LRFD FOUNDATION DESIGN FOR FLYOVER 13 OVER I-95 AND I-73

CDM Smith

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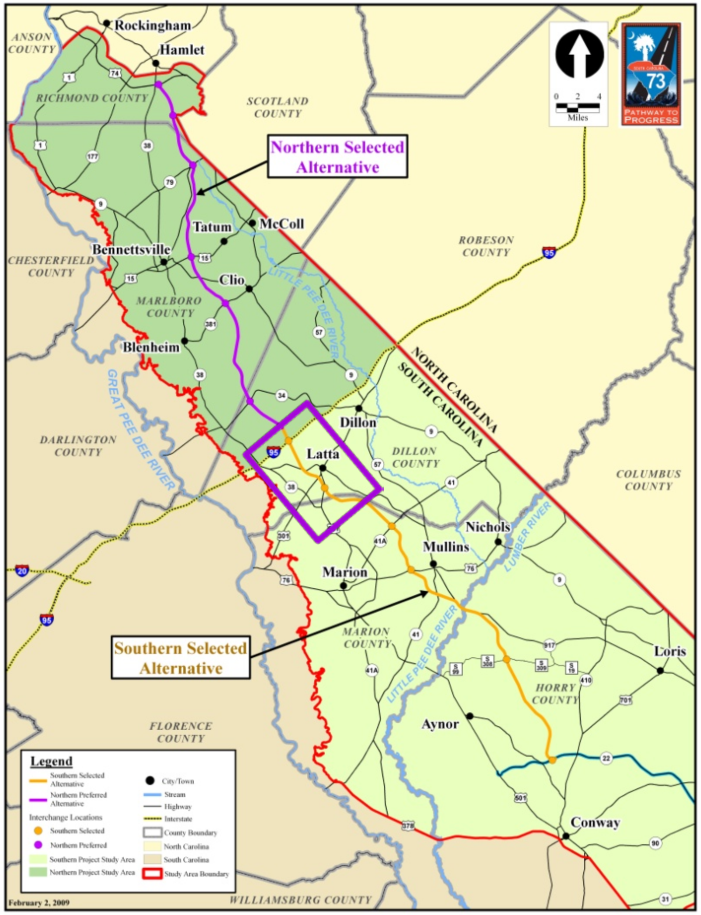
Geo^3 T^2 Conference

I-73 Phase 1 Overview

- I-95 to US-501
- $166 Million Construction Cost
- About 5.7 mi of Interstate Hwy.
- 10 Bridges
- Partial Interchange at I-95



Bridge 4B Design

- Ramp from I-95 South to I-73 South
- Crossing over I-95 and I-73
- 2,514 ft. in length
- 8 spans
- Post-tensioned concrete segmental box girder
- Hammerhead piers on drilled shaft groups
- Steel piles at abutments

Geotechnical Design Procedure

- Geotechnical Exploration and Laboratory Testing
- Conduct Site Response Analysis
  - Design Acceleration Response Spectra
  - Design Acceleration Time History Data Sets
  - Analysis of Seismic Hazards
- Design of Bridge Foundations
- Design of Embankments and Retaining Walls
- Foundation Substructure Analysis
    - Dynamic Stiffness and Damping compatible with Superstructure Model

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Geotechnical Exploration

- Preliminary (Right-of-way) Phase
  - 5 SPT borings
  - Seismic CPT soundings
  - Deep boring to 500 feet with shear wave velocity measurements
- Final (Construction Plans) Phase
  - Borings at abutments and interior bents
  - Borings at approach embankments and MSE wall locations
- Laboratory Testing

