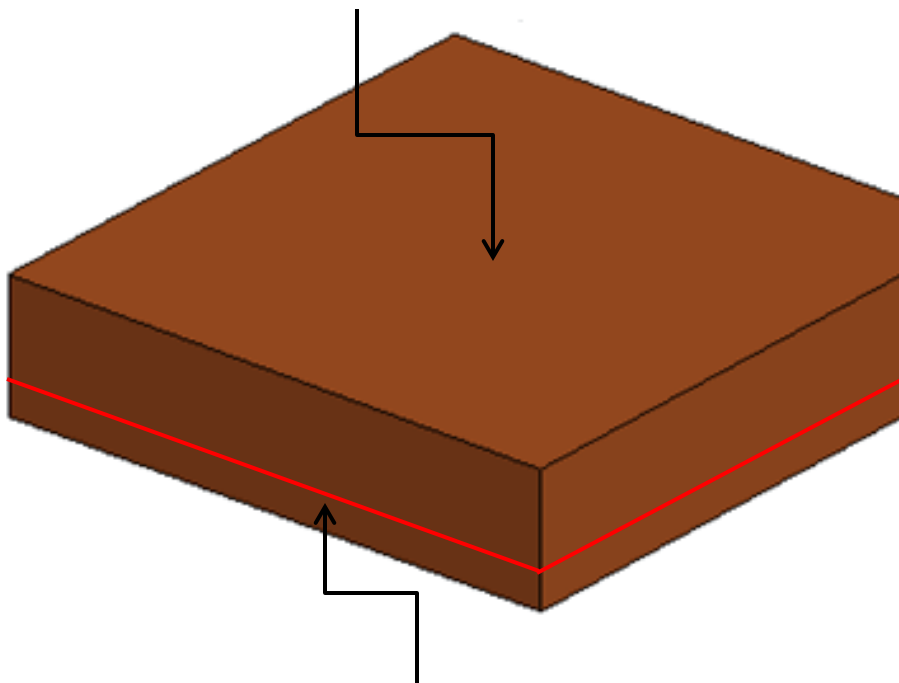
Initial Base Input = Target Record



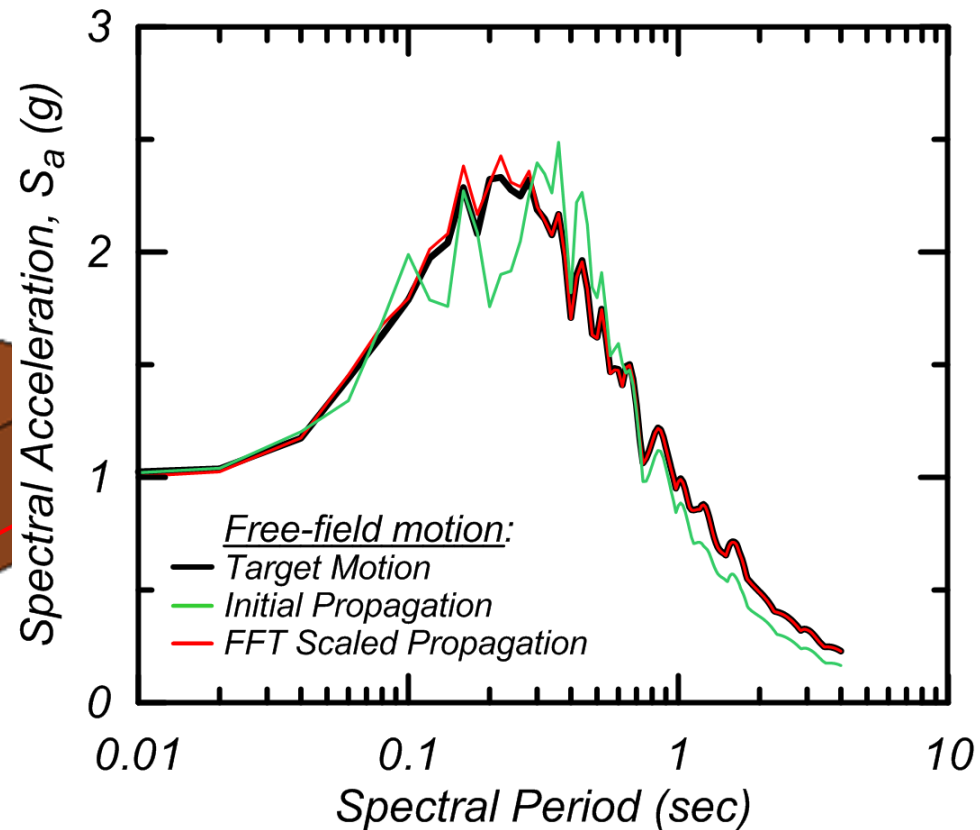
Frequency Domain Scaling

Free Field Model

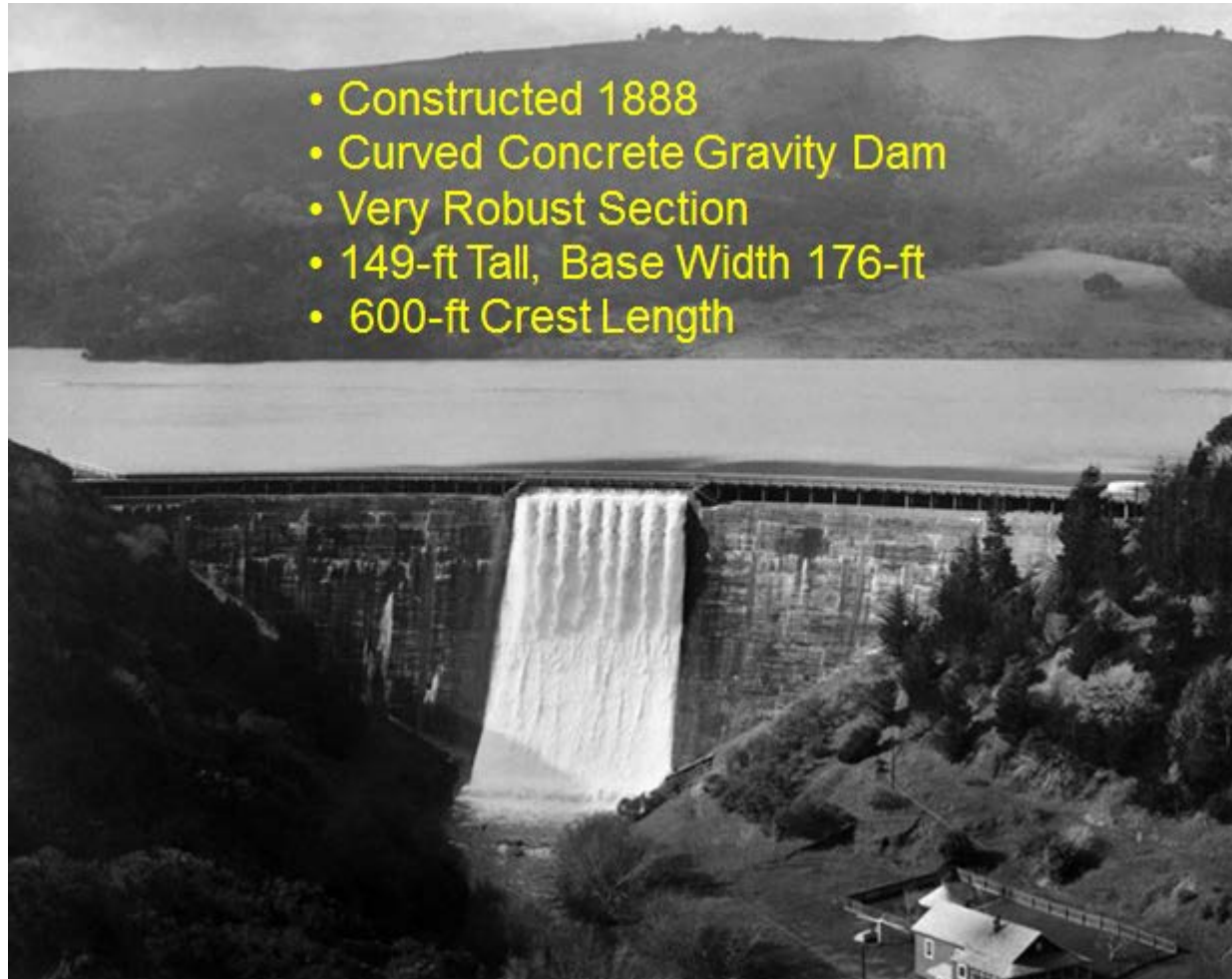
Computed Free Field \neq Target Record



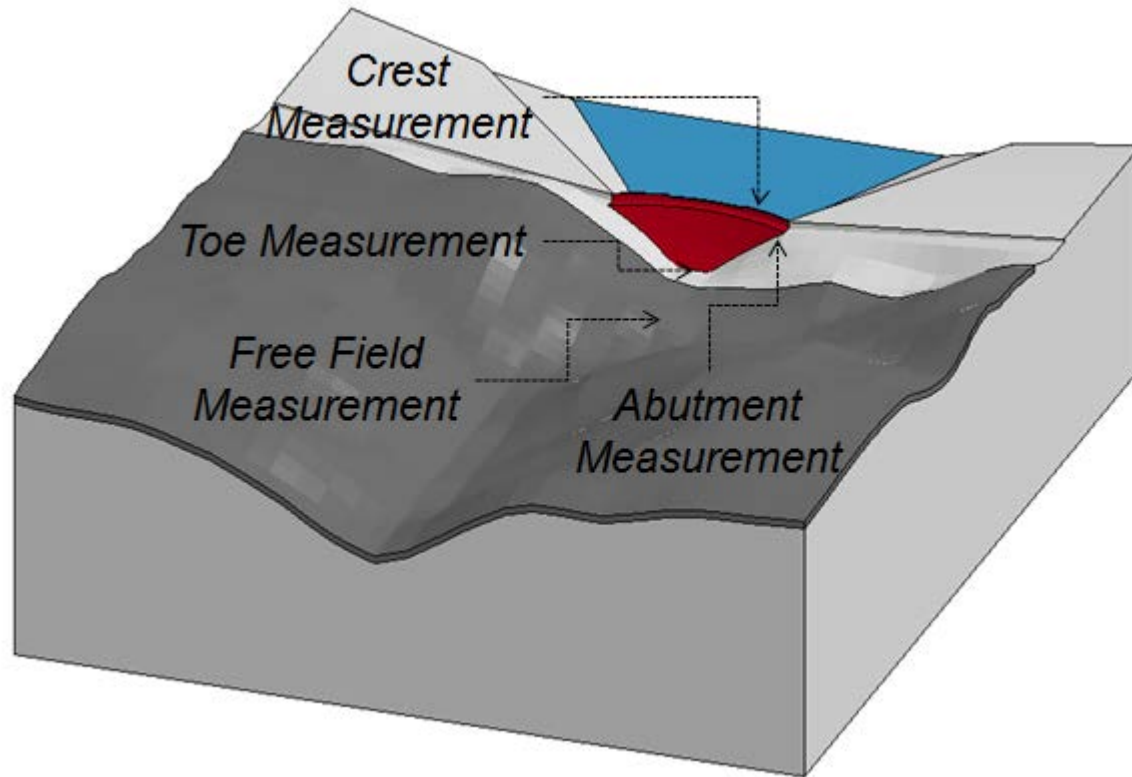
