I-880 Bridge Testbed Simulations: Soil–Foundation–Structure Interaction Issues

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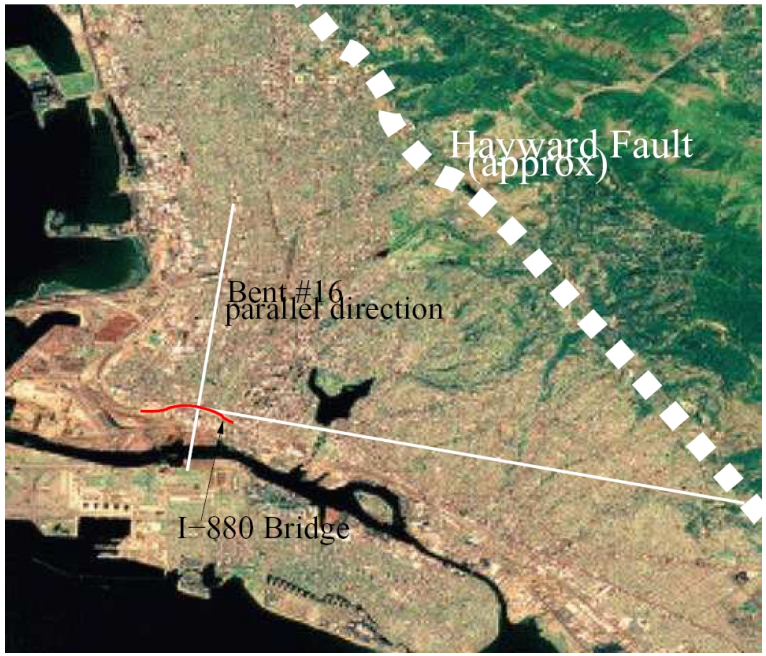
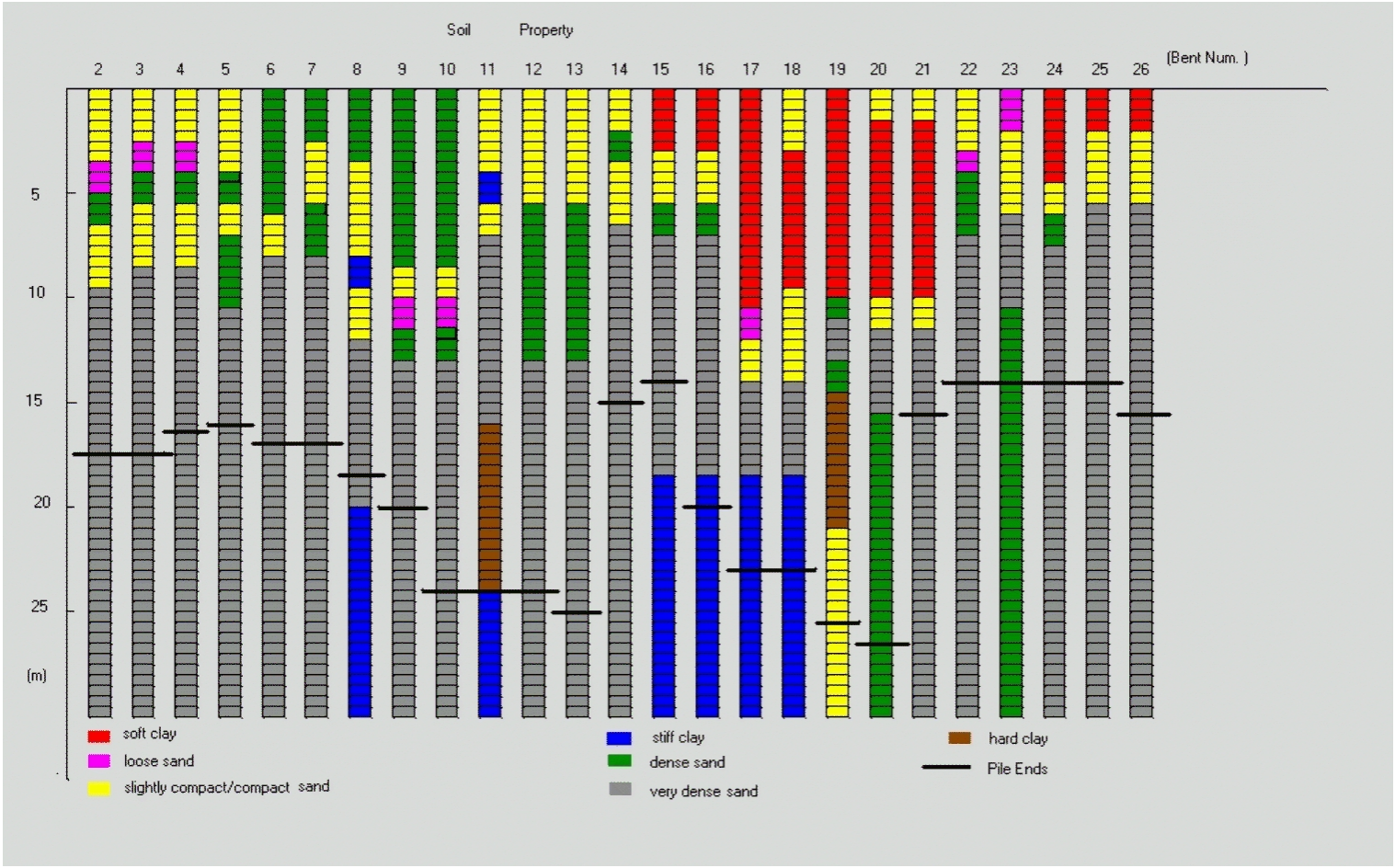
I–880 Bridge SFSI Issues

