

Benefits and Detriments of Soil–Foundation–Structure Interaction

Boris Jeremić, Guanzhou Jie and Matthias Preisig

University of California, Davis, U.S.A.
and

Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Funding: NSF–CMS–0324661, NSF–TeraGrid,
NSF–EEC–9701568

Hypothesis
oo

Models
oo

SFSI Case Study
oo
ooooooo
ooooo

Summary

Outline

Hypothesis

SFS System Evolution

Models

High Fidelity, 3D

SFSI Case Study

Northridge and Kocaeli Earthquakes

Behavior for Short Period Motions

Behavior in Long Period Motions

Summary

SFSI Hypothesis

- ▶ Flexibility (elastic) of foundations and soils modifies dynamic properties of the SFS system (Gazetas and Mylonakis)
- ▶ Reduction in stiffness (elasto–plasticity) of the SFS system modifies those dynamic properties even more so
- ▶ Energy balance: input (seismic) and dissipated (inelasticity, radiation, coupling) will control fate of SFS system
- ▶ NEHRP-94 seismic code states that: "*These [seismic] forces therefore can be evaluated conservatively without the adjustments recommended in Sec. 2.5 [i.e. for SFS interaction effects]*".
- ▶ Use detailed FEM models to study prototype models

SFS System Changes

- ▶ Earthquake intensity increase (with predominant period)
- ▶ SFS system period is elongated
- ▶ Earthquake period and SFS period might coincide for some time
- ▶ If energy dissipation $>$ input \Rightarrow probably small damage in SFS system
- ▶ If energy dissipation $<$ input \Rightarrow probably large damage in SFS system, possibly resonance

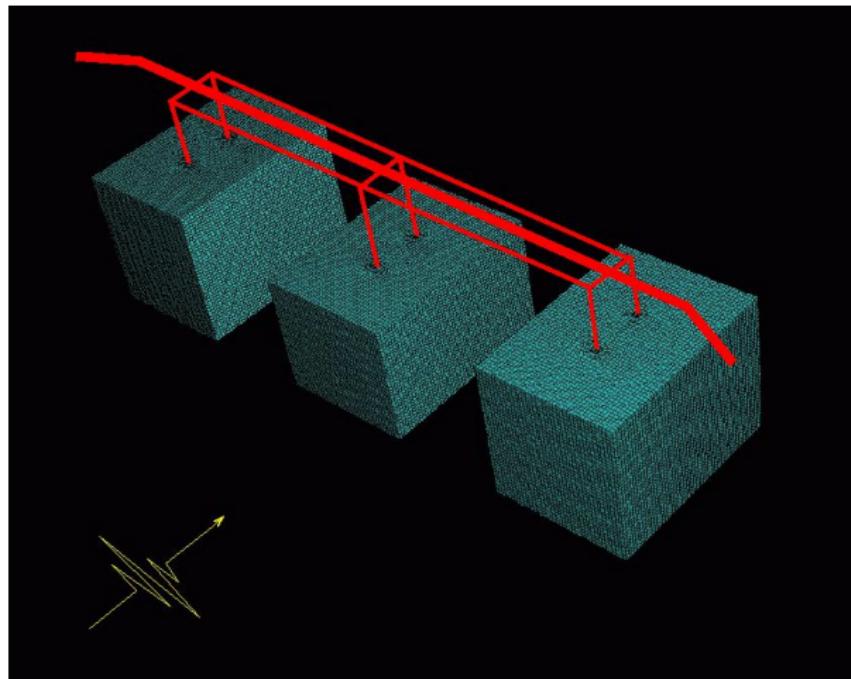
Detailed 3D, FEM model

- ▶ Construction process
- ▶ Two types of soil: stiff soil (UT, UCD), soft soil (Bay Mud)
- ▶ Deconvolution of given surface ground motions
- ▶ Use of the DRM (Prof. Bielak et al.) for seismic input
- ▶ Piles → beam-column elements in soil holes
- ▶ No artificial damping (only mat. dissipation, radiation)
- ▶ Structural model developed at UCB (Prof. Fenves et al.)
- ▶ Element size issues (filtering of frequencies)

model size (el)	el. size	f_{cutoff}	min. G/G_{max}	γ
12K	1.0 m	10 Hz	1.0	<0.5 %
15K	0.9 m	>3 Hz	0.08	1.0 %
150K	0.3 m	10 Hz	0.08	1.0 %
500K	0.15 m	10 Hz	0.02	5.0 %