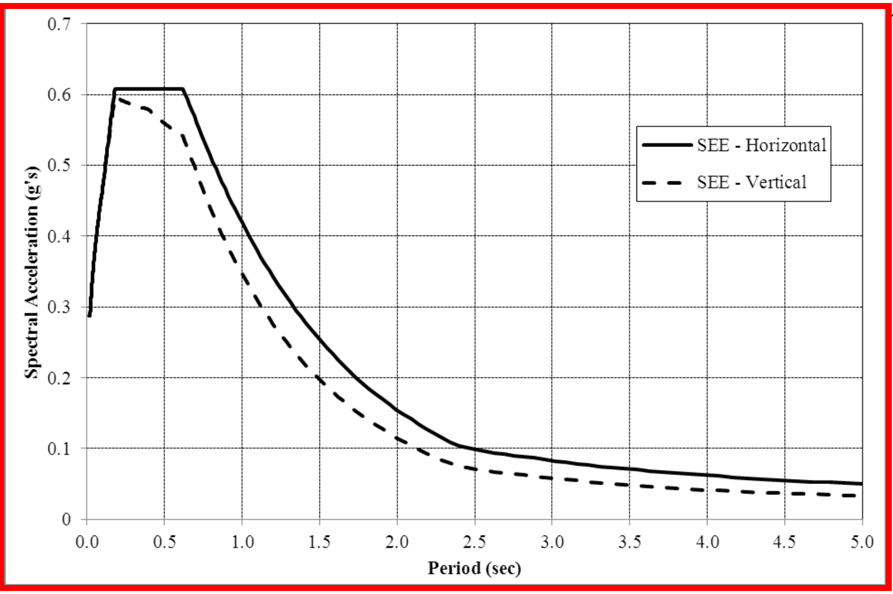
Subsurface Conditions

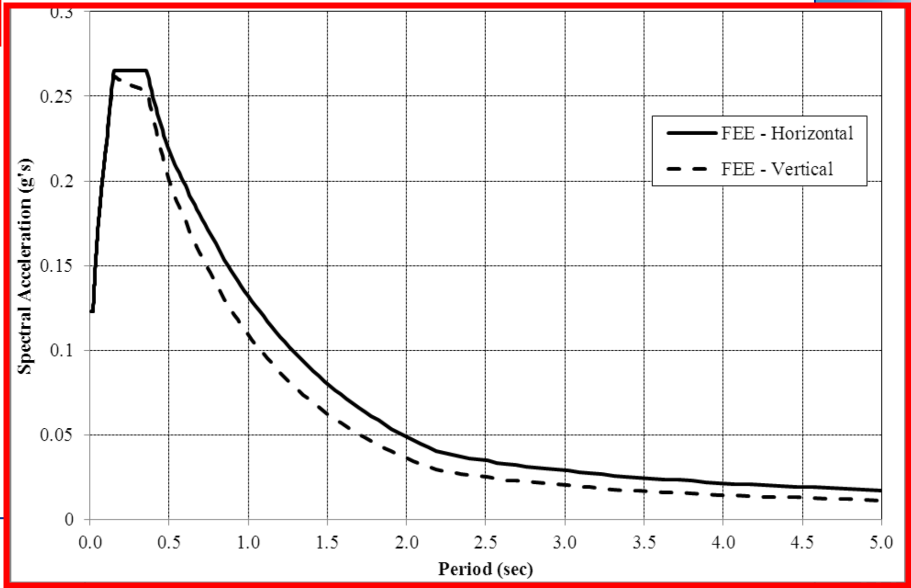
- 25 to 40 feet of Pleistocene soils
  - Sands with clay and silt
  - Measured SPT from WOH to 26
- 10 to 25 feet of Bear Bluff soils
  - Sands with clay and silt, some fat clay
  - Measured SPT from 3 to 28
- Black Creek soils to bottom of borings
  - Sands and silty sands, low plasticity fines, some cementation
  - Measured SPT from 5 to 86

Site Response Analysis

- SEE and FEE Design Scenarios
- SHAKE Analysis – South Carolina Soils
- Development of site specific Acceleration Response Spectra
  - Horizontal
  - Vertical
- Development of spatially incoherent and spectrum compatible acceleration time histories for SEE
  - 3 sets total
  - Horizontal and vertical components
  - Developed at support locations (abutments and interior bents)