Initial Base Input = Target Record



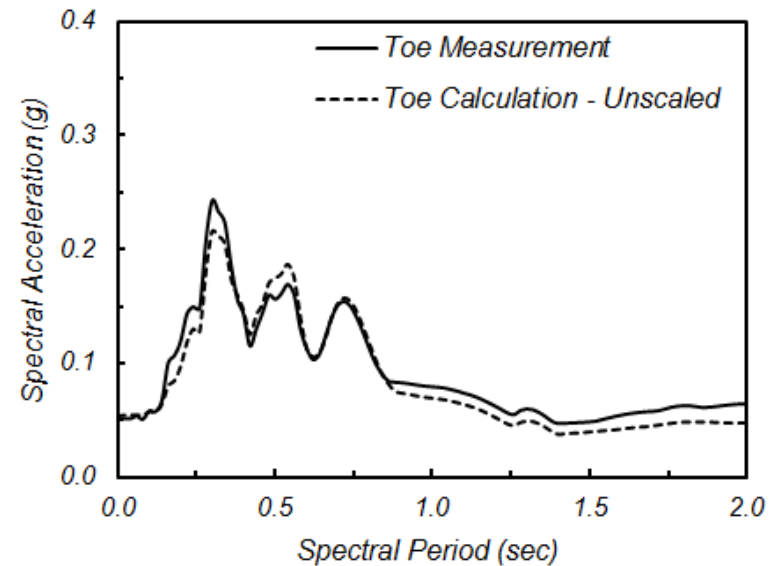
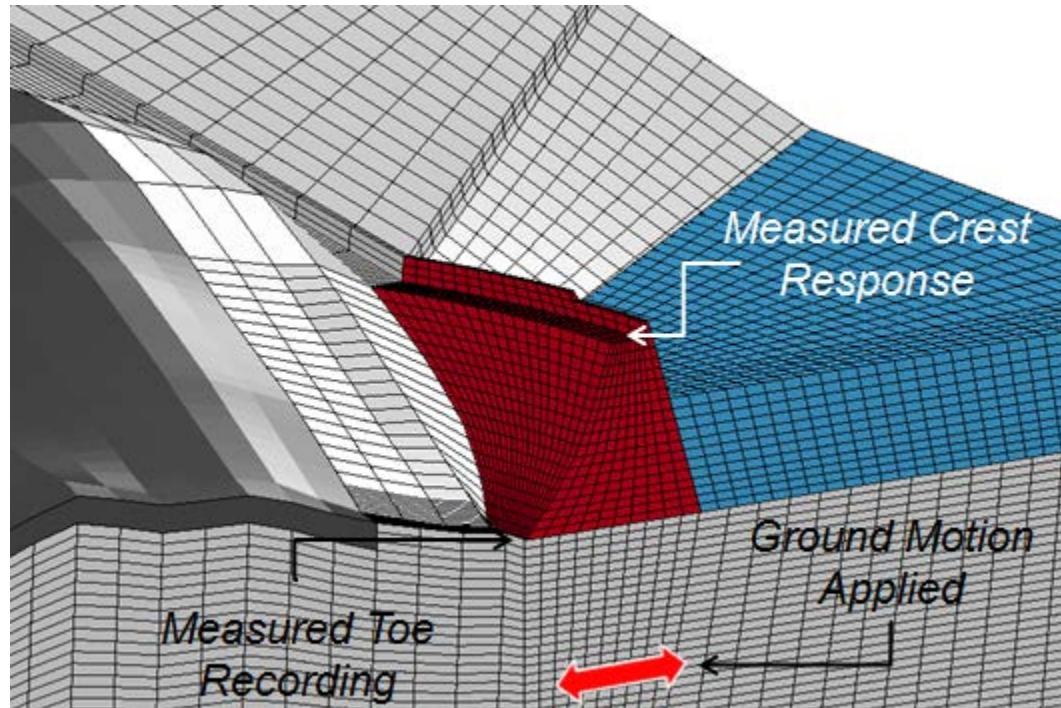
System Response Validation



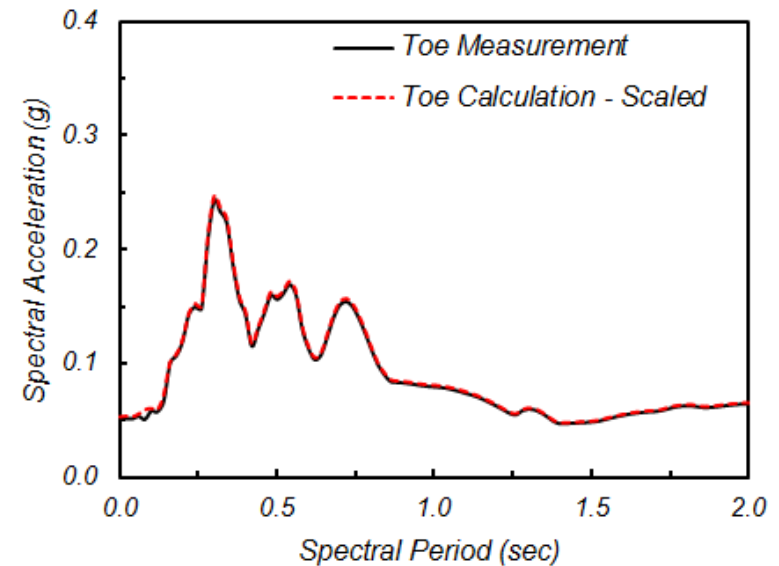
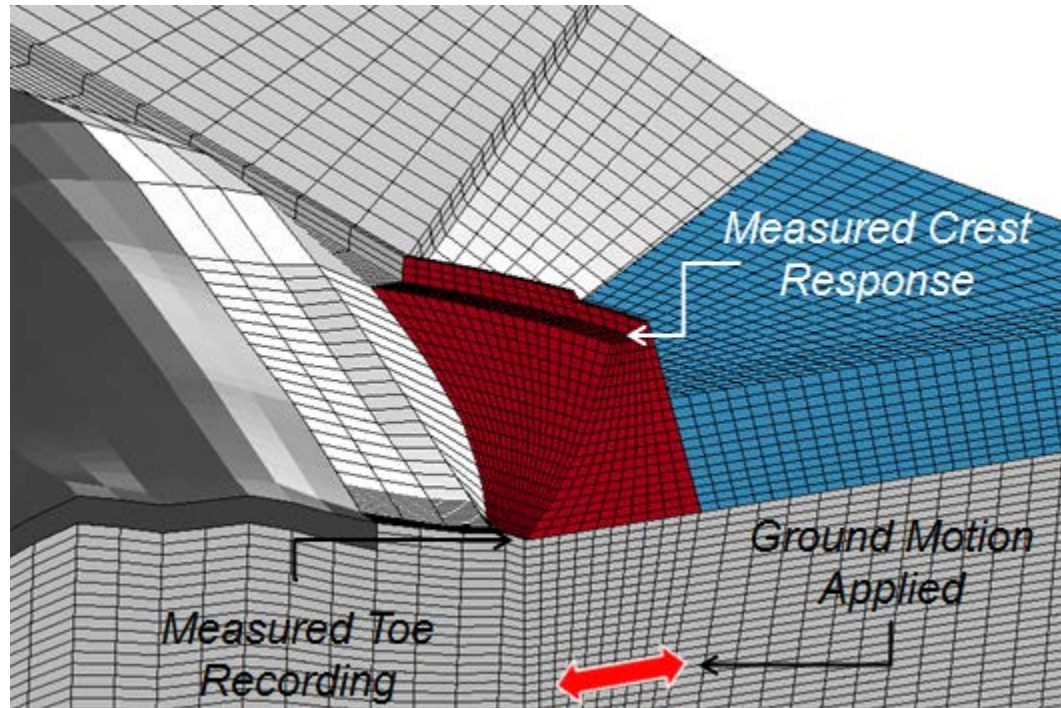
LS-DYNA 3D Model



