

# The Alamillo Bridge: A Case Study on the Merits of Seismic Design Codes

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- 1.541 Mechanics and Design of  
Concrete Structures

# A Few Questions...

- Why a case study?
  - Apply concepts from class
  - Compare to industry practice
- Why the Alamillo bridge?
  - Famous, highly recognizable
  - Uses concrete in an interesting way

# Background

- Seville, Spain for 1992 Expo
- Santiago Calatrava
- Facts
  - Span: 200 m
  - Pylon Height: 142 m
  - 13 Pairs of Stays
  - 58° Incline

# Mechanics

- “Balancing Act”
  - Overturning from stays
  - Self-weight of pylon
  - Maintain equilibrium w/o bending
- Changing Load Cases
  - Create significant bending
  - Large compared to back-stayed, vertical pylon

# Design Philosophy

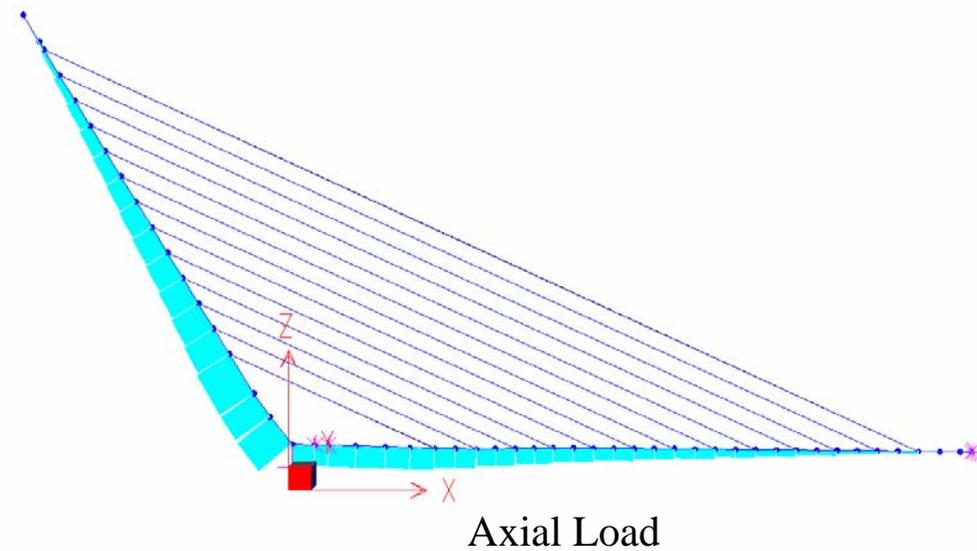
- Equivalent Static Analysis
  - Strength-Based Approach
  - Allowable Stress
  - Neglects or Lacks Emphasis On:
    - Deflections
    - Dynamic Analysis (Resonance?)
- Dynamic Analysis
  - Time-History Earthquake Response
  - Develop Better Understanding of Structural Response
  - Emphasize Deflections/Deformations

# Seismic Design of Concrete

- Steel Caisson Shell
- Reinforced Concrete Fill
- Interface
  - Confinement
  - Biaxial Loading
  - Ductility
    - Important for EQ Design
    - $\mu > 6$  for Confined Concrete

# Analysis

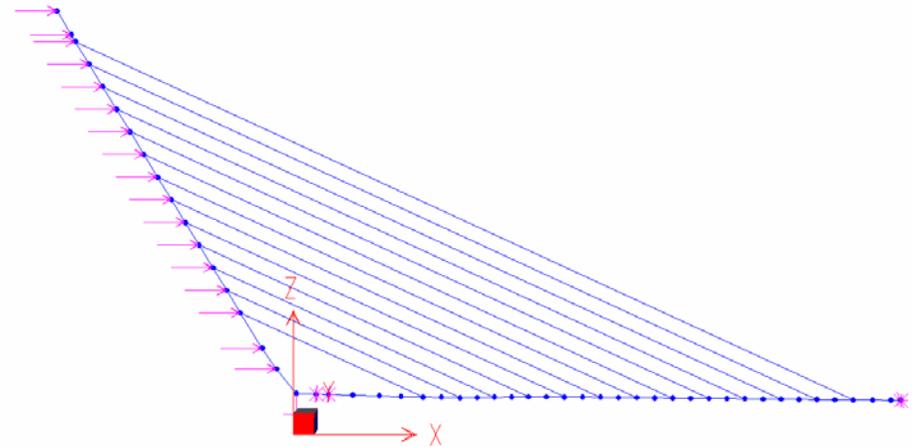
- Finite-Element
  - SAP2000
  - Loads
    - Dead
    - Funicular Loading:  
Results in Minimal  
Bending of Pylon
    - Compression