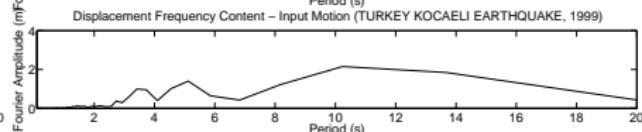
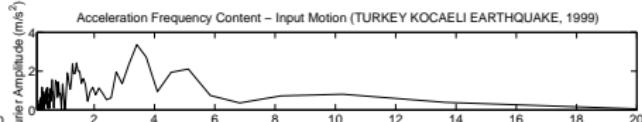
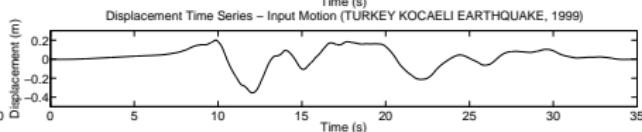
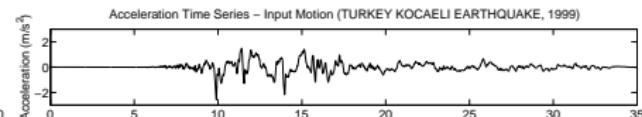
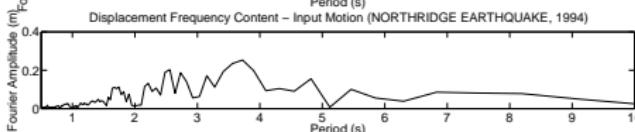
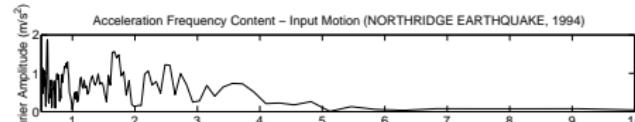
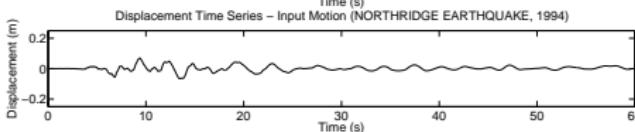
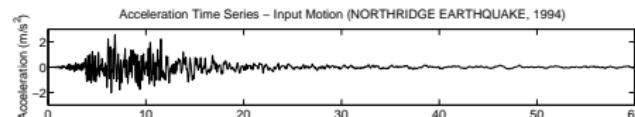
High Fidelity, 3D

FEM Mesh (one of)



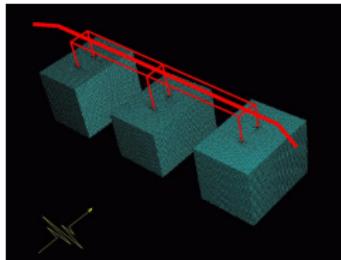
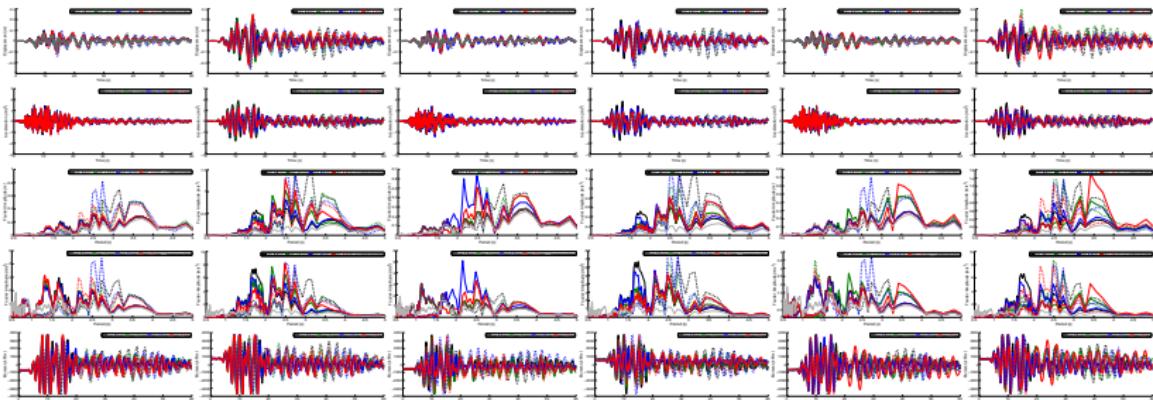
Northridge and Kocaeli Earthquakes