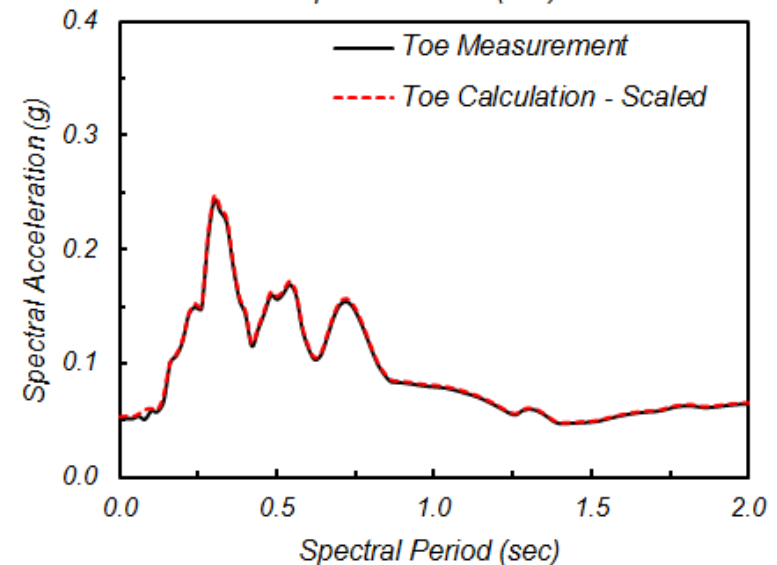
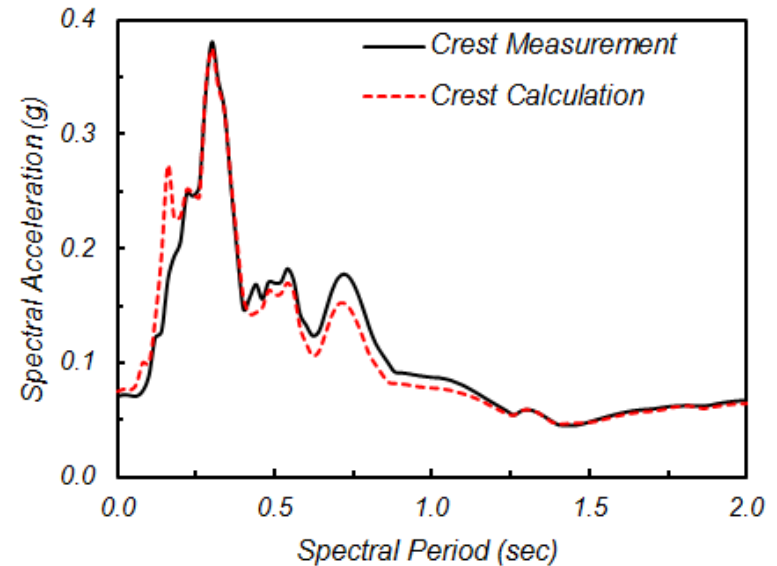
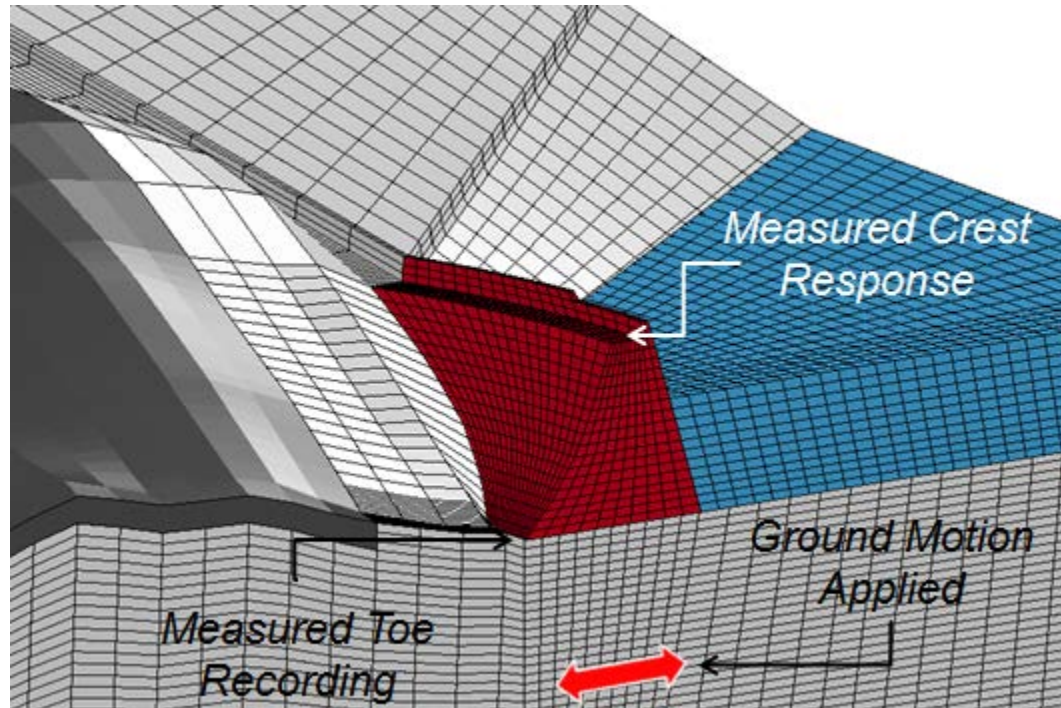
Matched Recording at Toe