Design Response Spectra : 5% Damping



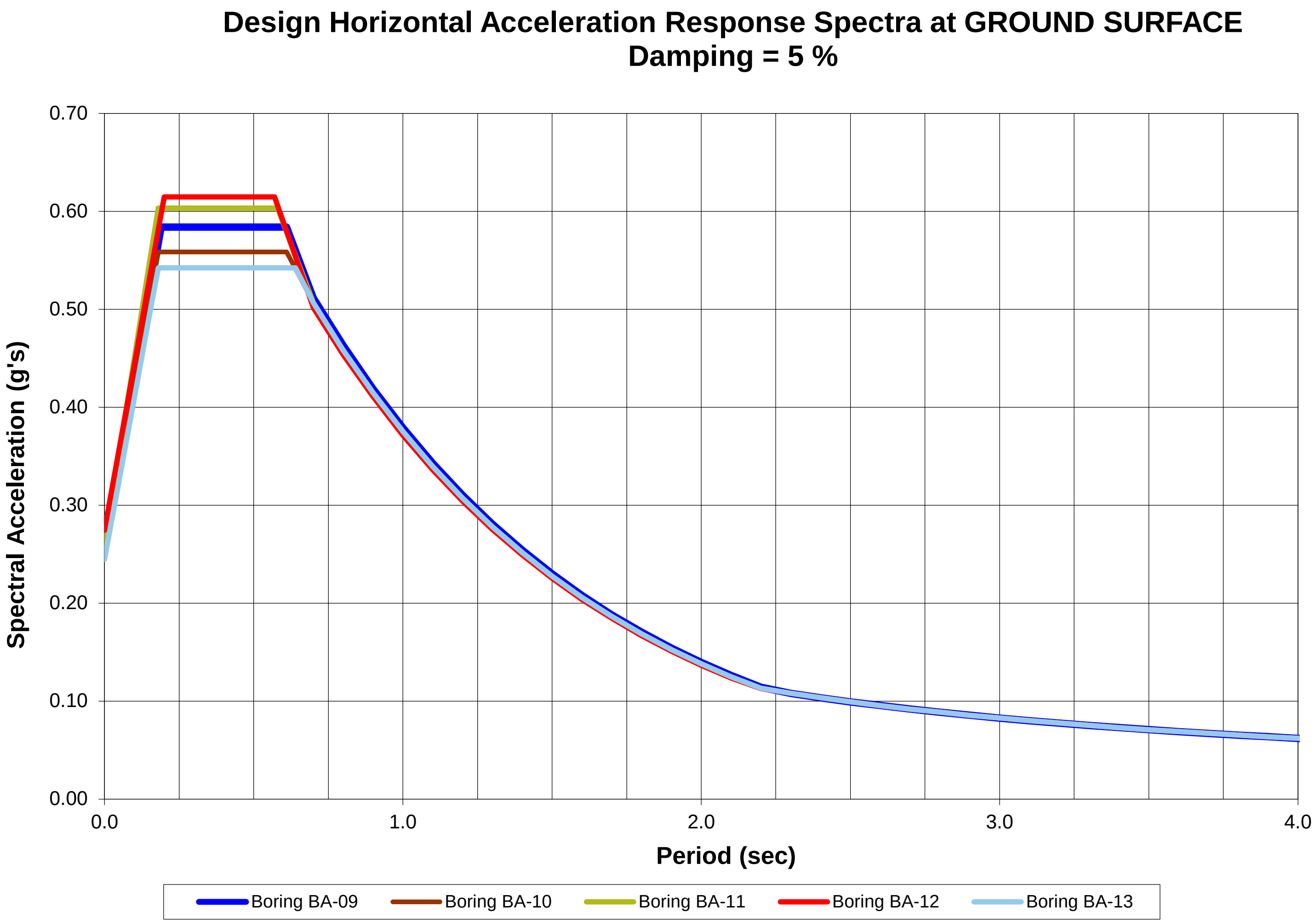


Site Response Analysis

Development of Spectrum Compatible Horizontal and Vertical Acceleration Time Histories

- Variability – subsurface conditions
- Spatial variability of motion – wave passage effects
- Incoherency of motion