Northridge and Kocaeli Input Motions



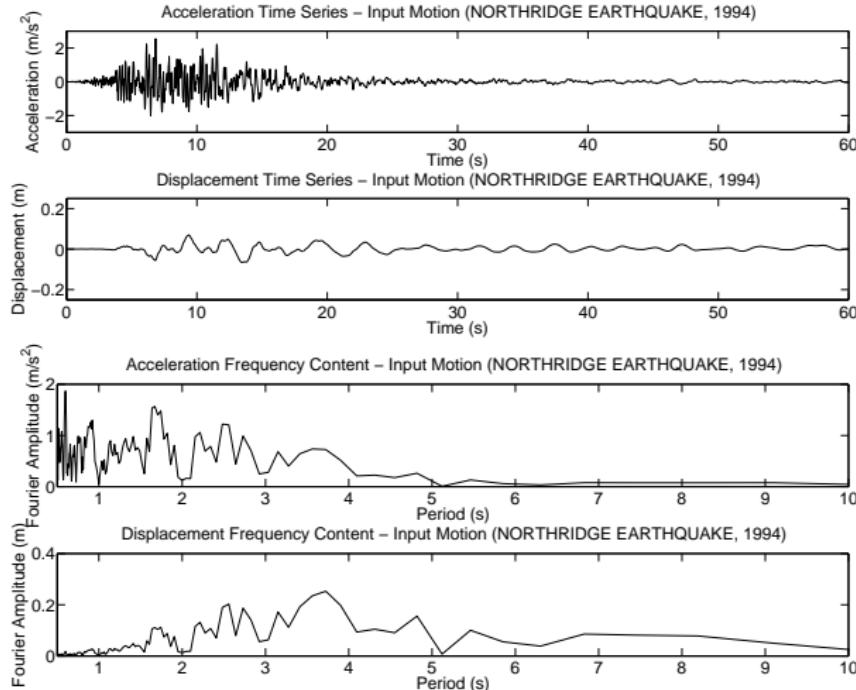
Northridge and Kocaeli Earthquakes

Simulation Results



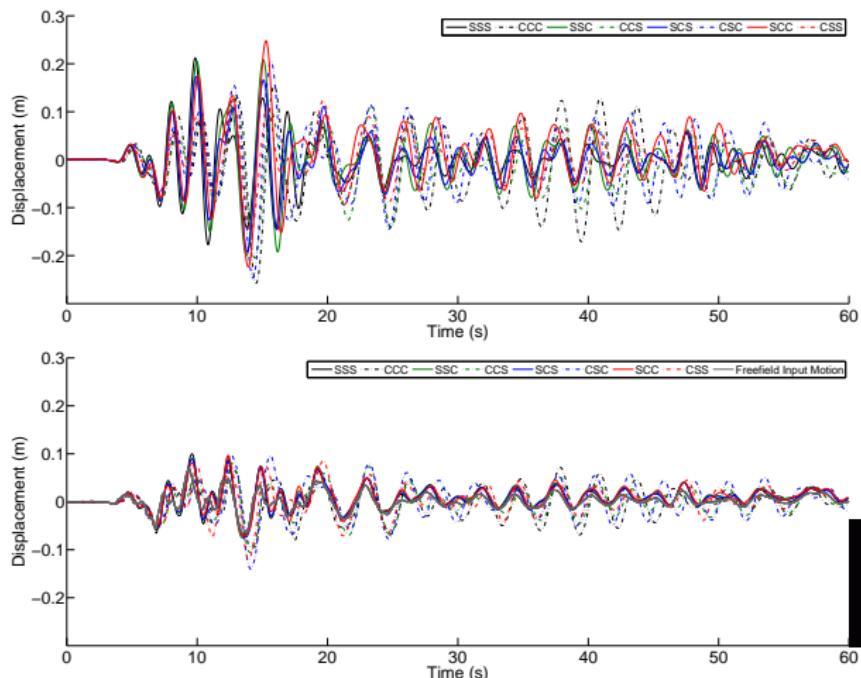
Behavior for Short Period Motions

Northridge Input Motions



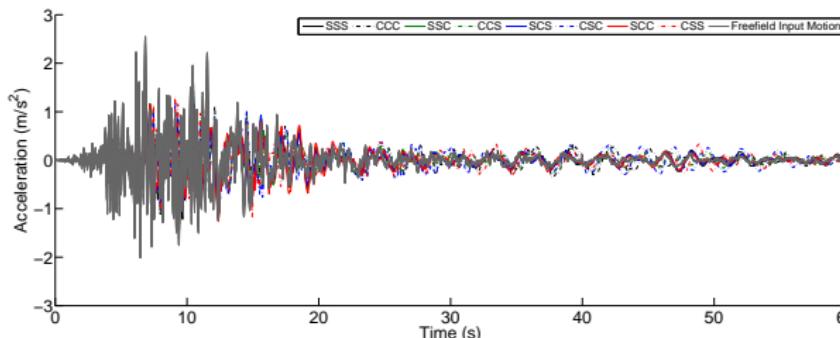