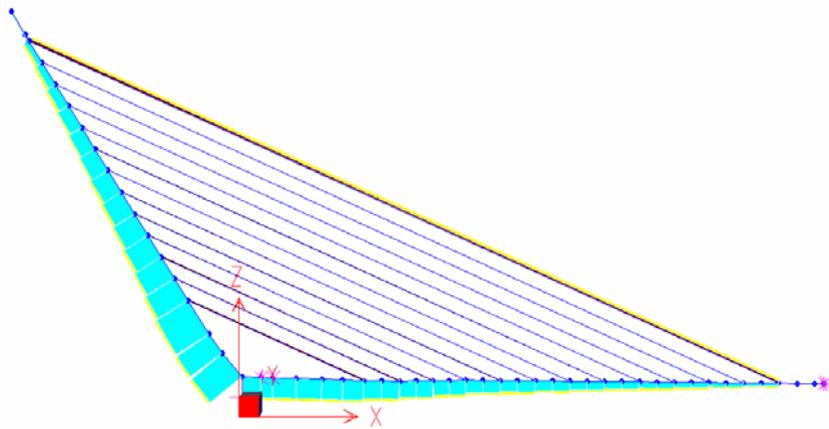
# Analysis

- Time-History Response
  - Actual Earthquake Records
  - Variety of EQ Characteristics
    - Northridge 1994
    - Imperial Valley 1940
    - San Fernando 1971
- Compare
  - Internal Actions
  - Deflections & Deformations