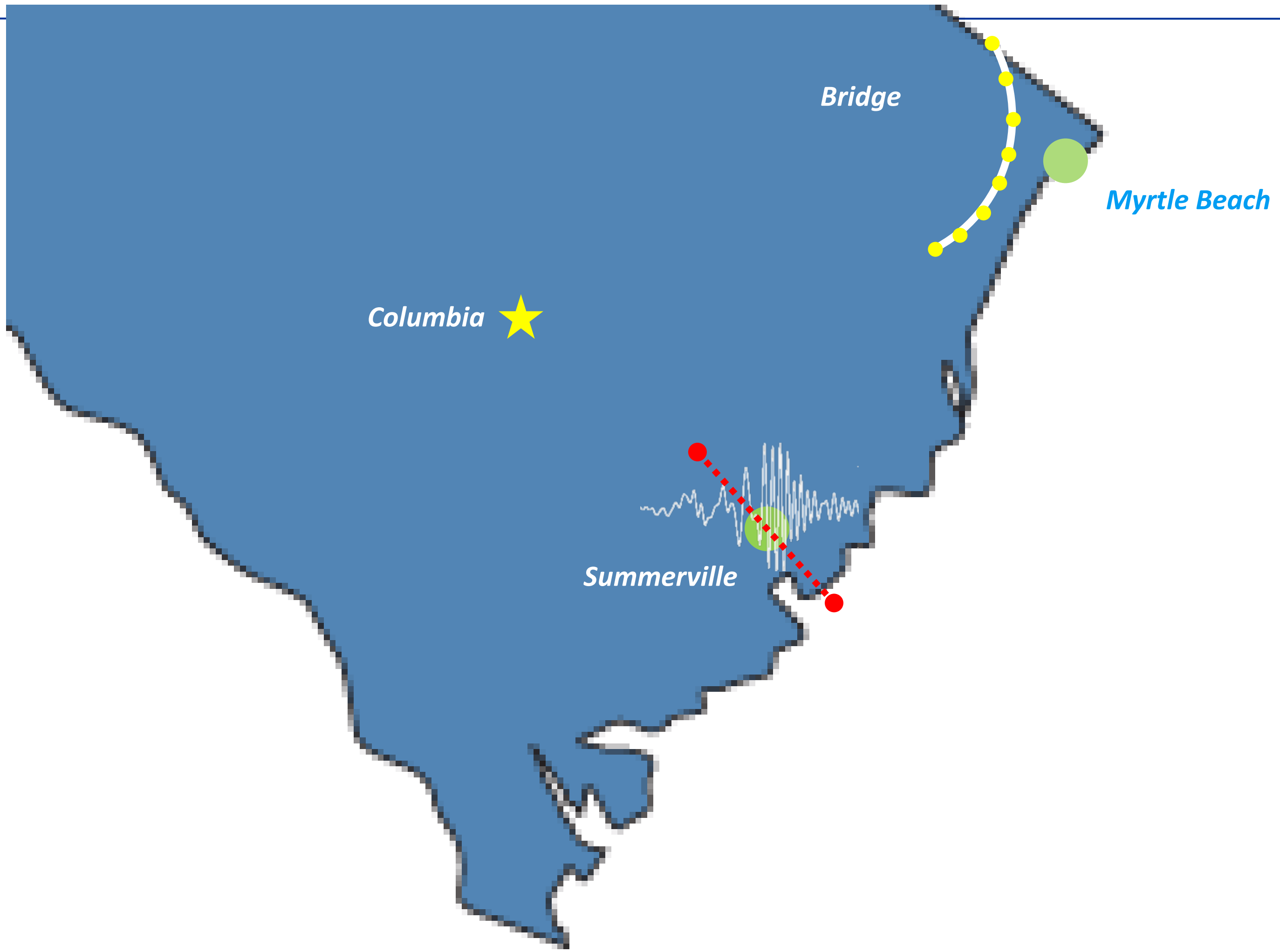
Subsurface Variability



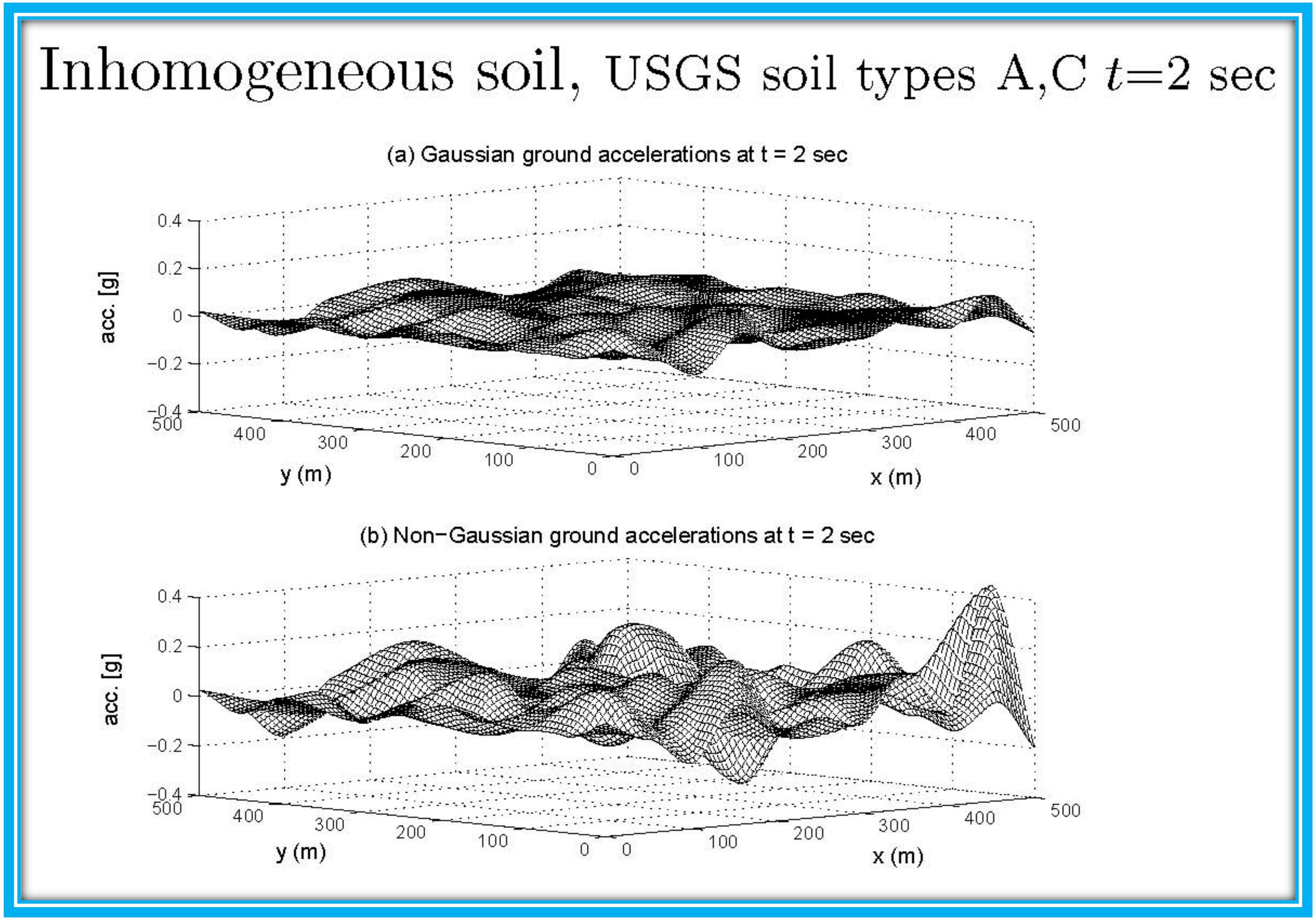
Wave Passage Effects

- Spatial Variability of Motion
- Incoherency of Motion

Spatial Variability



Incoherency of Motions



Seismic Hazards

- Idriss and Boulanger, 2008 Monograph + SCDOT GDM
- Site Specific Demands from SHAKE (CSR)
- Liquefaction and Cyclic Softening
- Seismically Induced Settlements
- Horizontal Movements
- Residual Shear Strengths
- Downdrag loads
- Mitigation at abutments – earthquake drains