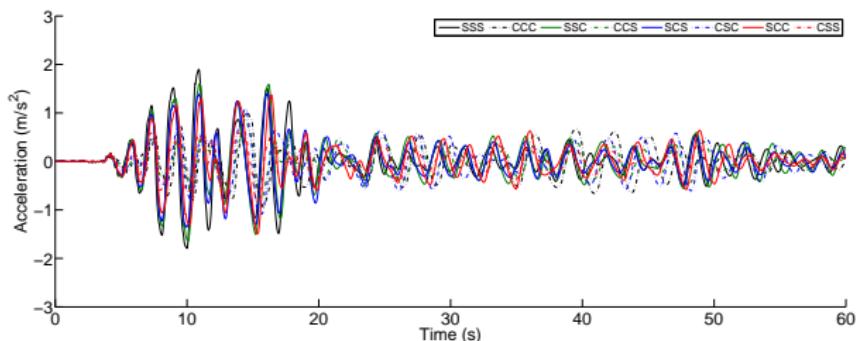
Behavior for Short Period Motions

Short Period E.: Left Bent, Structure and Soil, Disp.



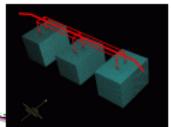
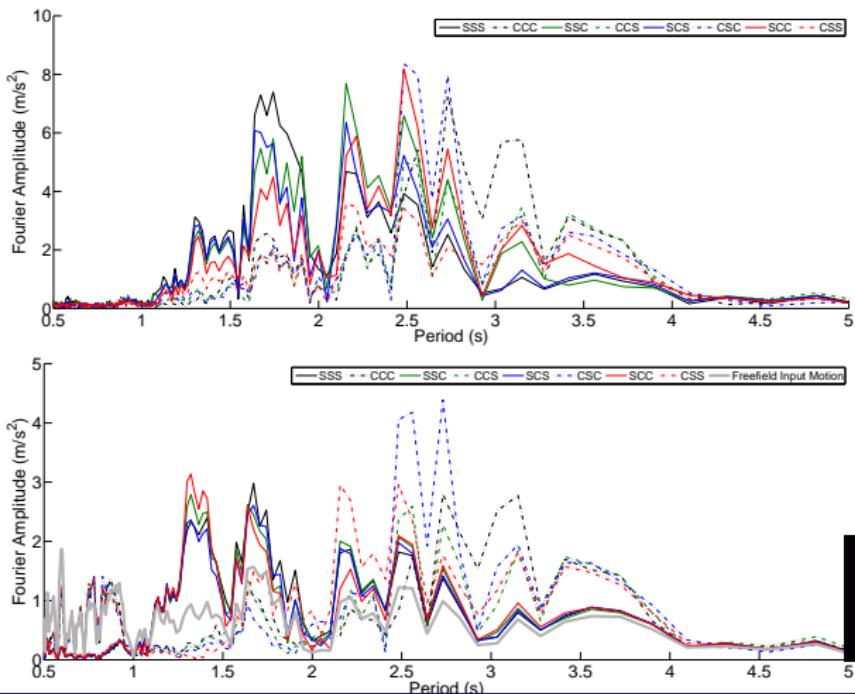
Behavior for Short Period Motions

Short Period E.: Left Bent, Structure and Soil, Acc.