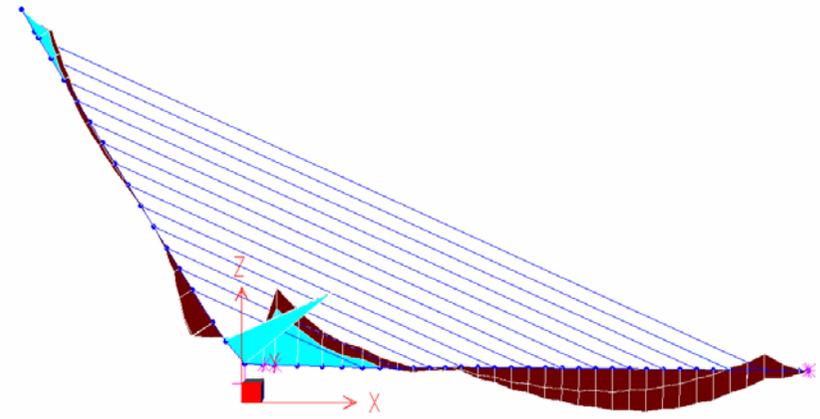
- Equivalent Static Procedure



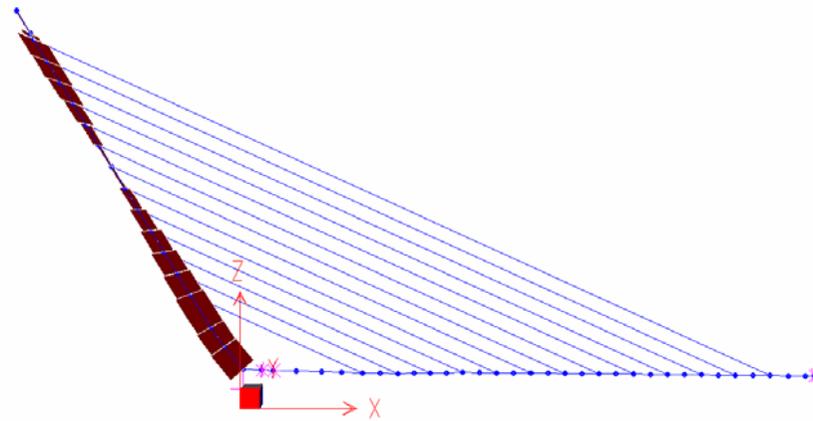
# Results



Axial Force



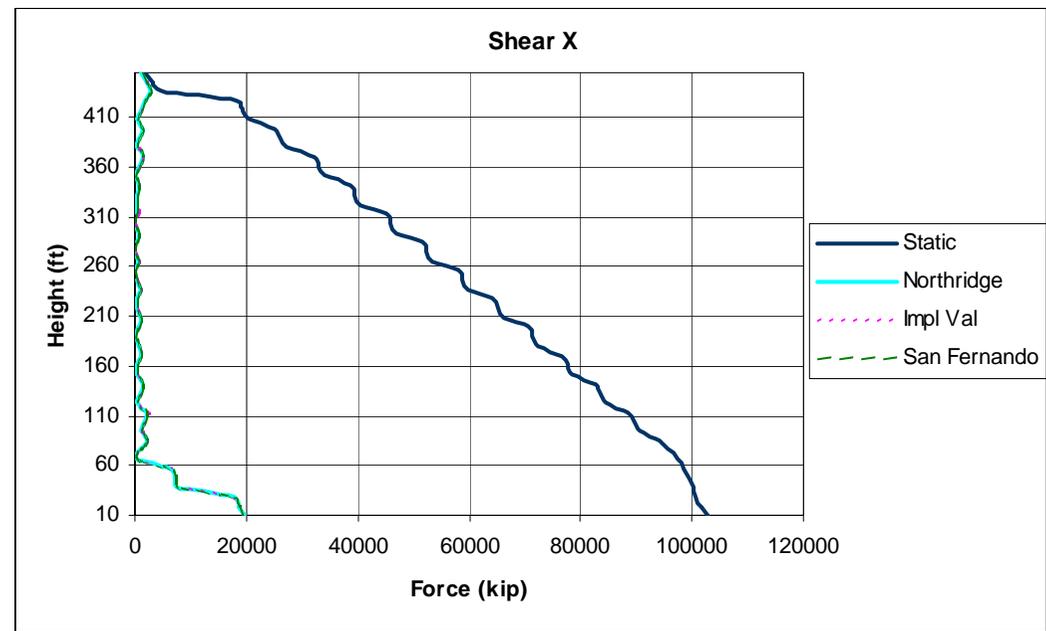
Bending



Shear

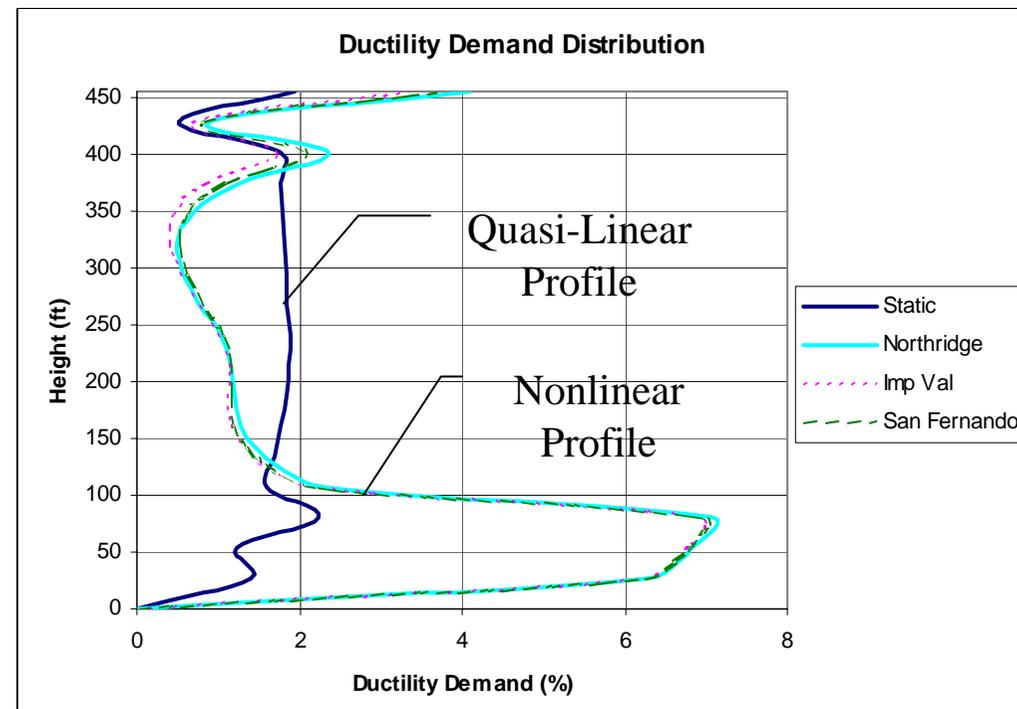
# Internal Actions

- Bending
- Shear
- Static very conservative with respect to dynamic analysis
- Time-History Response: Very consistent even with various earthquake characteristics