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Design of Bridge Foundations

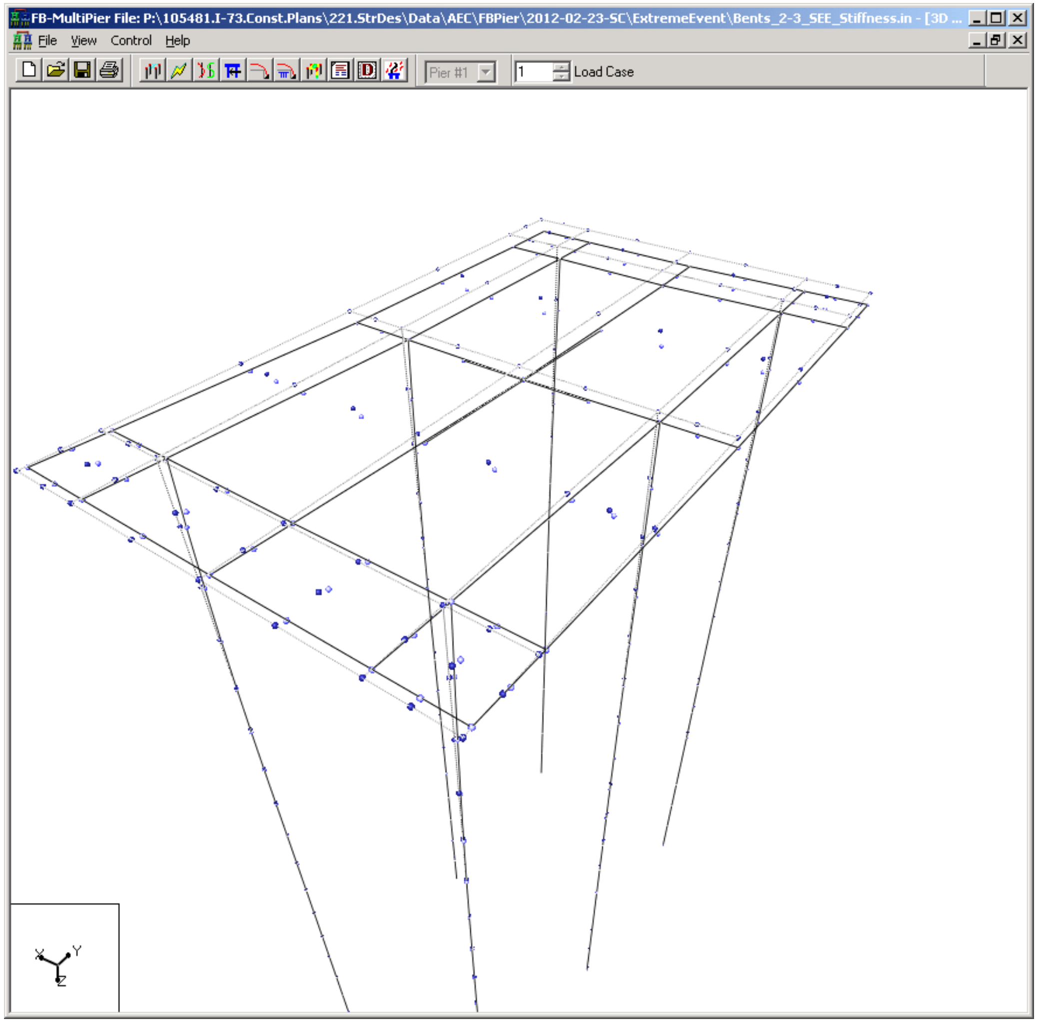
- AASHTO LRFD 2010 + SCDOT GDM
- Driven pile group at abutments
- Drilled shaft group at interior bents
- Limit States
  - Service
  - Strength
  - Construction (Strength)
  - Extreme Event

Design of Bridge Foundations

- Group analysis using FB-Multipier
  - Movements : Service
  - Shaft demands : Strength and Extreme Event
  - Equivalent linear stiffness – compatible with superstructure analyses