- Seismic response of I–880 viaduct using performance based engineering
- Hierarchical set of SFSI simulations models developed to represent engineering demand parameters (EDP)
- Local site conditions (inelastic SFSI interaction problem)
- Wave propagation over the bridge length (scale problem)
- Single point (spatial) far field input motions
- Stochastic distribution of materials (properties) over spatial scales

I–880: Where in the World?



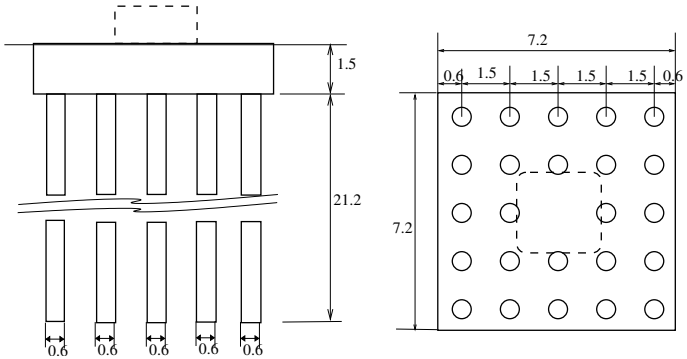
I–880: Local Site Conditions

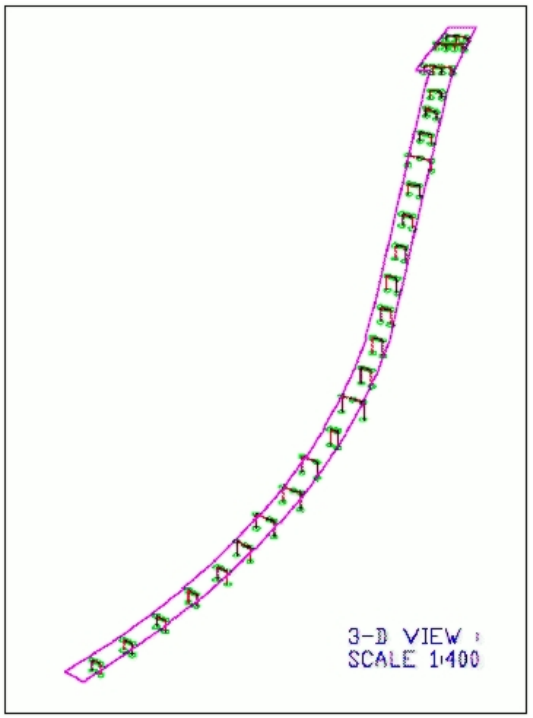


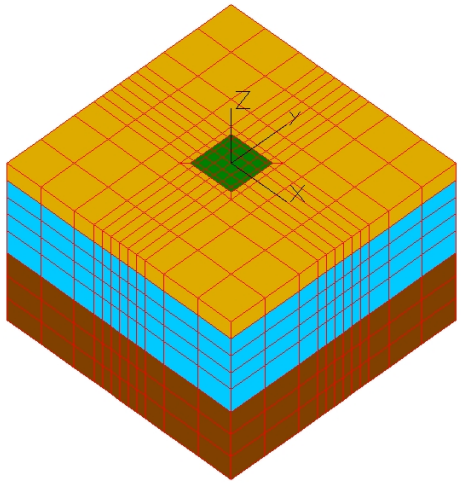
- Adjacency of foundations in soft and stiff soil
- Spatial distribution of soil materials (?)