# Deflection

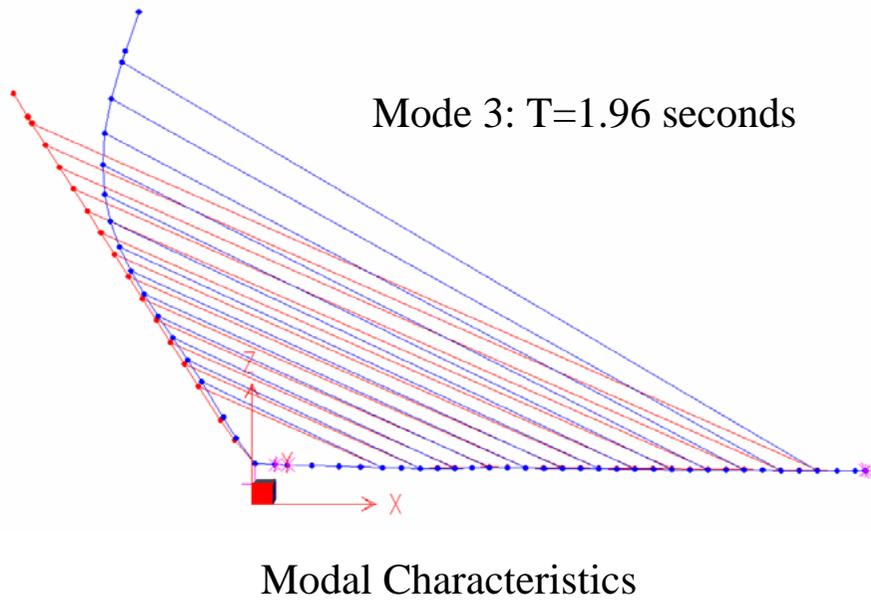
- Static Analysis  
NON-conservative  
with respect to  
Dynamic
- High Ductility  
Demand, also  
highly nonlinear



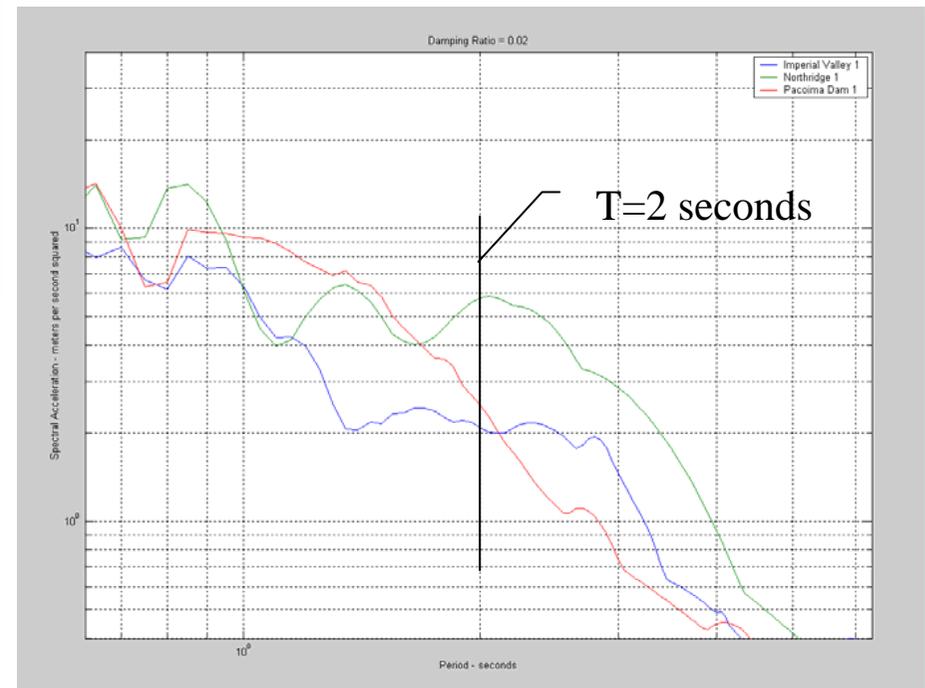
# Why the Discrepancy?

- Higher Order Dynamic Response
  - ASCE gives consideration only to 1<sup>st</sup> Mode for basic seismic design
  - Neglects
    - Higher modes
    - Earthquake characteristics
- Other Reasons?