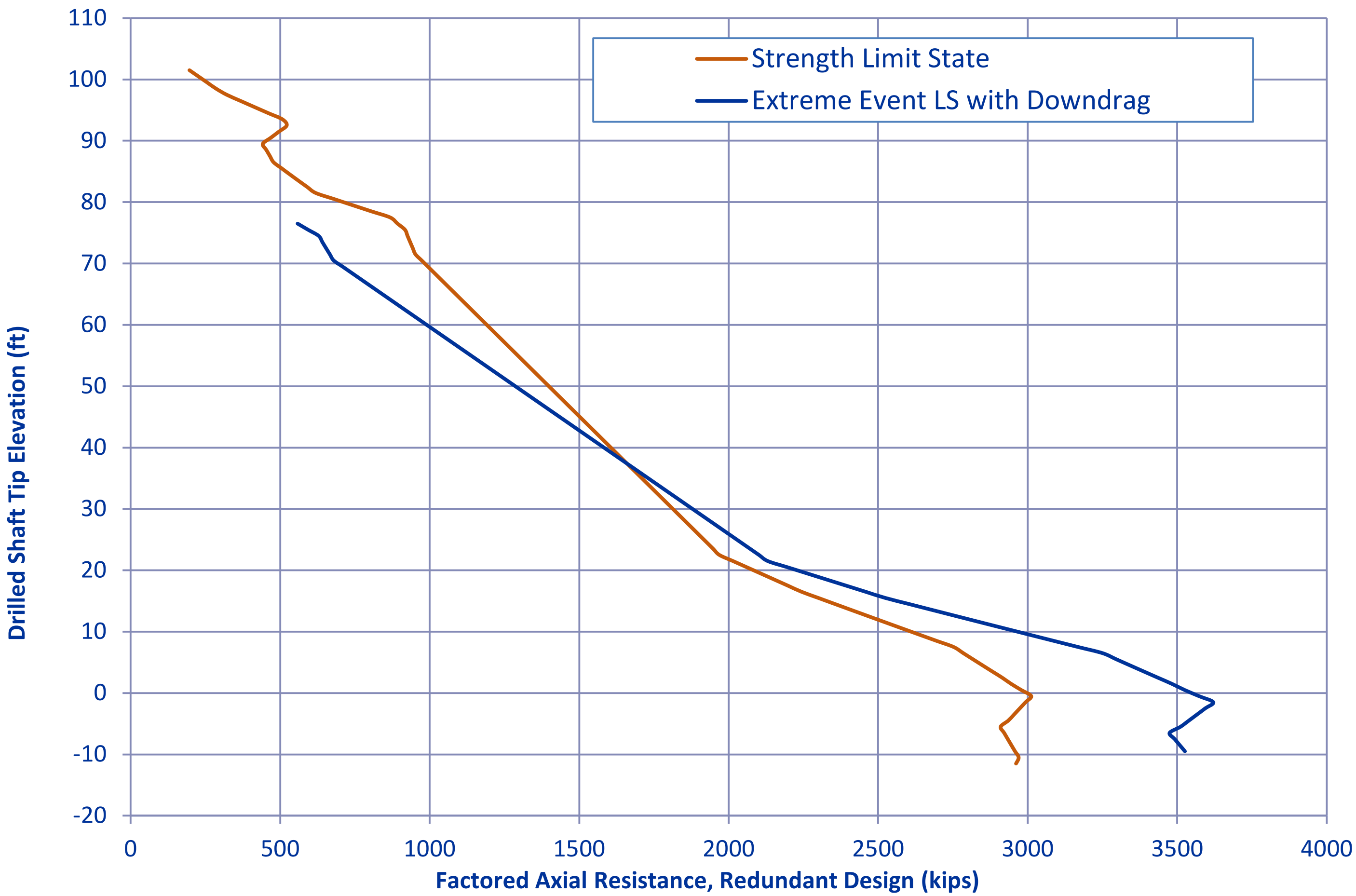
- Shaft axial resistance
  - AASHTO + SCDOT Resistance Factors
  - Load test data
  - Group effects
  - Downdrag from seismic settlements