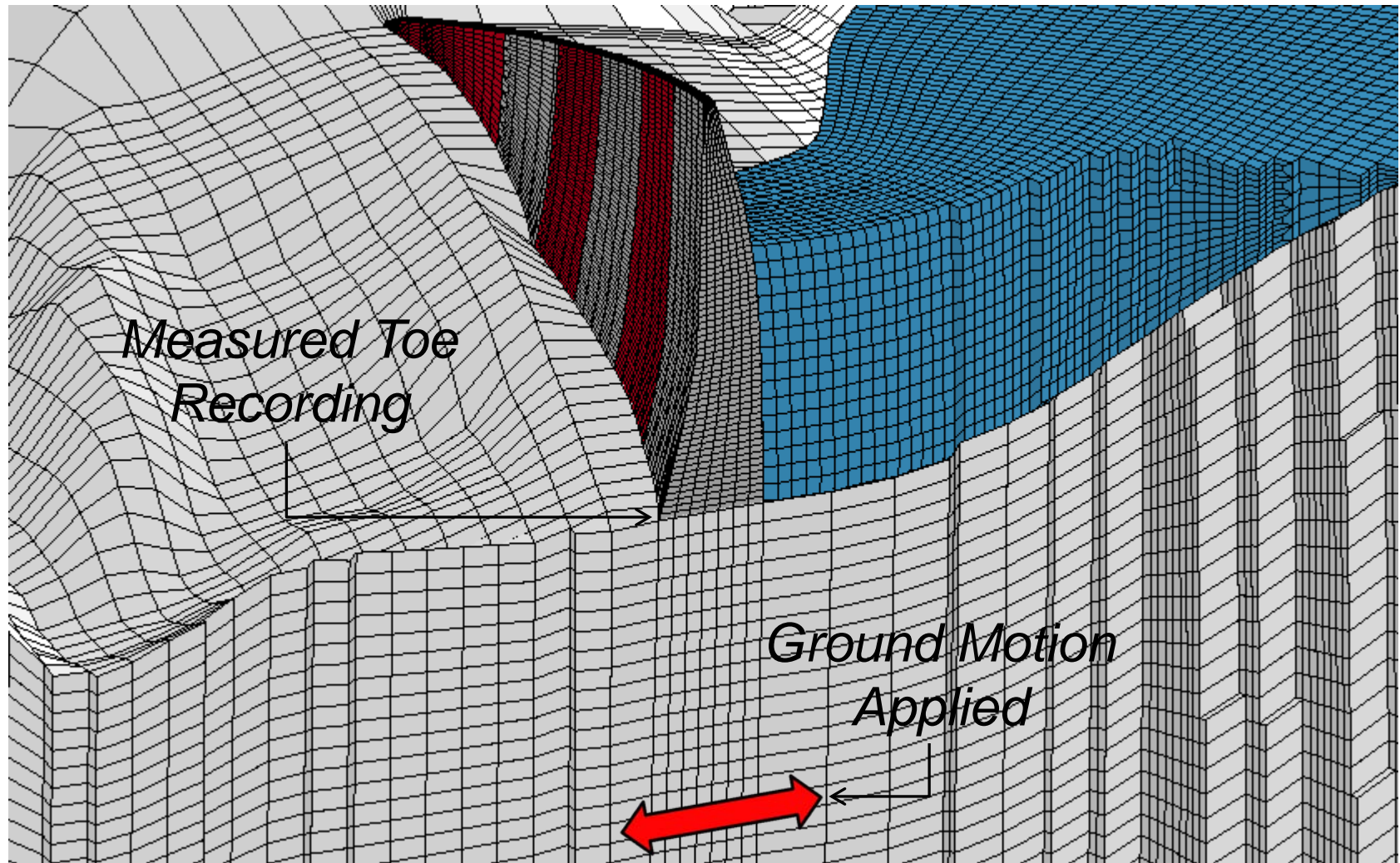
Matched Recording at Toe



Crest Comparison

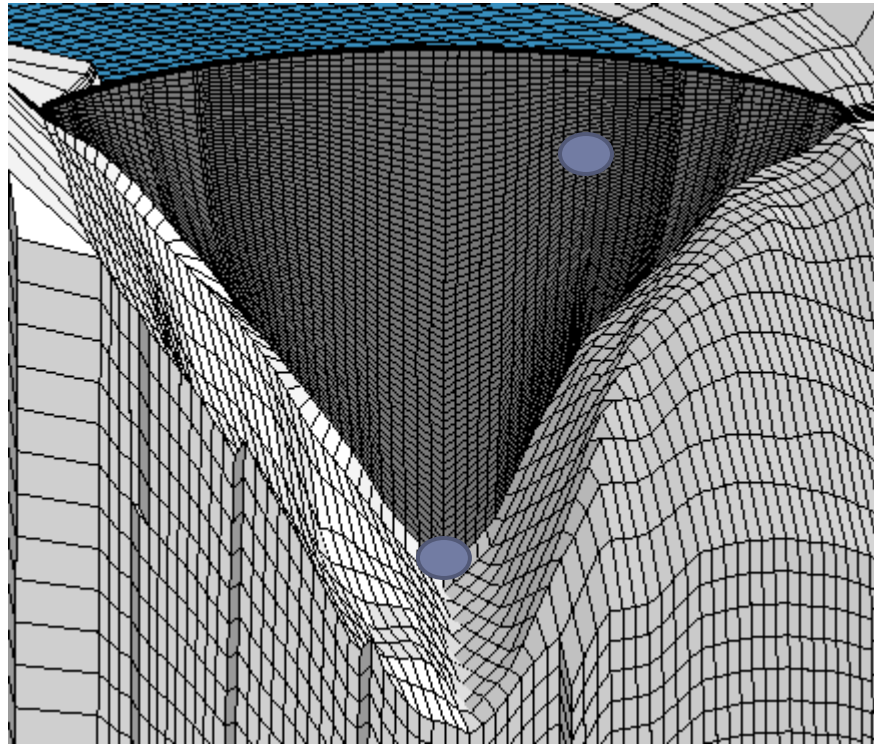


Pacoima Dam

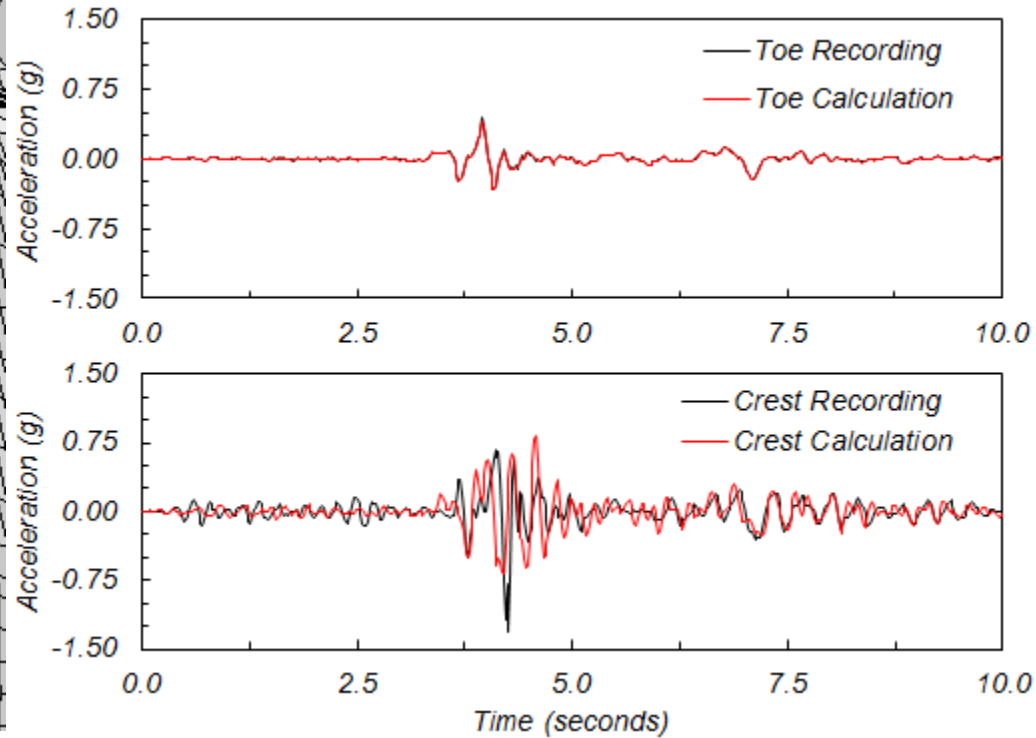


Pacoima Dam

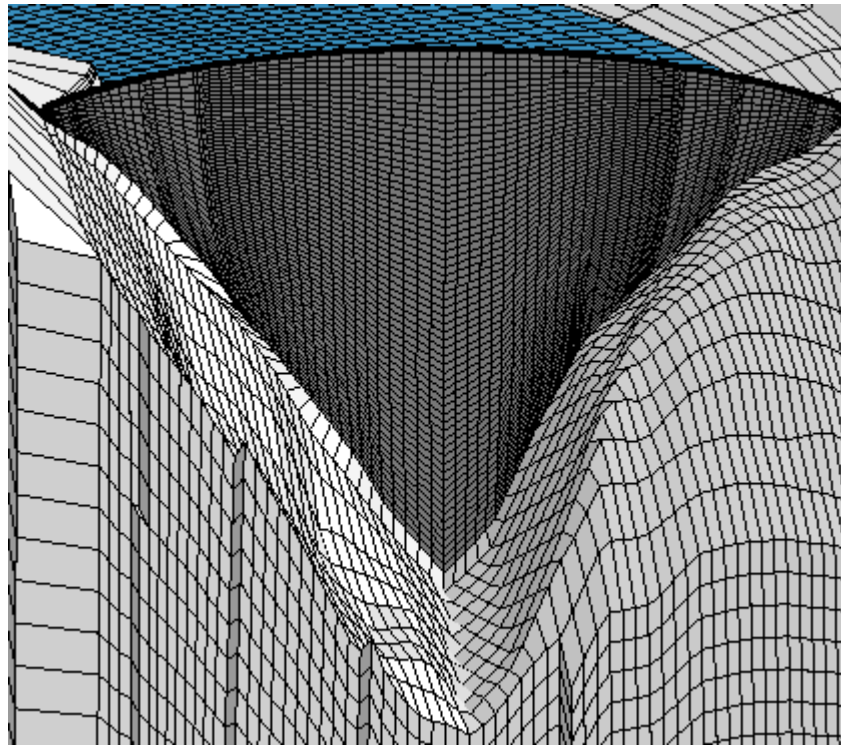
Northridge EQ



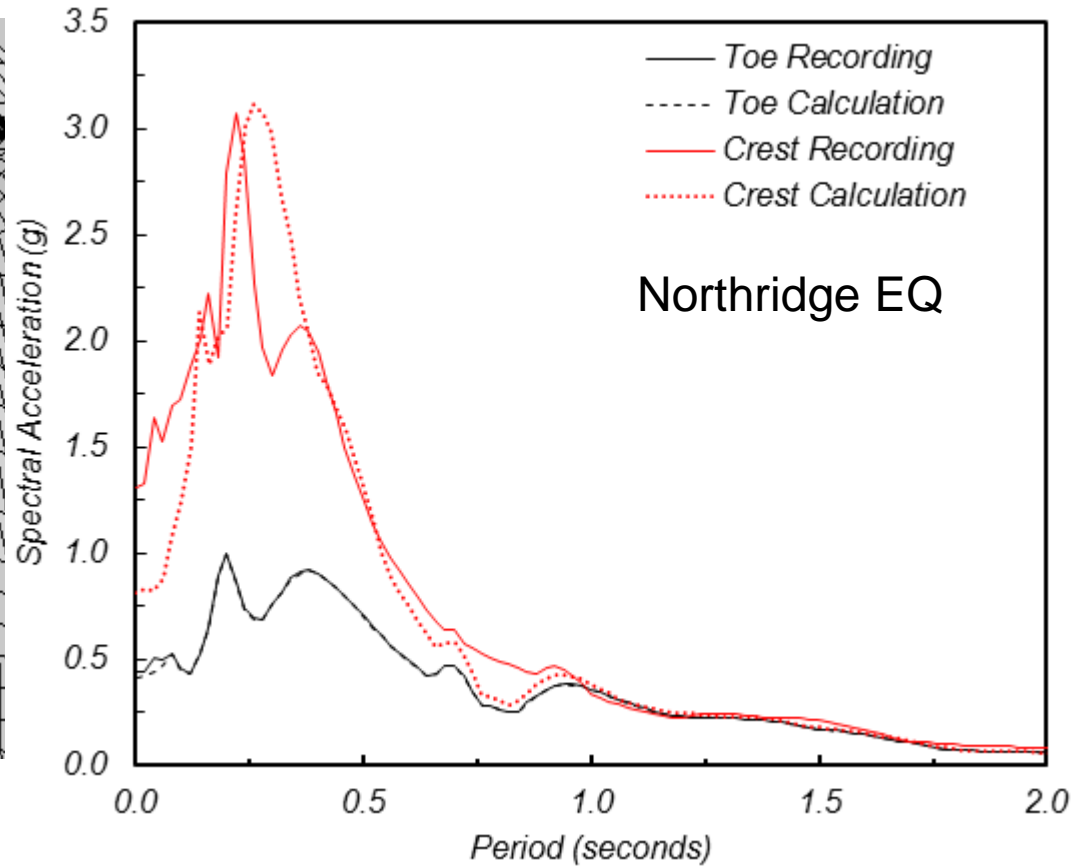
Monolithic Dam Model



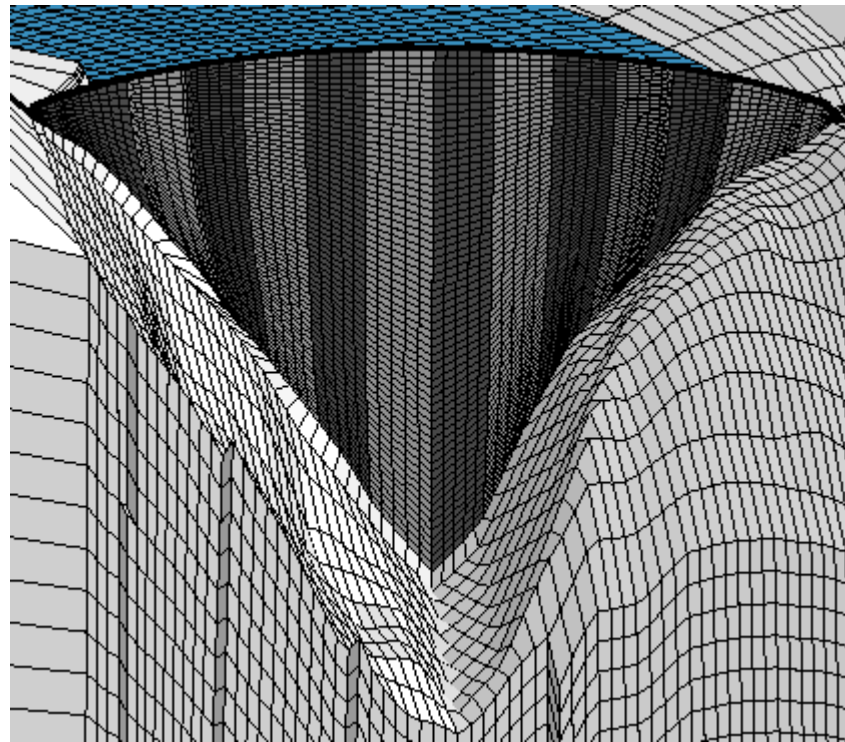