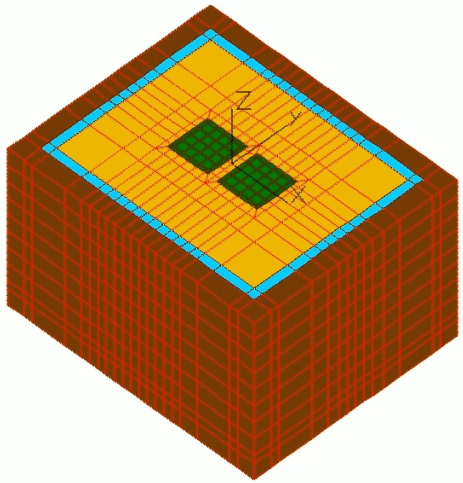
I–880: Foundation System

- Similar pile group beneath all piers

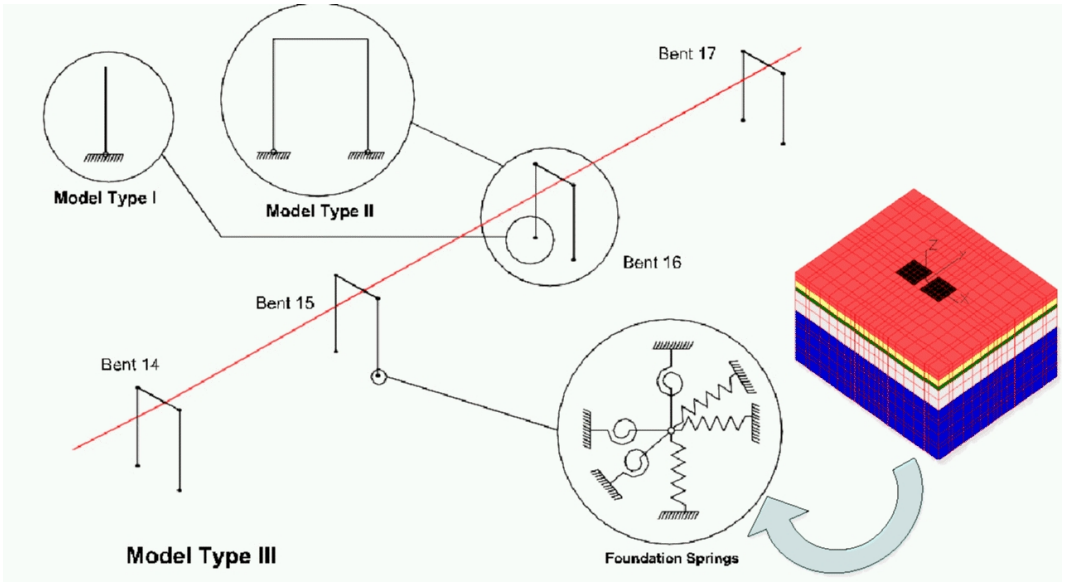


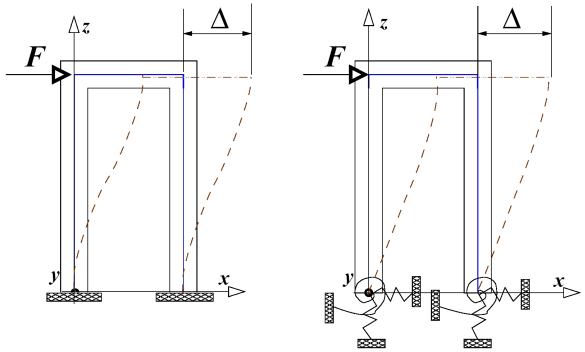


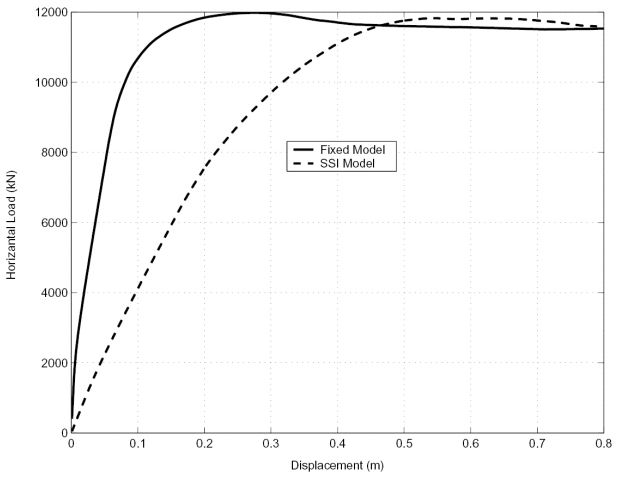


