High Performance, Parallel Computing for NEES, The Plastic Domain Decomposition Method

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NEES annual meeting, Washington DC, June 2006

Outline

- High Performance Computing (HPC) for NEES
  - Need for HPC: SFSI Hypothesis
  - SFSI can be Beneficial and/or Detrimental
- Plastic Domain Decomposition (PDD) Method
  - HPC Simulations for Large Inelastic SFSI Models
  - PDD: Current Status
- SFS Interaction Behavior of a Prototype Bridge
  - Model Description
  - Selected Results

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SFSI Hypothesis: Energy Balance

- Energy input from the earthquake
- Energy dissipation in SFS system:
  - Inelasticity of the superstructure (plasticity, damage, friction, active and passive dampers)
  - Inelasticity of the foundation system (piles, shallow foundations)
  - Inelasticity of soils around piles, shallow foundations and abutments (plasticity; viscous coupling of solids and fluids (water, air...)
  - Radiation damping

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

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PDD Method: Design Goals

- Graph partitioning → balance multiple phases simultaneously, while also minimizing the inter-processor communications costs
- It is a multi-objective optimization problem (minimize both the inter-processor communications, the data redistribution costs and create balanced partitions)
- Take into the account (deterministic or probabilistic):
  - heterogeneous element loads that change in each iteration
  - heterogeneous processor performance (multiple generations nodes)
  - inter-processor communications (LAN or WAN)
  - data redistribution costs

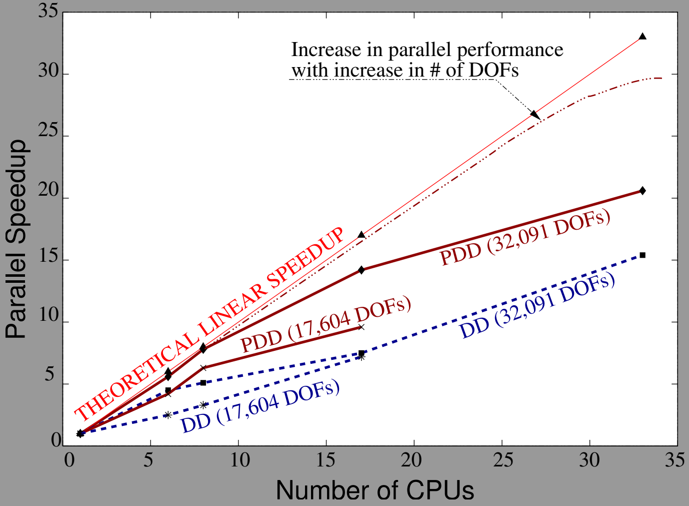
PDD Method: Implementation

- Perform global optimization for both (a) internal state determination and system of equatons solution phases
- Adaptive partitioning done using ParMETIS
- Iterative system of equations solver PETSC
- OpenSees: standard interface and framework
- Works on SMPs, local DMPs, grids of computers

Features

- Initial domain partitioning
- Adaptive domain repartitioning depending on CPU imbalance, LAN and/or WAN performance
- Repartitioning works with loads, constraints..., all necessary movable objects
- Available for all elements (solid, structural) that provide the standard OpenSees interface (sendSelf, RecvSelf, timer or CL weight estimate)
- Scalable to a large number of CPUs
- Using implicit, iterative solver (PETSC)
- Performance tuning (local cluster GeoWulf, SDSC, TACC,)