Pacoima Dam



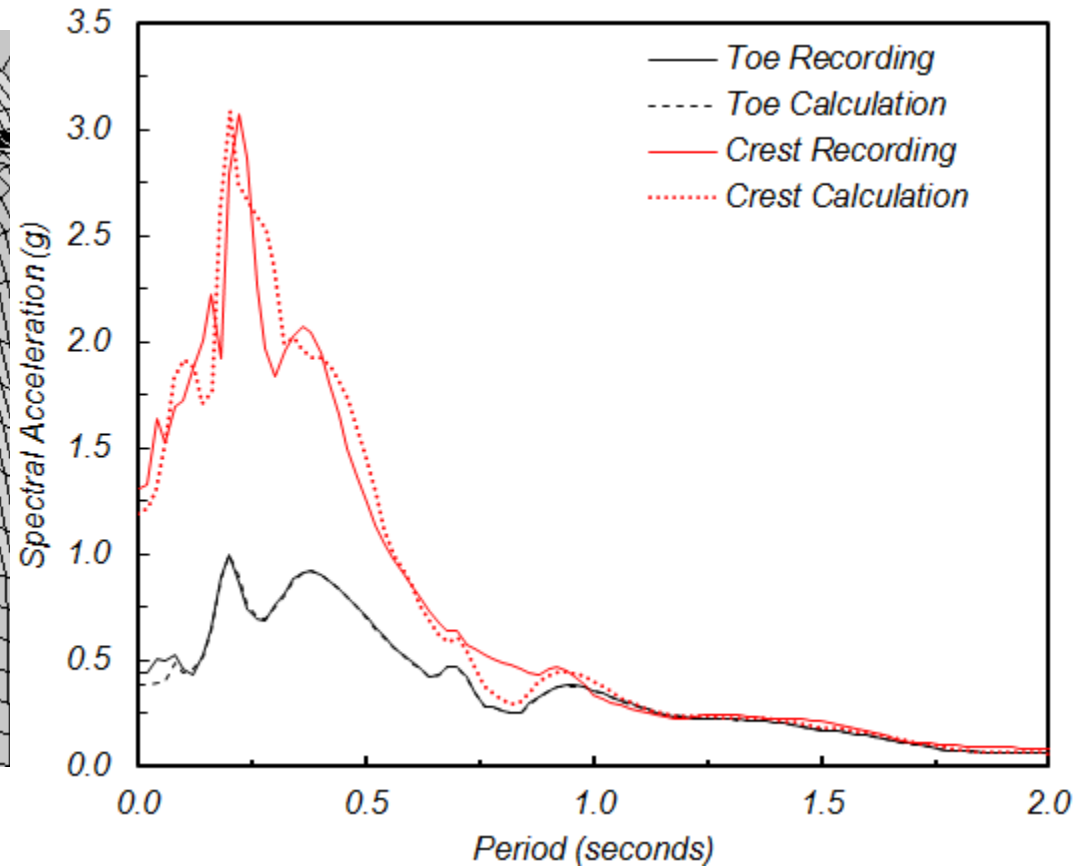
Monolithic Dam Model



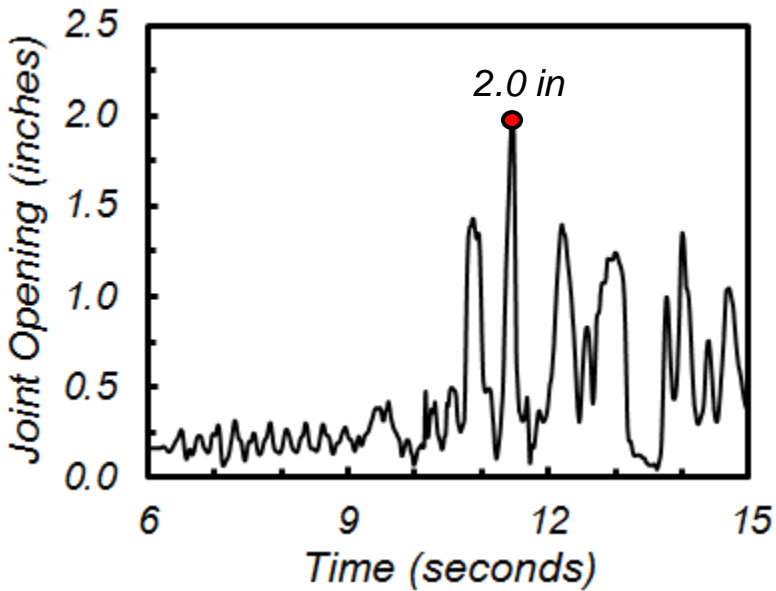
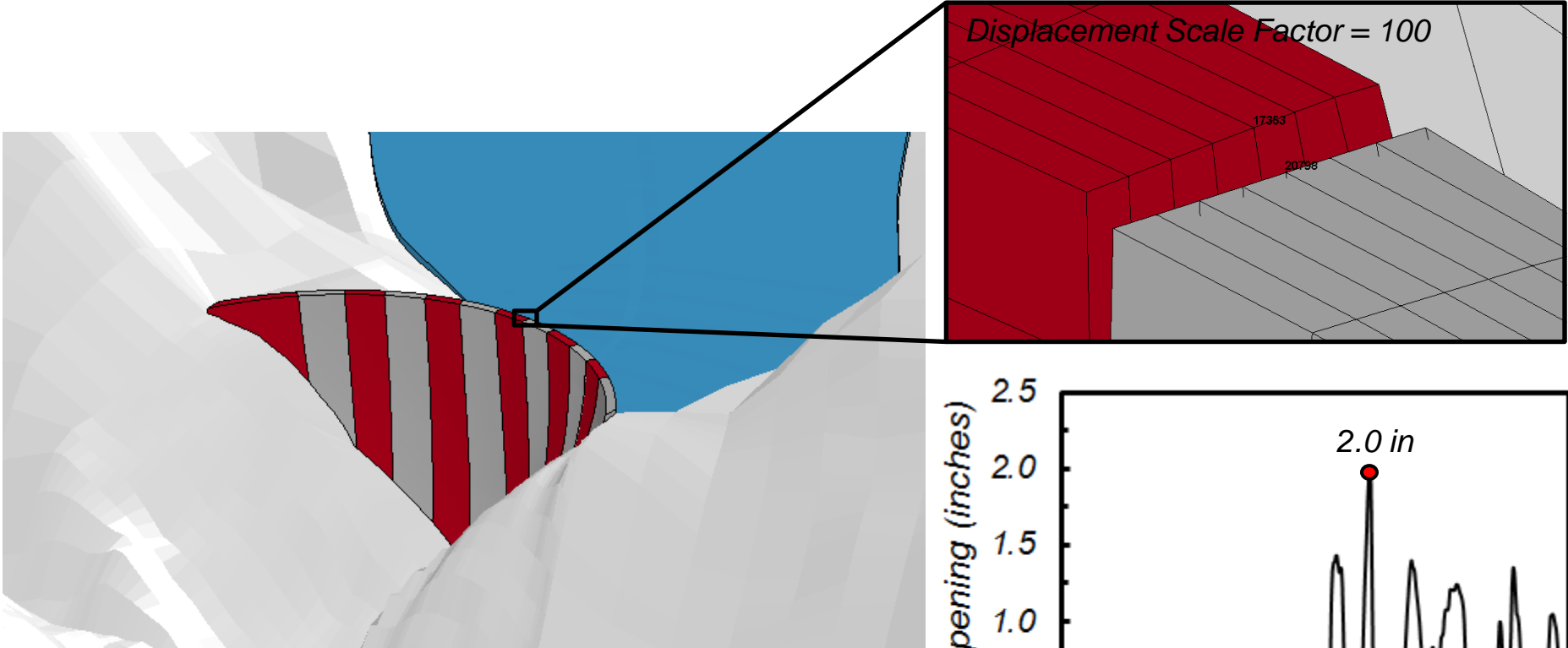
Pacoima Dam



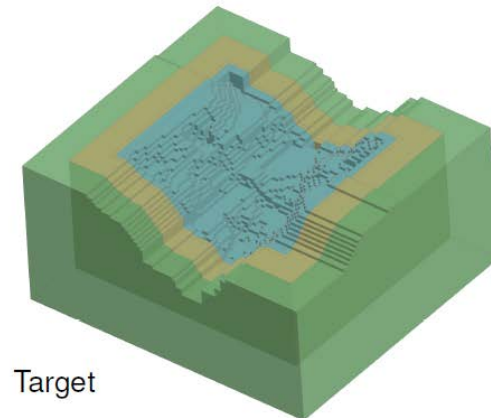
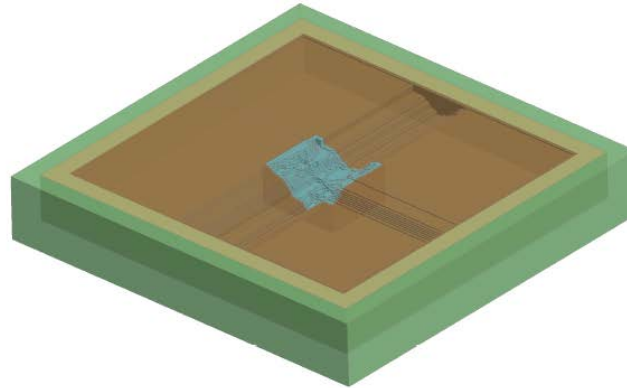
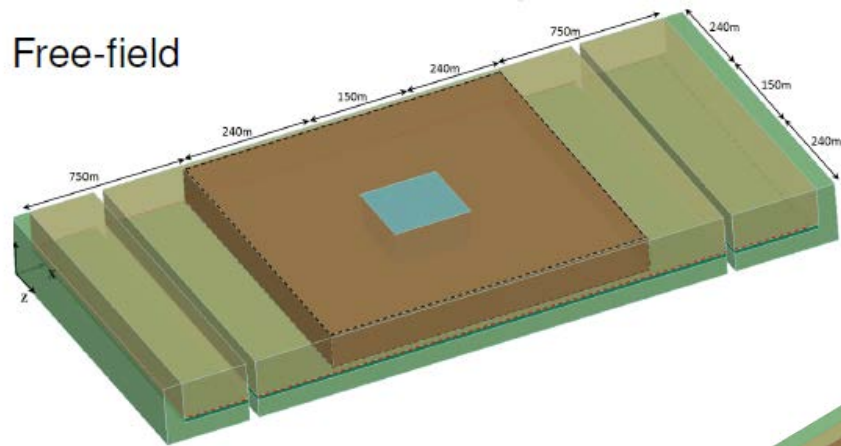
Model With Vertical Joints