FB-Multipier Models



Shaft Axial Resistance – Bent 4

Diameter = 7.0-ft



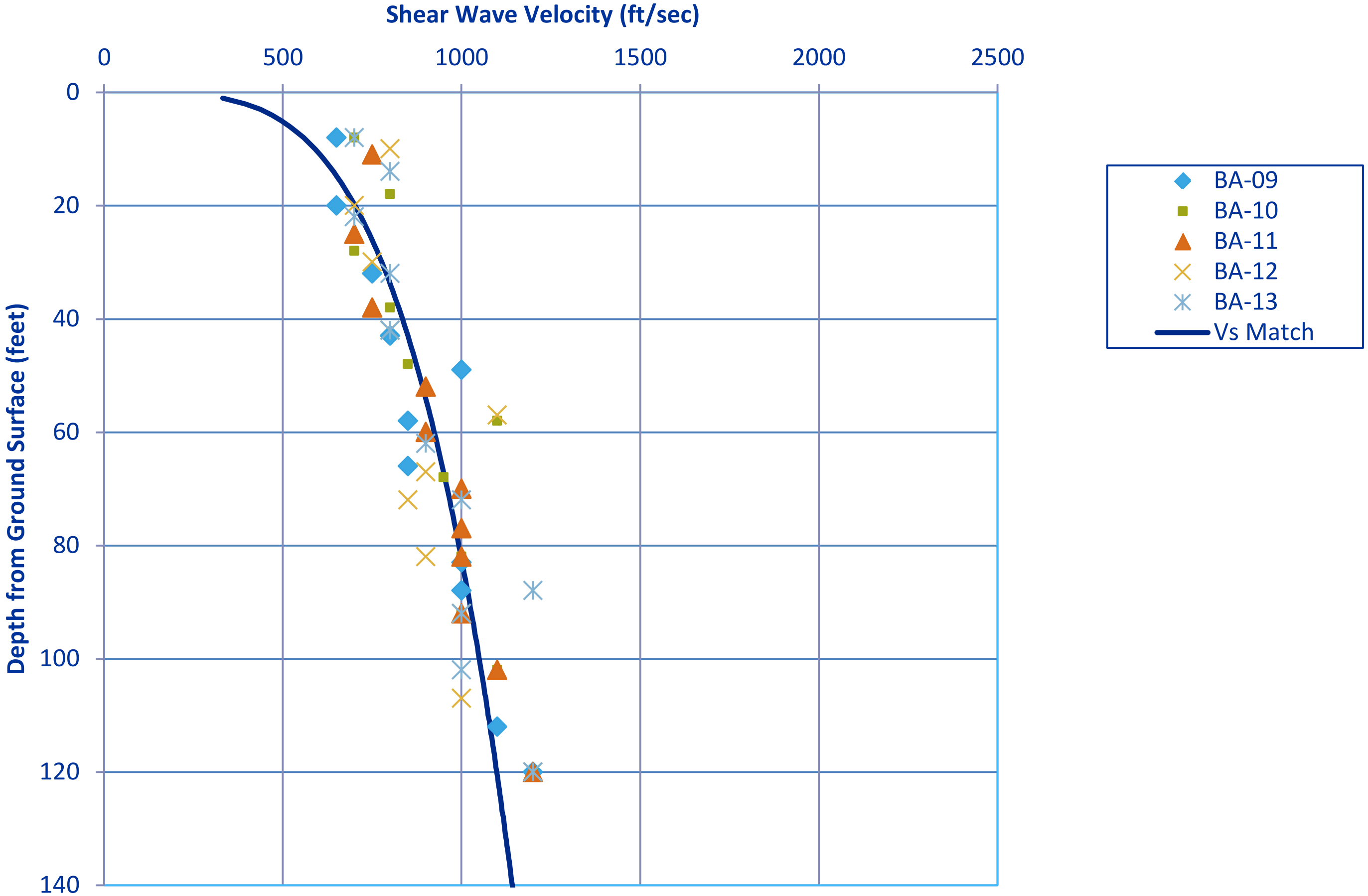
Drilled Shaft Design

Bent	Strength Limit State			Extreme Event Limit State : SEE		
	Maximum Factored Load (kips)		Minimum Tip Elevation - Strength (ft)	Maximum Factored Load (kips)	Minimum Tip Elevation EE (ft)	Required Minimum Tip Elevation (ft)
	Construction	Strength				
2	2,406	2,545	**6**	2,570	9	**6**
3	2,406	2,545	**15**	2,570	18	**15**
4	2,518	2,939	0	3,681	**-6**	**-6**
5	2,518	2,939	**9**	3,681	12	**9**
6	2,518	2,939	**-3**	3,681	-3	**-3**
7	2,390	2,484	**9**	2,603	40	**9**
8	2,390	2,484	**17**	2,603	42	**17**