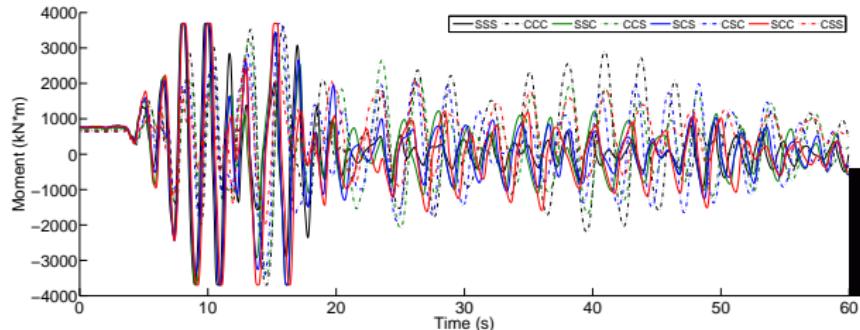
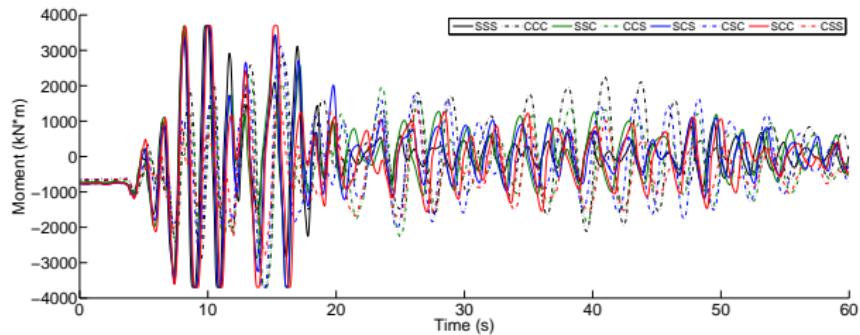
Behavior for Short Period Motions

Short Period E.: Left Bent, Structure and Soil, Acc.Sp.



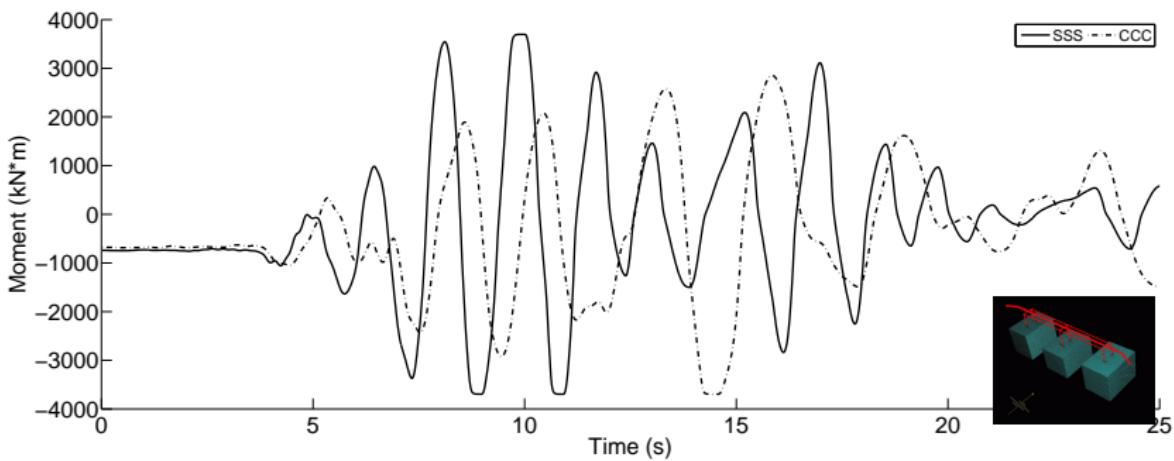
Behavior for Short Period Motions

Short Period E.: Left Bent, Structure and Soil, M.