Pacoima Dam



Effective Seismic Input Method

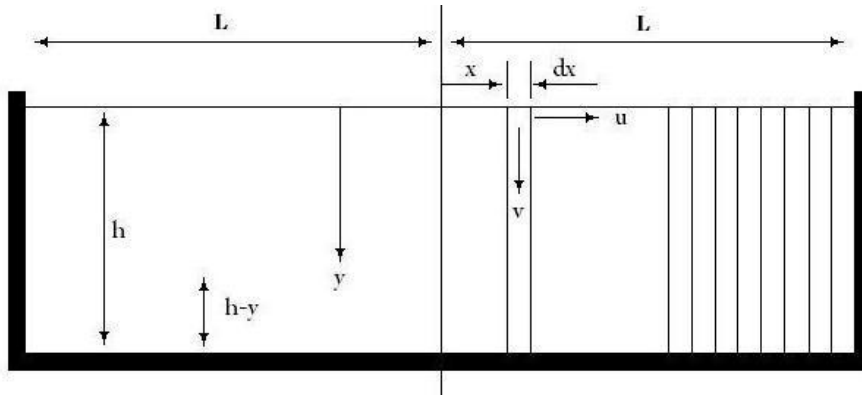


Target

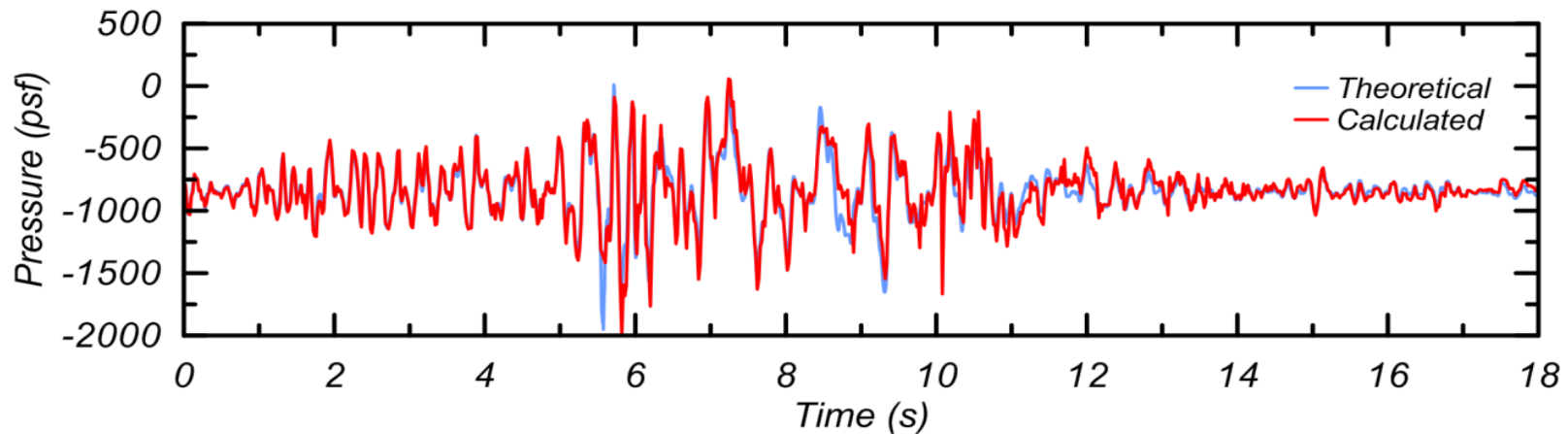
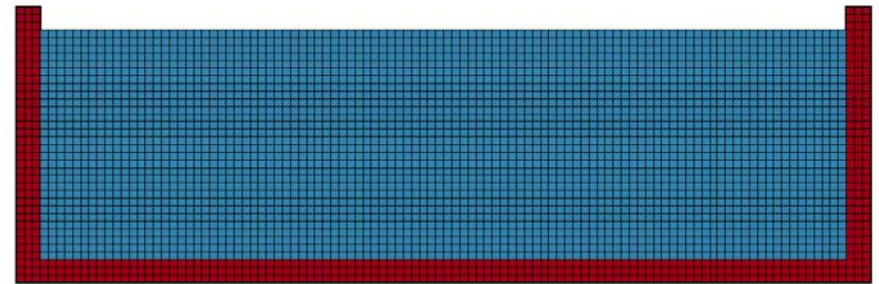


Fluid Element Calibration

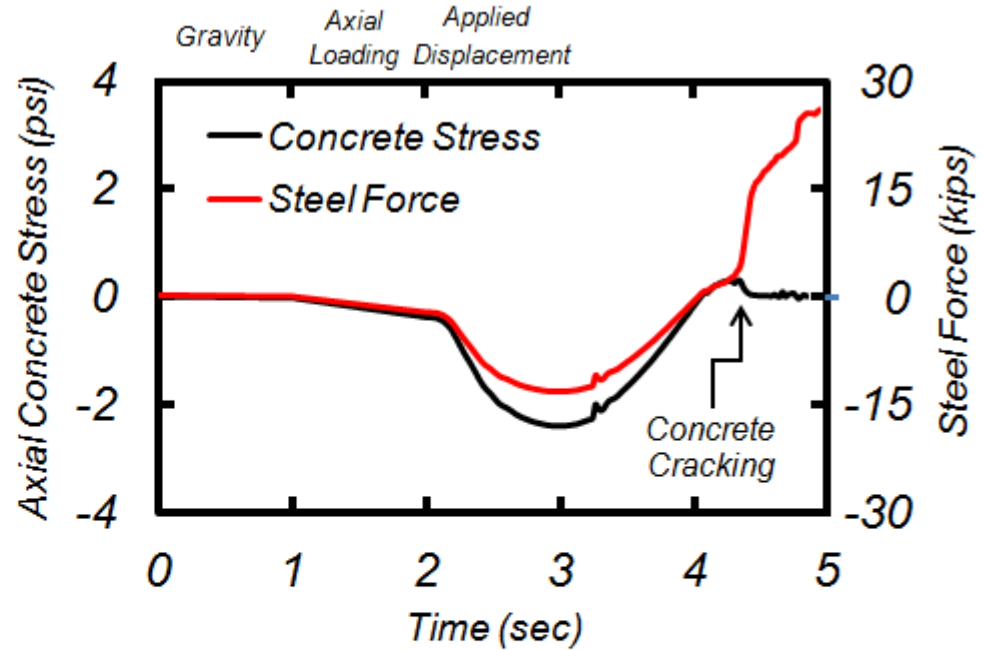
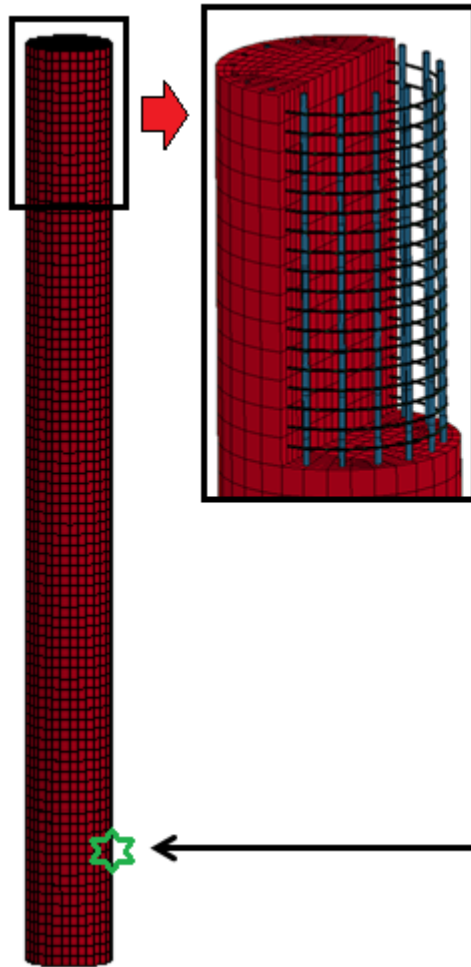
G.W. Housner Model (1954)



LS-DYNA Model

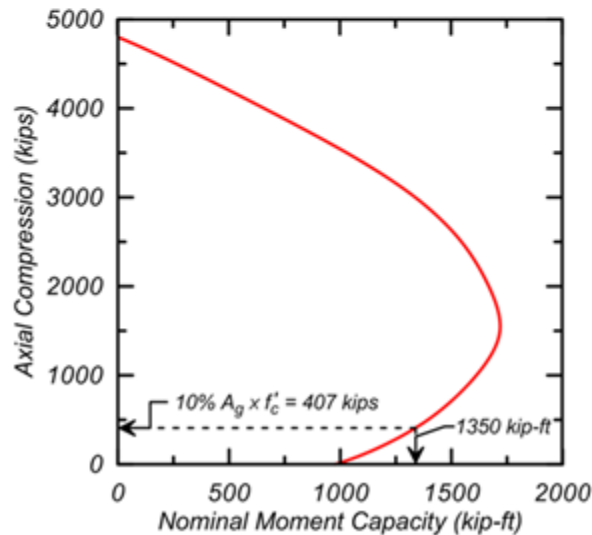
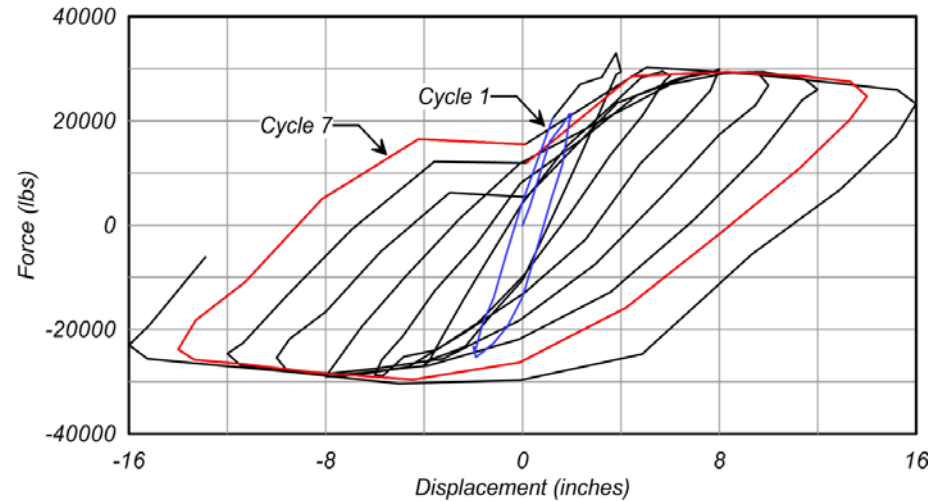
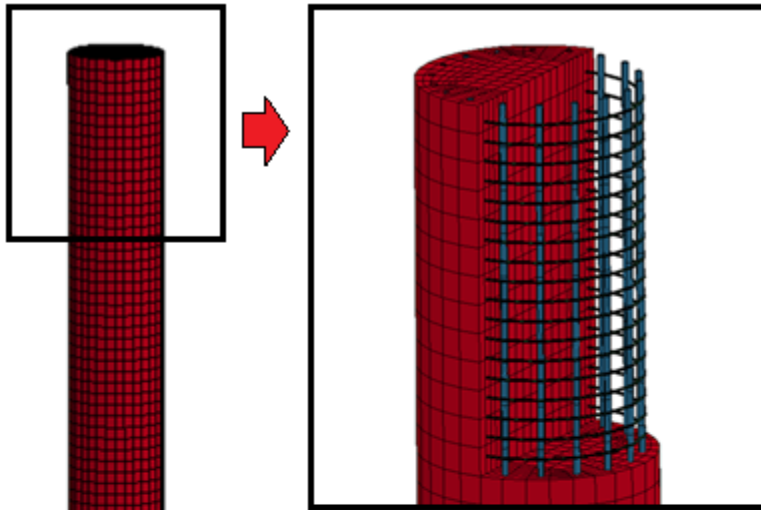