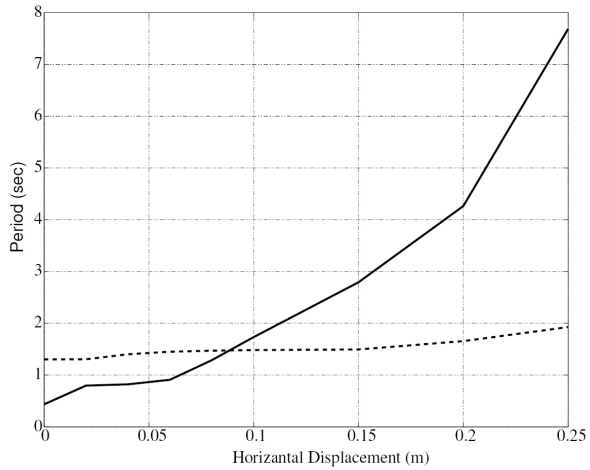


I–880: Hierarchy of Models









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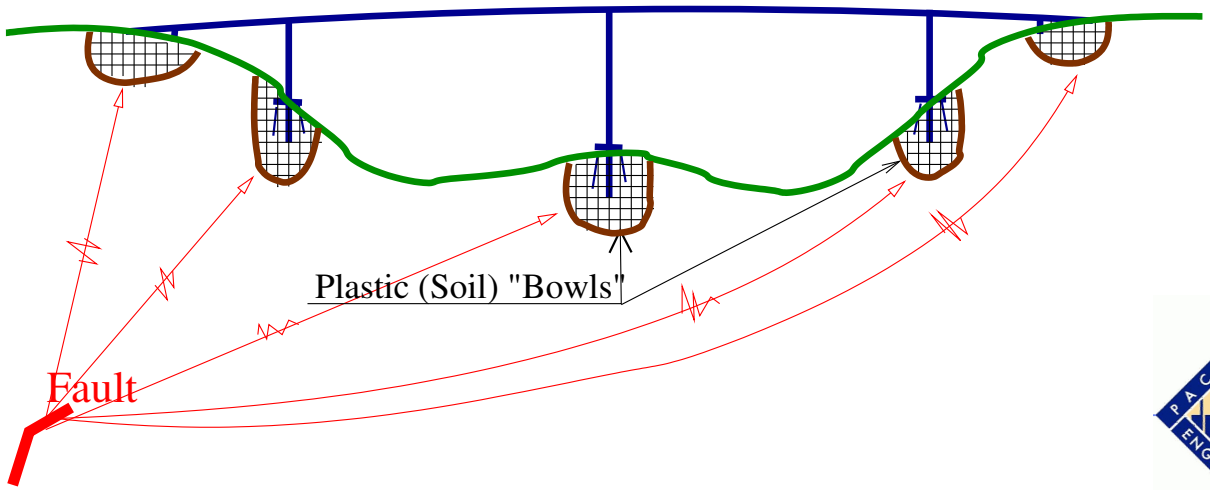
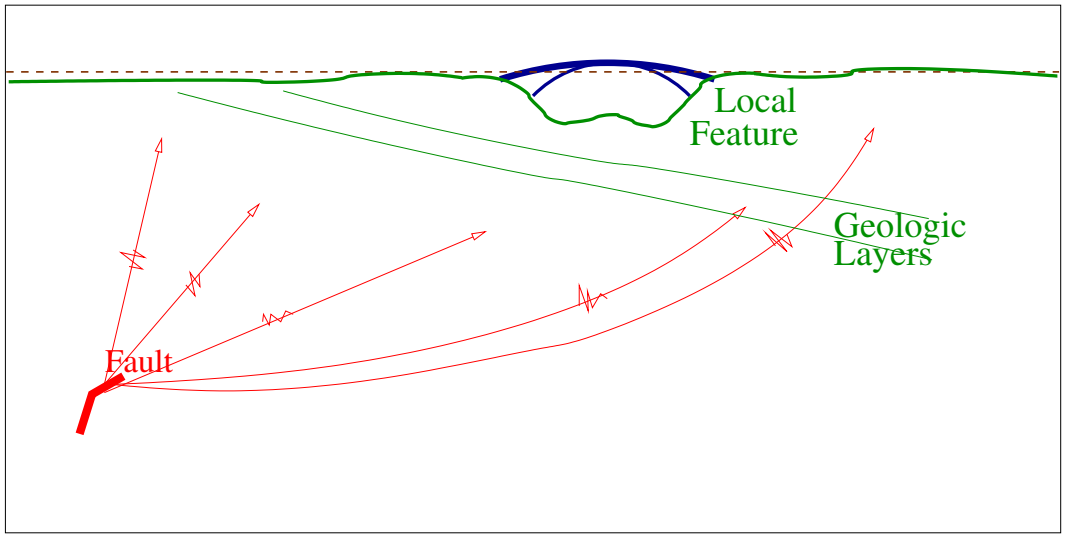
I–880: Systems Approach Where are we Going