Speedup Overview



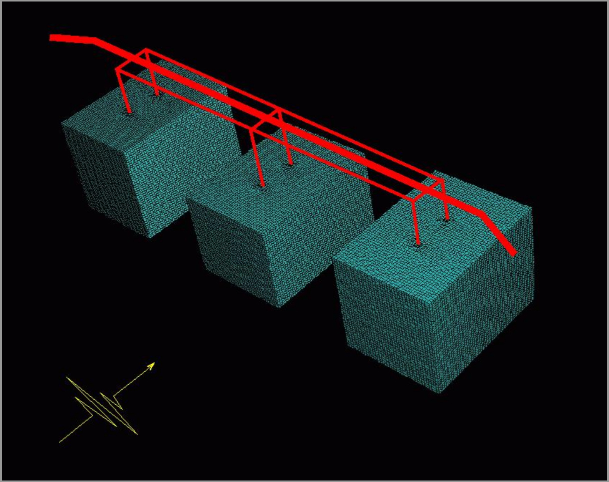
Outline

Detailed 3D, FEM model

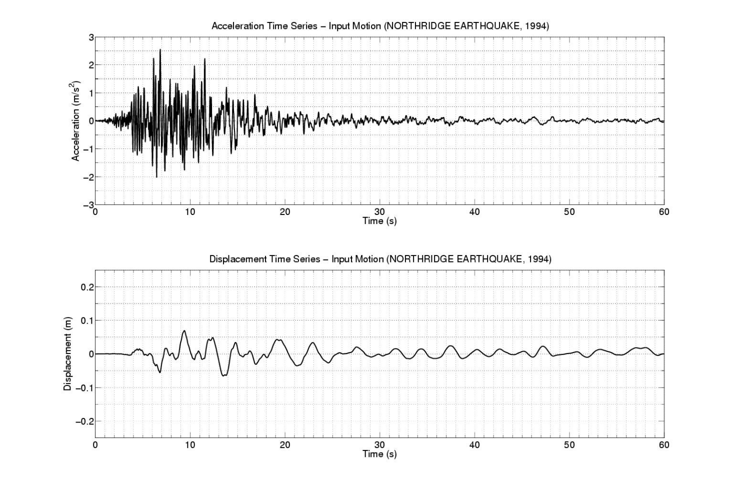
- Construction process
- Two types of soil: stiff soil (UT, UCD), soft soil (Bay Mud)
- Deconvolution of given surface ground motions
- Use of the DRM (Prof. Bielak et al.) for seismic input
- Piles $\rightarrow$ beam-column elements in soil holes
- Structural model developed at UCB (Prof. Fenves et al.)
- Element size issues (filtering of frequencies)

model size	el. size	f_{cutoff}	min. $G/Gmax$	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 %

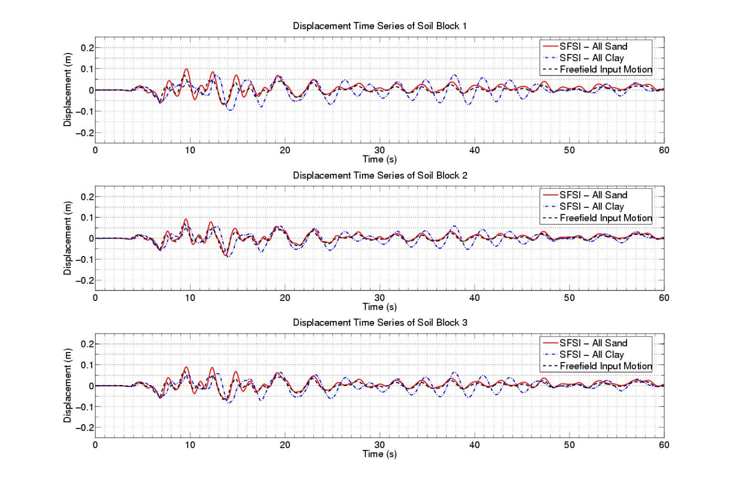
FEM Mesh (one of)



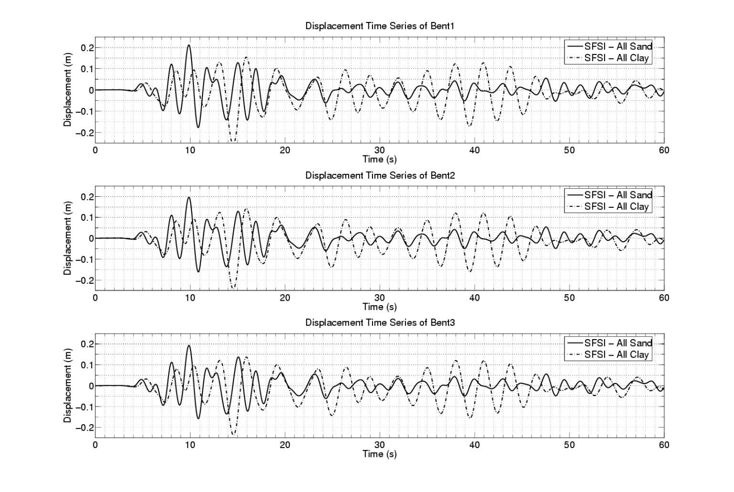
Input Motions, Northridge (one of)



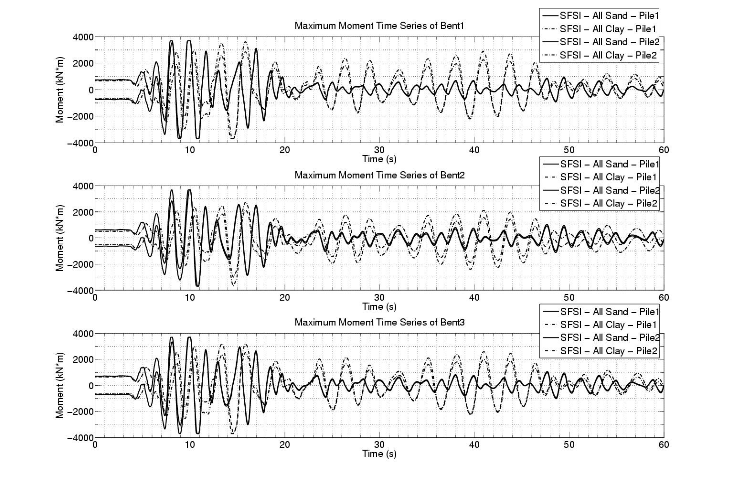
Changes to the Free Field Input Motions: SFSI



Structure Displacements



Moment Redistributions



Summary

- Need for high fidelity modeling of SFSI to gain better understanding of the system performance
- SFSI energy balance hypothesis
- HPC SFSI simulations are available, ready to be used