Nonlinear Concrete Material



Concrete Strength = 4,000 psi
Steel Strength = 60,000 psi
Longitudinal Bars = 18 # 8
Shear Bars = # 3 @ 3 in

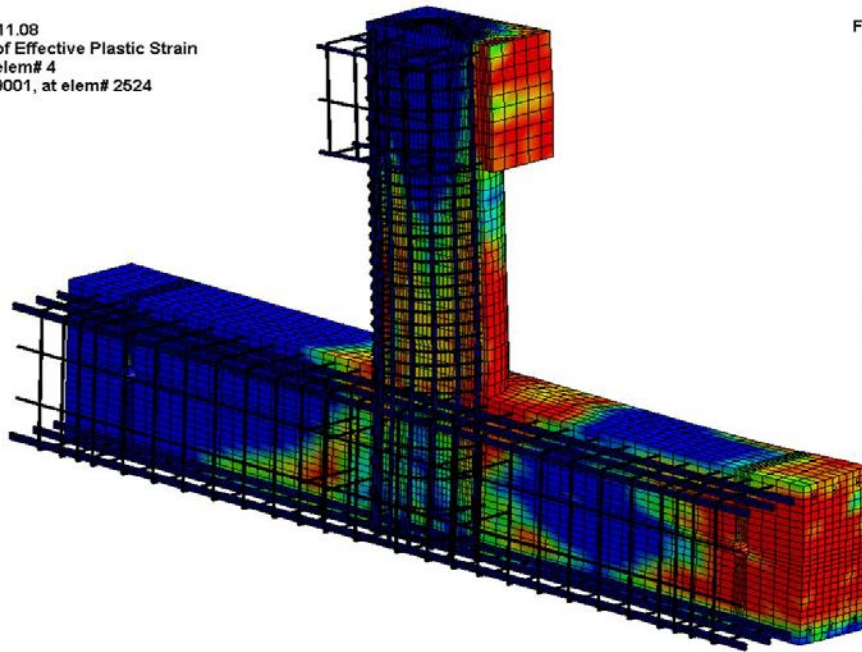
Nonlinear Concrete Material



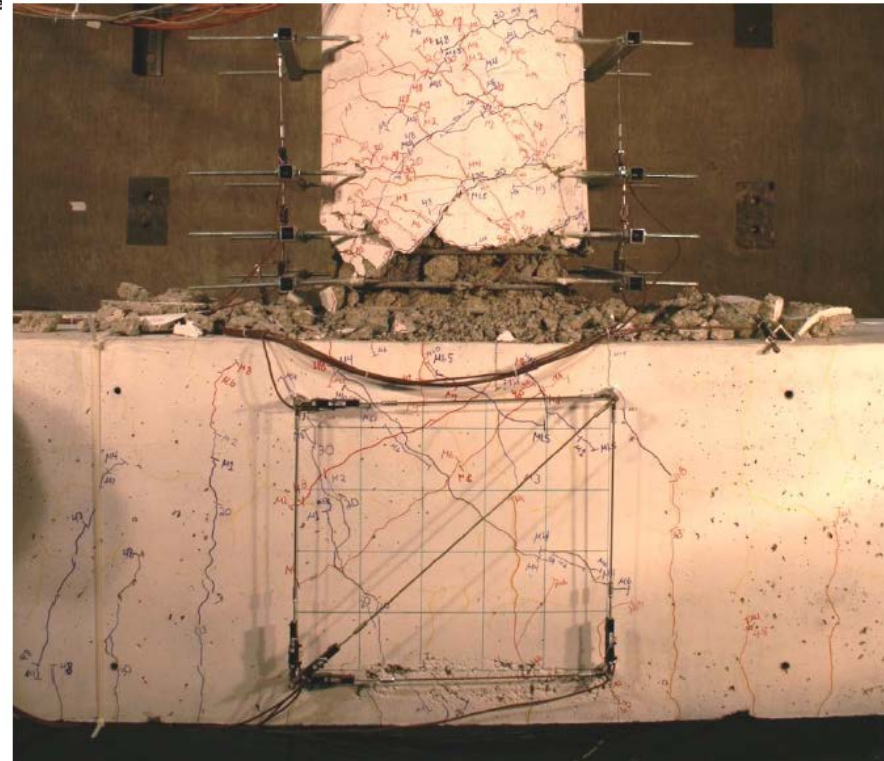
Realistic Hysteresis Loops
Realistic Load Capacity

Lab Test Validation

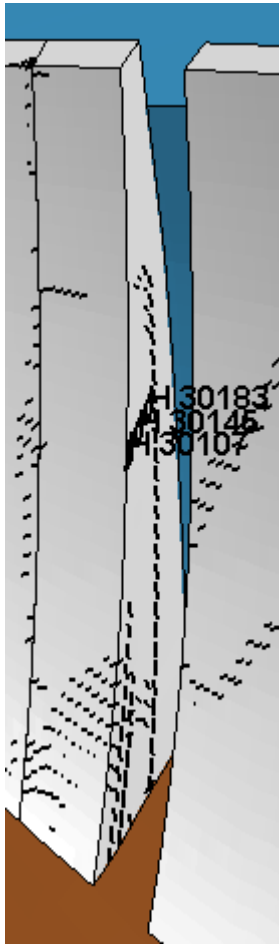
Time = 11.08
Contours of Effective Plastic Strain
min=0, at elem# 4
max=0.999001, at elem# 2524



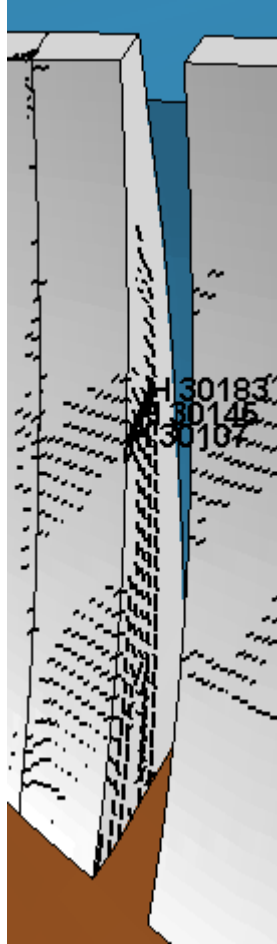
Fringe Levels



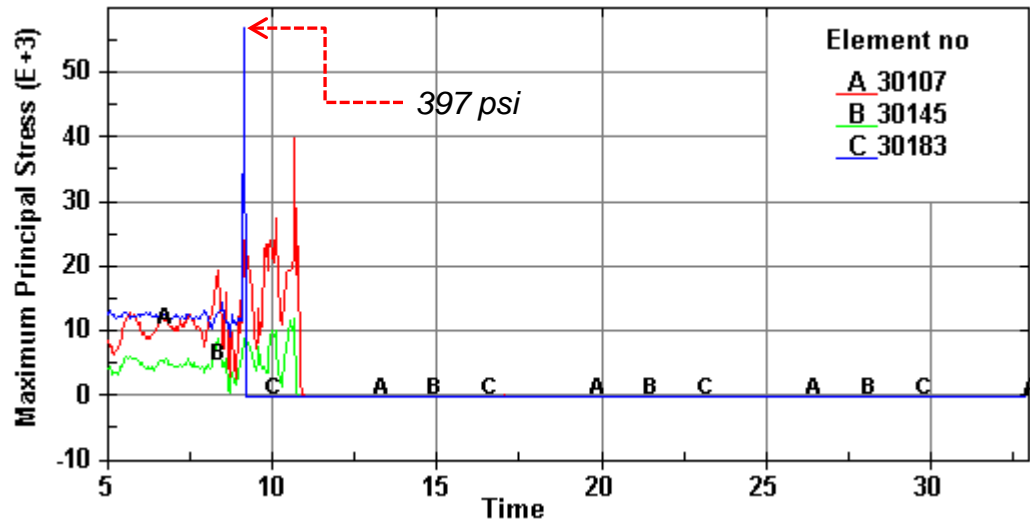
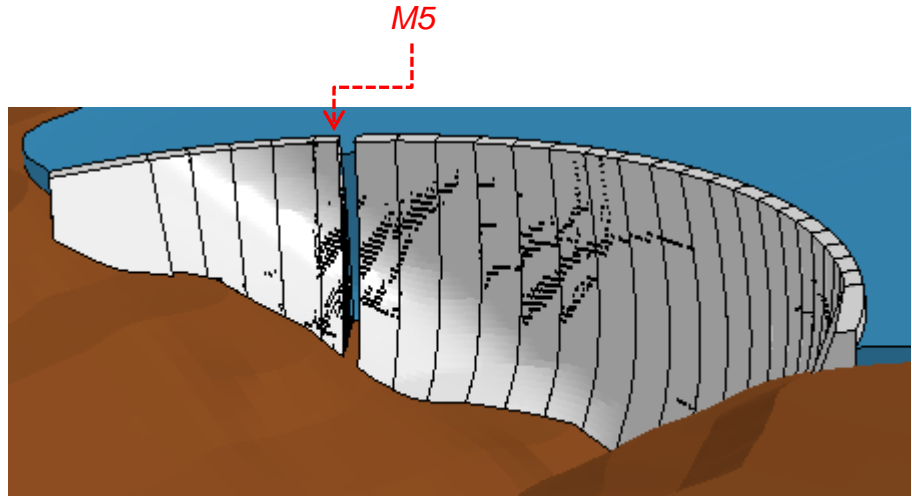
Concrete Cracking Model