- Currently investigated SFSI issues
  - Wave propagation over the bridge length (scale problem)
  - Single point (spatial) far field input motions
  - Stochastic distribution of materials (properties) over spatial scales
- Application of the Domain Reduction Method to the bridge system simulations



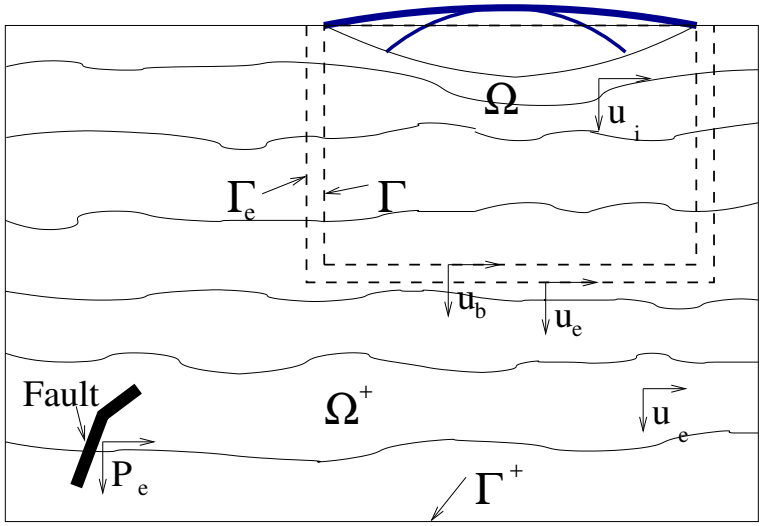
Domain Reduction Method (DRM)

- Work by Bielak et al. (since 1986, current paper: 2003, Bulletin of the Seismological Society of America) at CMU.
- Modular, two step procedure for large 3D dynamics problems.
  - Background wave field on simplified domain
  - Local wave field (coupled through acc. and disp.)
- Green's functions solutions, Quake system, SCEC database, SHAKE, 3D downhole arrays,