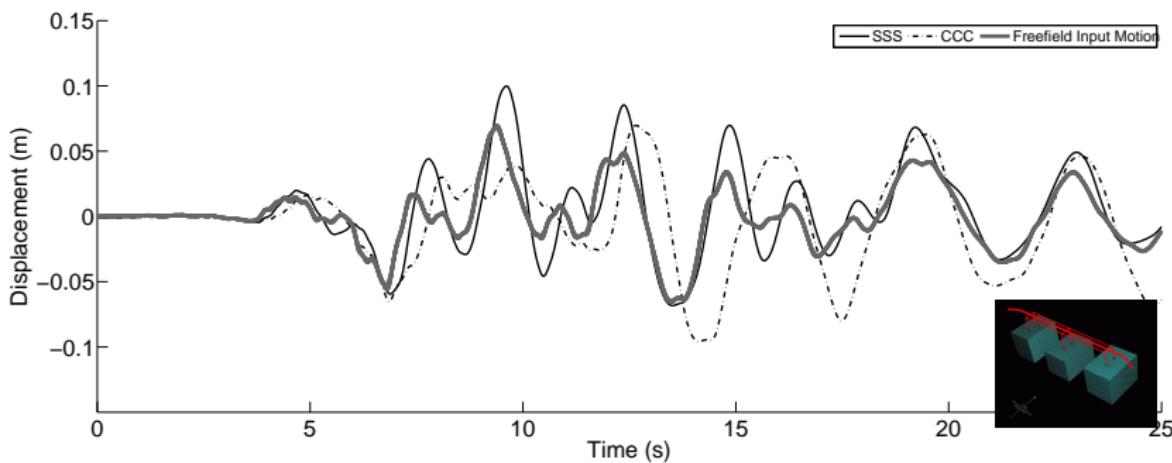
Behavior for Short Period Motions

Short Period E.: Left Bent, Structure and Soil, M.



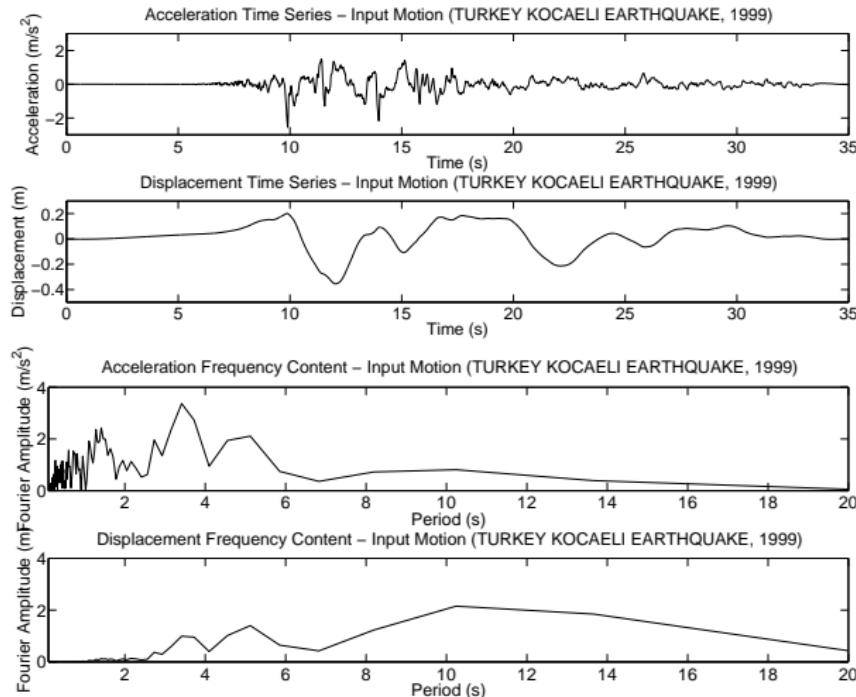
Behavior for Short Period Motions

Short Period E.: Left Bent, Free Field vs Real Disp.