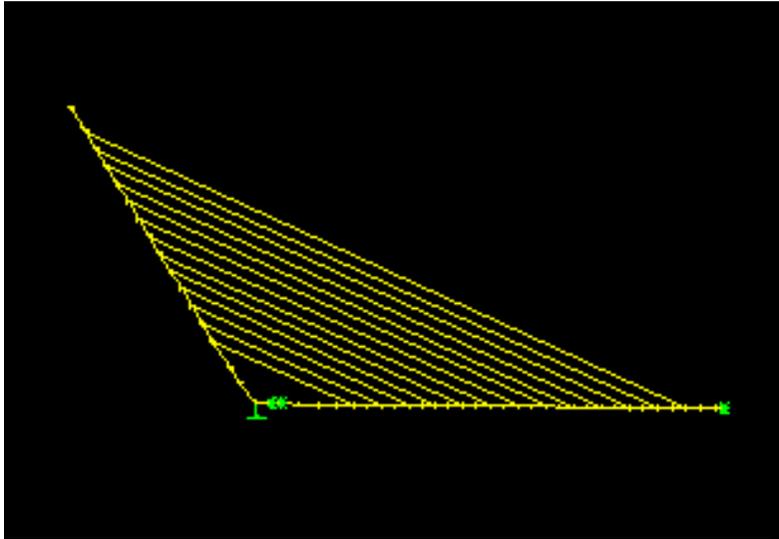
# Dynamic Characteristics



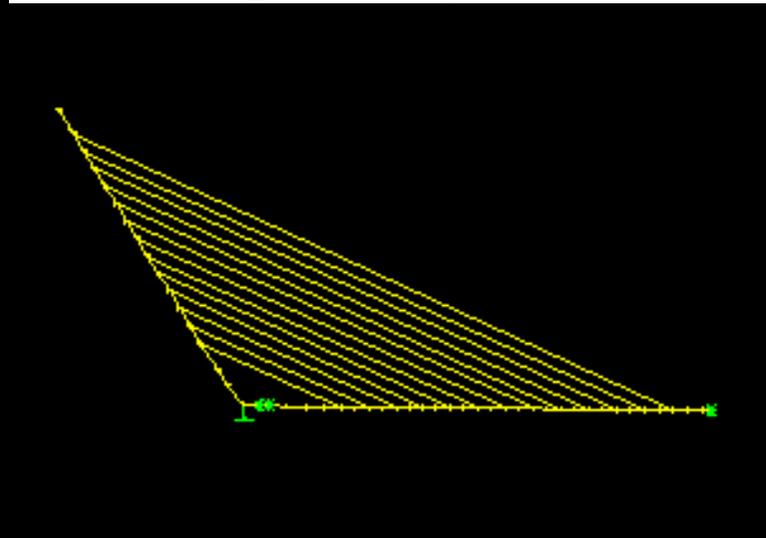
## Spectral Acceleration



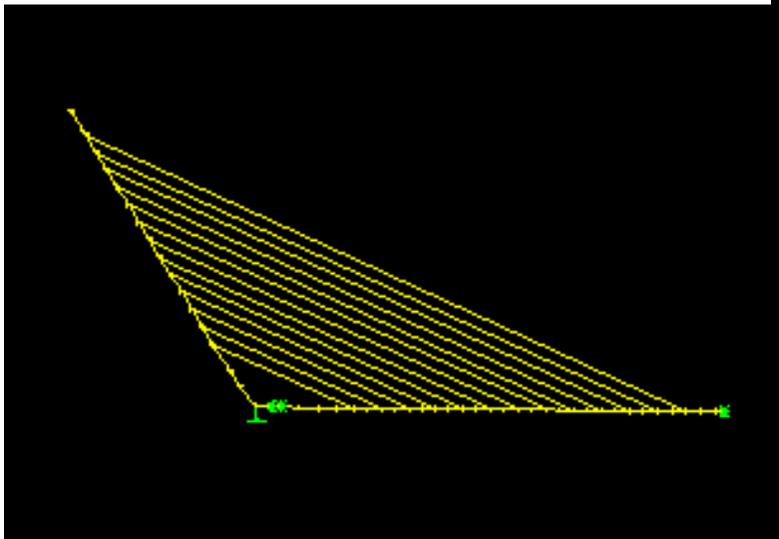
Northridge 1994



Imperial Valley 1940



San Fernando 1971



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# Conclusions

- Static Design
  - Still provides good 1<sup>st</sup> order approximation
  - Need greater understanding of dynamics
- Trend Towards Performance-based Criteria
  - Necessitates damage control
  - Damage control=Deflection control
- Dynamic Analysis Tools
  - Can lead to more efficient engineering
  - Can be done easily with technological advancements
  - Still need fundamental understanding of structural behavior

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