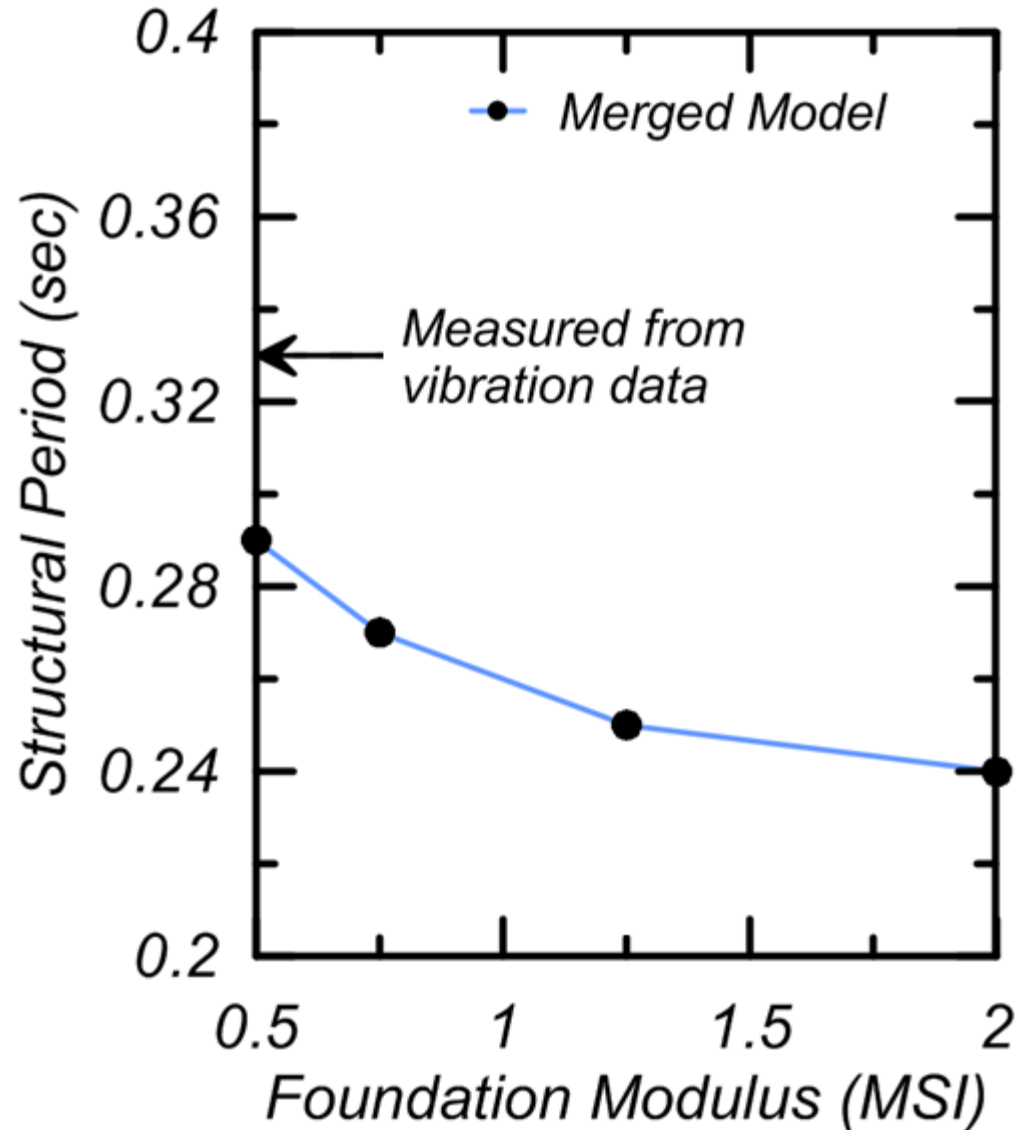
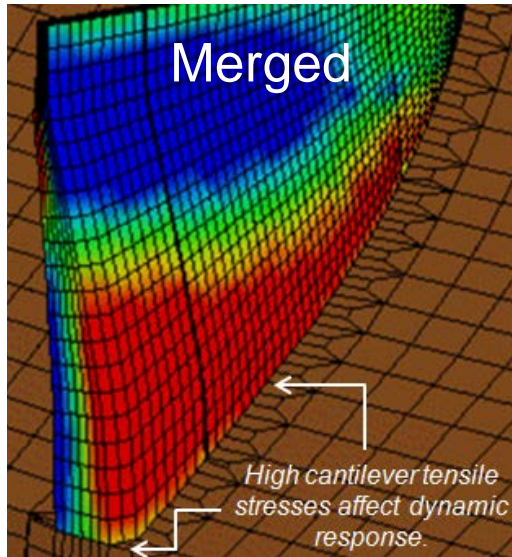
Time = 5 sec



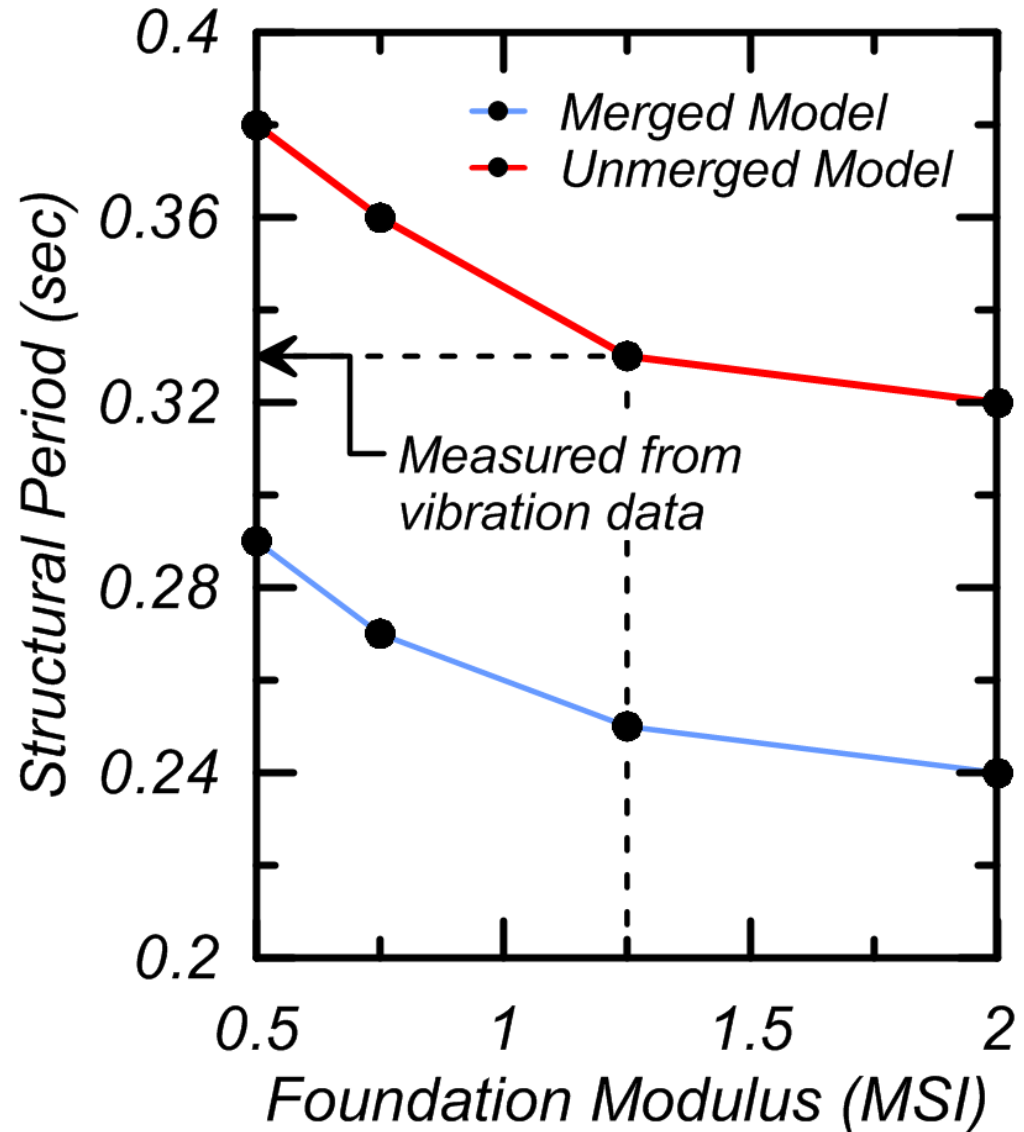
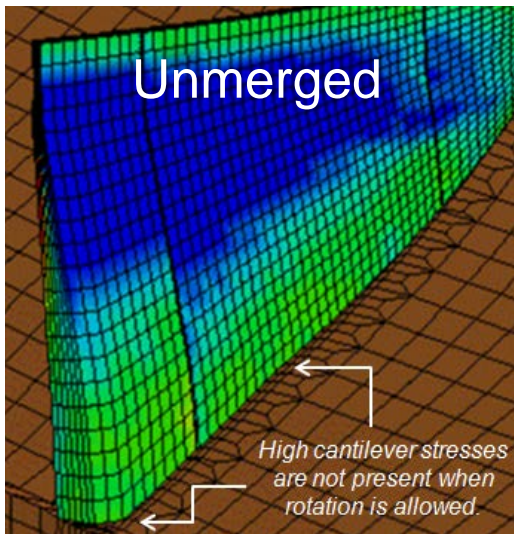
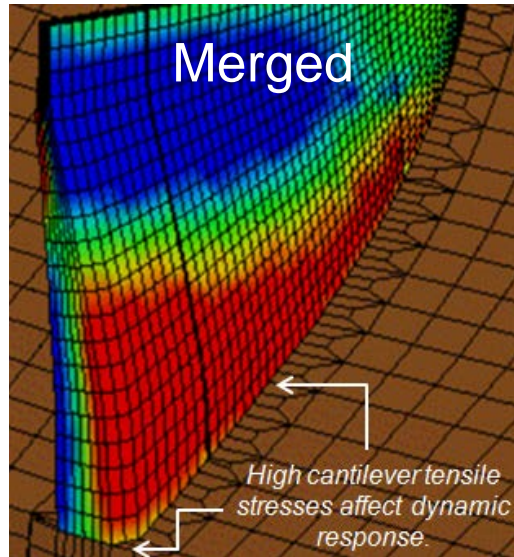
Time = 12 sec



Dam-Foundation Interface



Dam-Foundation Interface



Questions?