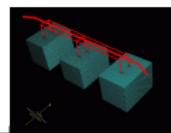
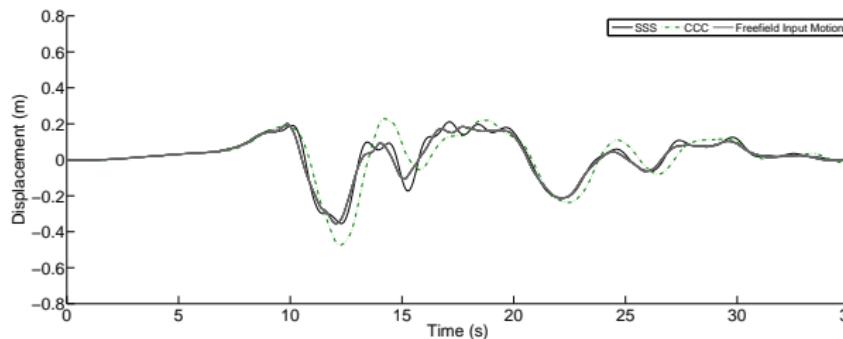
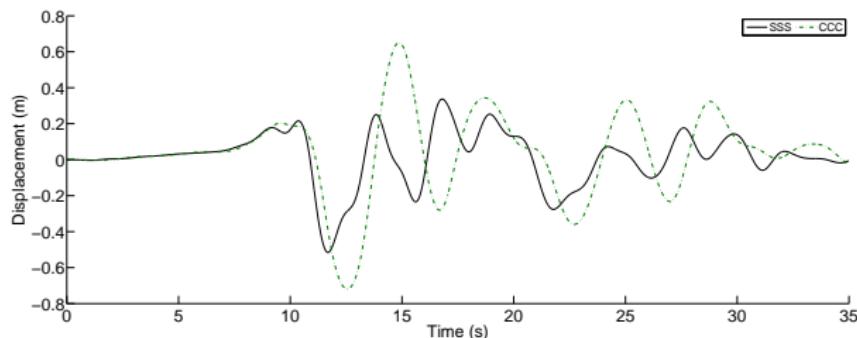
Behavior in Long Period Motions

Kocaeli Input Motions



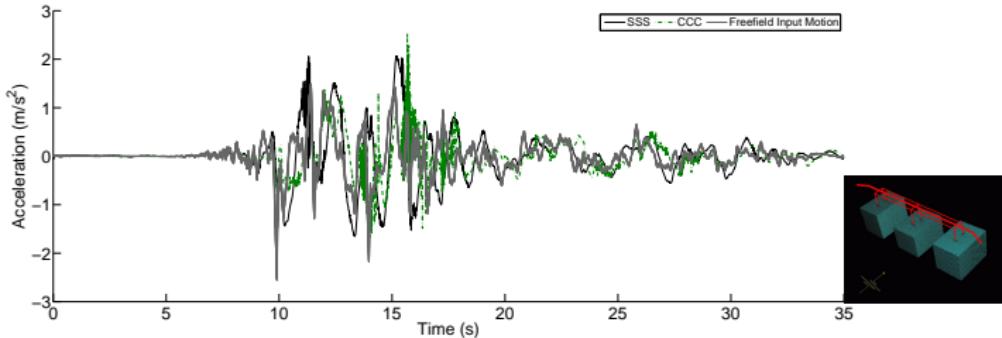
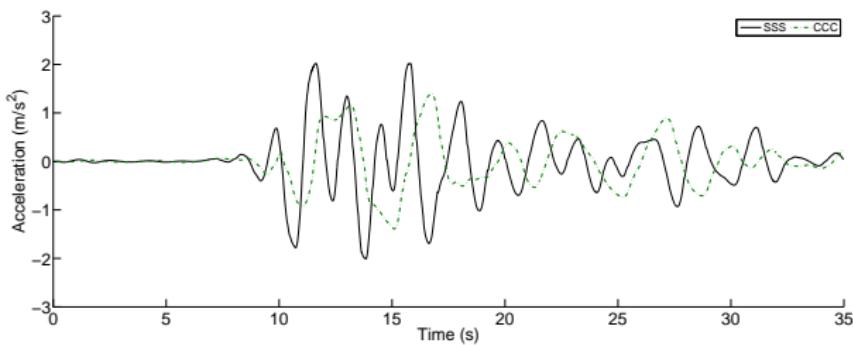
Behavior in Long Period Motions

Long Period E.: Left Bent, Structure and Soil, Disp.