Foundation Model for Time History Analysis

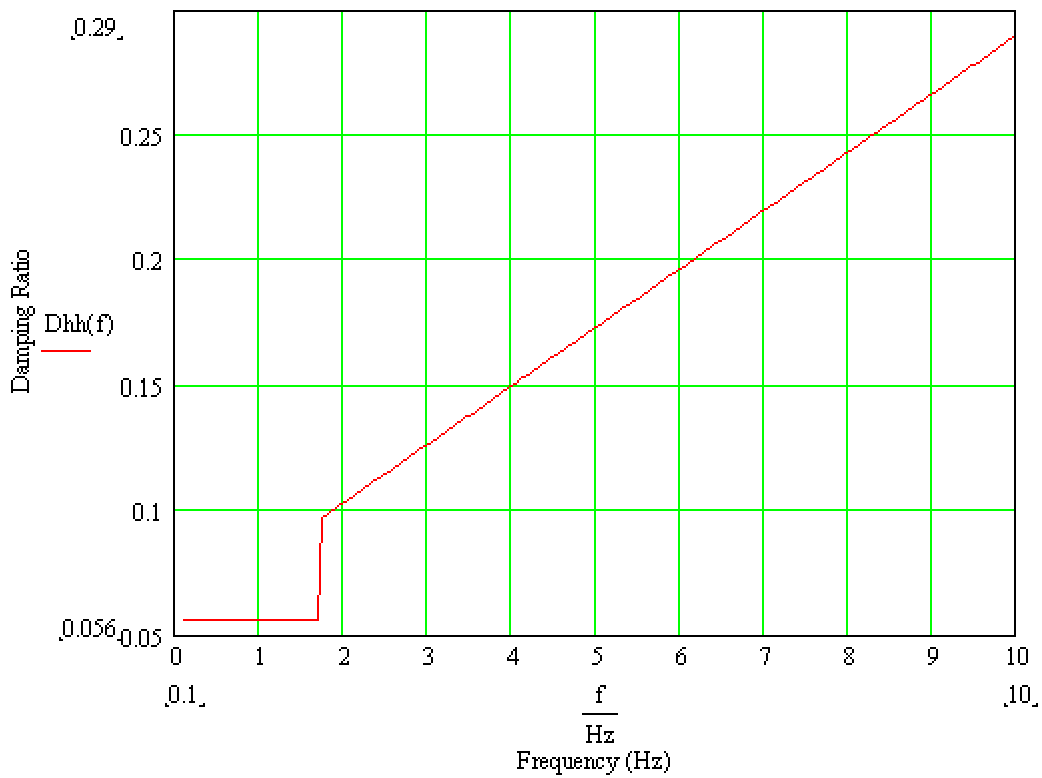
- Equivalent static stiffness for SEE loads
  - 6x6 stiffness matrix for group
  - Iterations for compatibility
- Frequency dependent damping
  - Shear wave velocity/Shear Modulus profile
  - Frequency dependent damping ratio/dashpots
  - Horizontal, rocking, vertical and cross-coupling terms

Shear Wave Velocity Model

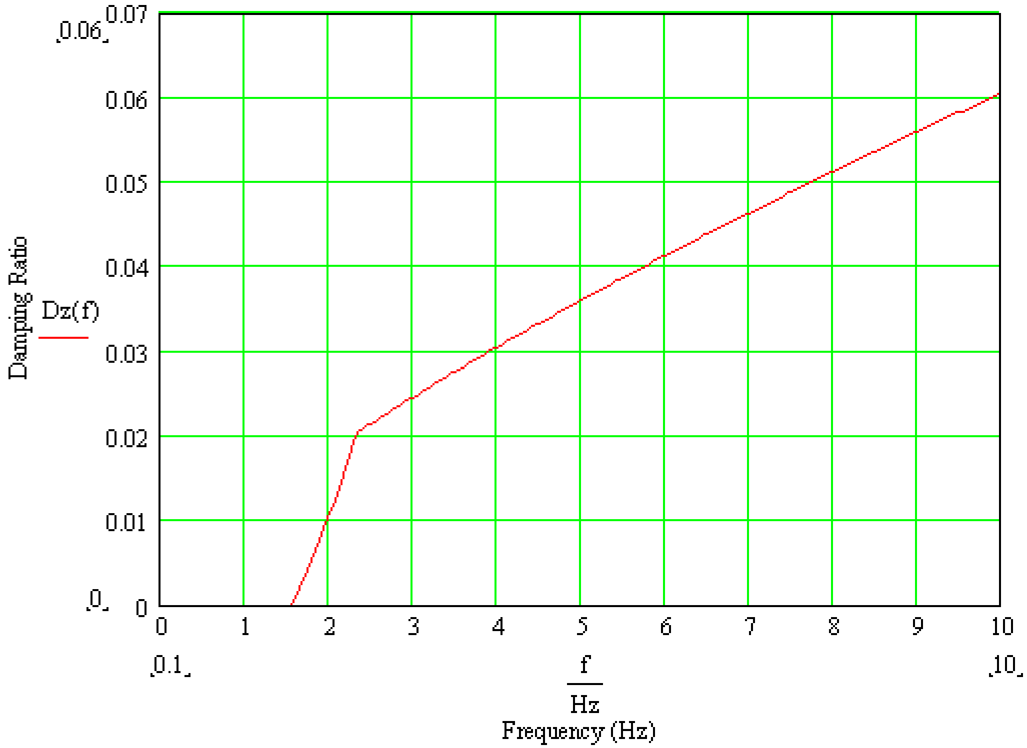


Shear Wave Velocity Model based on SHAKE site-specific analyses models

Shaft Head Damping – Lateral Swaying



Shaft Head Damping – Vertical (Axial)



Seismic Analysis of Superstructure

- Michael Baker Corp. and CDM Smith
  - Response Spectrum
  - Pushover
  - Time History
- Multiple iterations to achieve compatibility between substructure and superstructure models

I-73/I-95 Interchange Bridge 4B

- Questions?