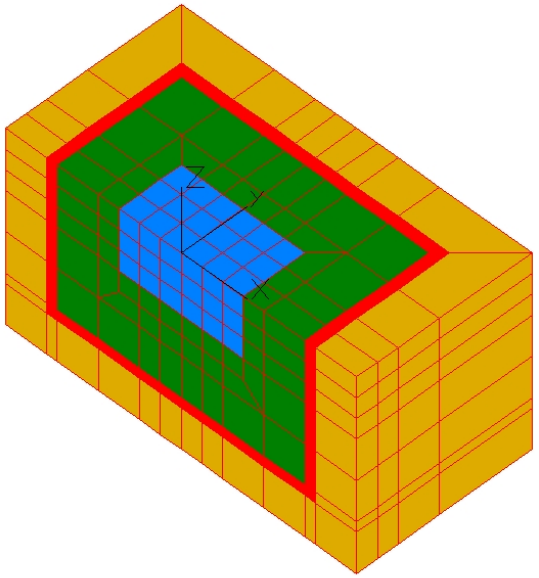
DRM: Dynamic (Seismic) Forces

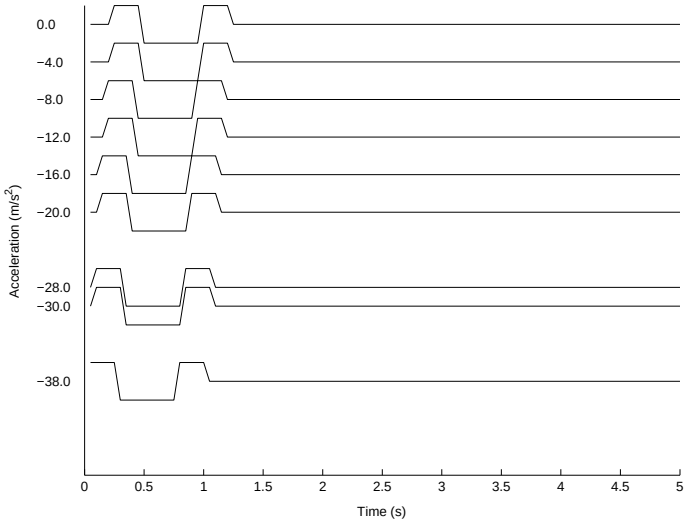
$$\left\{ \begin{array}{c} P_i^{eff} \\ P_b^{eff} \\ P_e^{eff} \end{array} \right\} = \left\{ \begin{array}{c} 0 \\ -M_{be}^{\Omega+}\ddot{u}_e^0 - K_{be}^{\Omega+}u_e^0 \\ M_{eb}^{\Omega+}\ddot{u}_b^0 + K_{eb}^{\Omega+}u_b^0 \end{array} \right\}$$

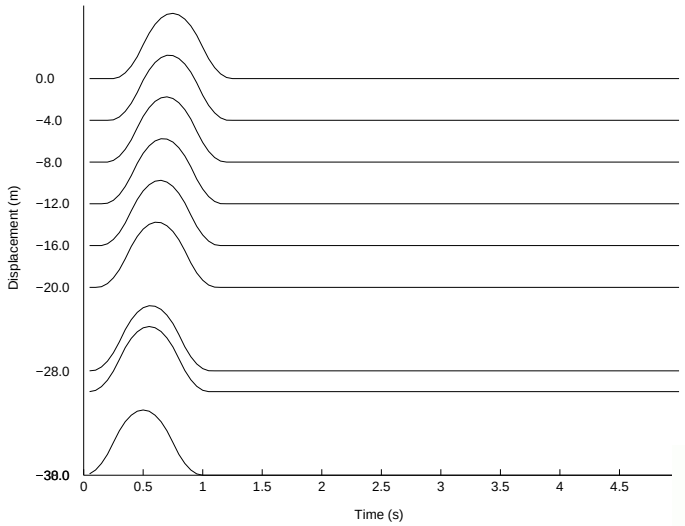


- Seismic forces P_e replaced by the effective nodal forces P^{eff},
- P^{eff} involve only submatrices, M_{be},K_{be},M_{eb},K_{eb}
- They vanish everywhere except in the single layer of elements in Ω^+ adjacent to Γ.
- The material inside Ω does not have to be linear elastic