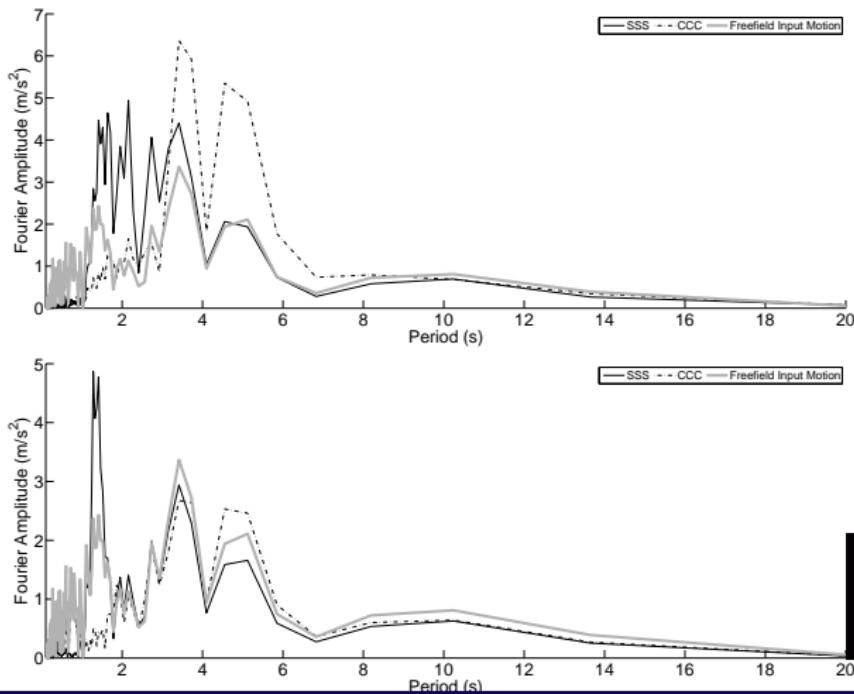
Behavior in Long Period Motions

Long Period E.: Left Bent, Structure and Soil, Acc.



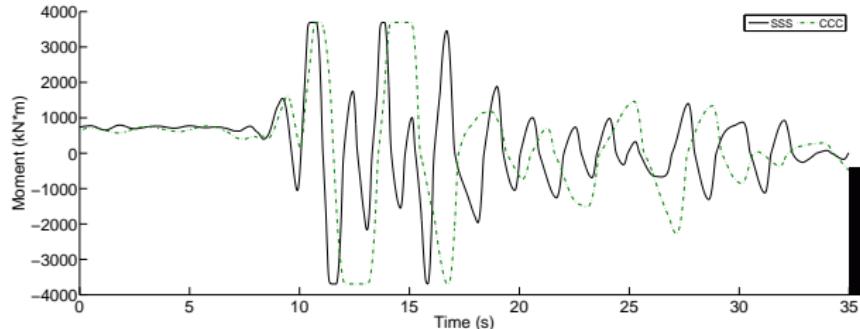
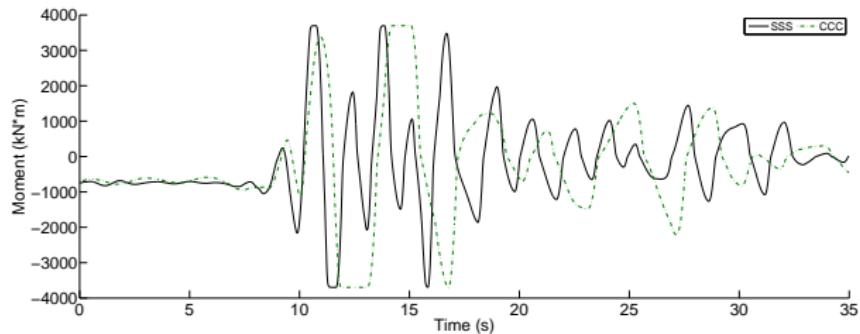
Behavior in Long Period Motions

Long Period E.: Left Bent, Structure and Soil, Acc.Sp.



Behavior in Long Period Motions

Long Period E.: Left Bent, Structure and Soil, M.



Summary

- ▶ High fidelity FEM models of SFS Bridge system
- ▶ High performance parallel computations
- ▶ Matching of earthquake, soil and structural system needed for possible benefits or detriments of SFSI
- ▶ Available in public domain (Author's web site)