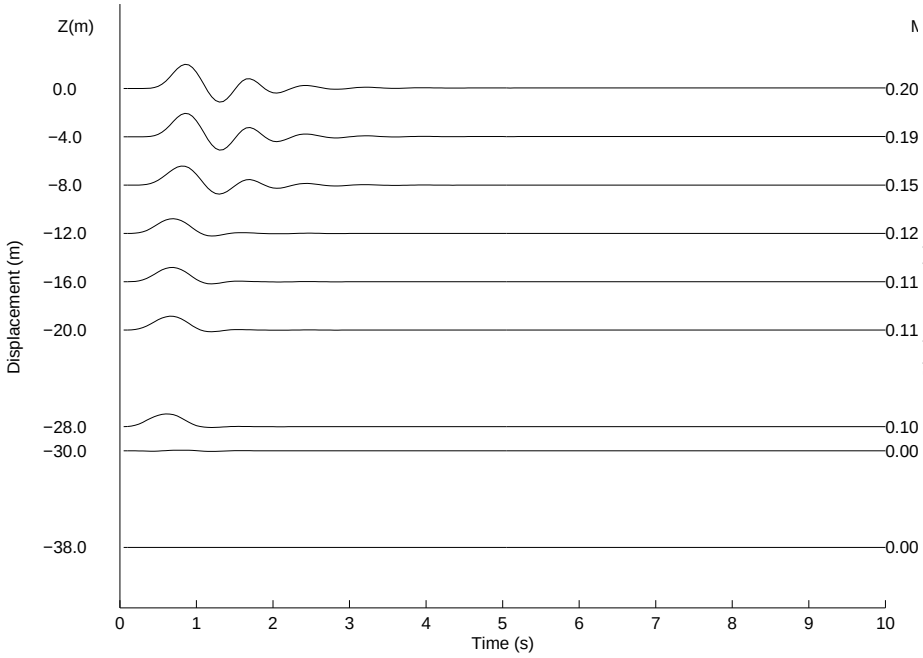
SSI Model


Z
Y
X

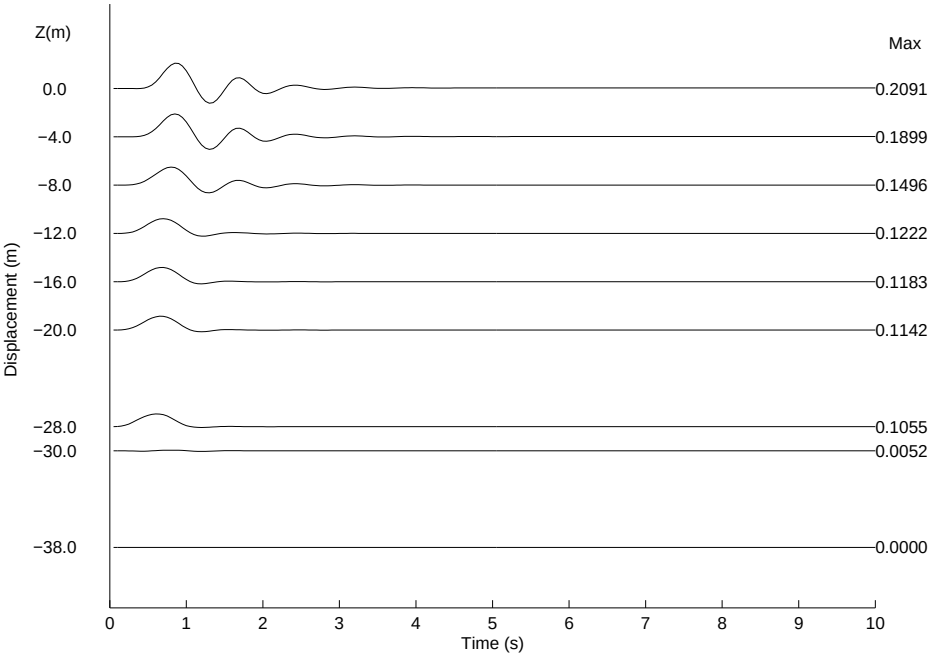

0.0
−4.0
−8.0
−12.0
−16.0
−20.0
−28.0
−30.0
−38.0
Acceleration (m/s²)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (s)


0.0
−4.0
−8.0
−12.0
−16.0
−20.0
−28.0
−30.0
Displacement (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Time (s)

SSI Model: Stiff Soil

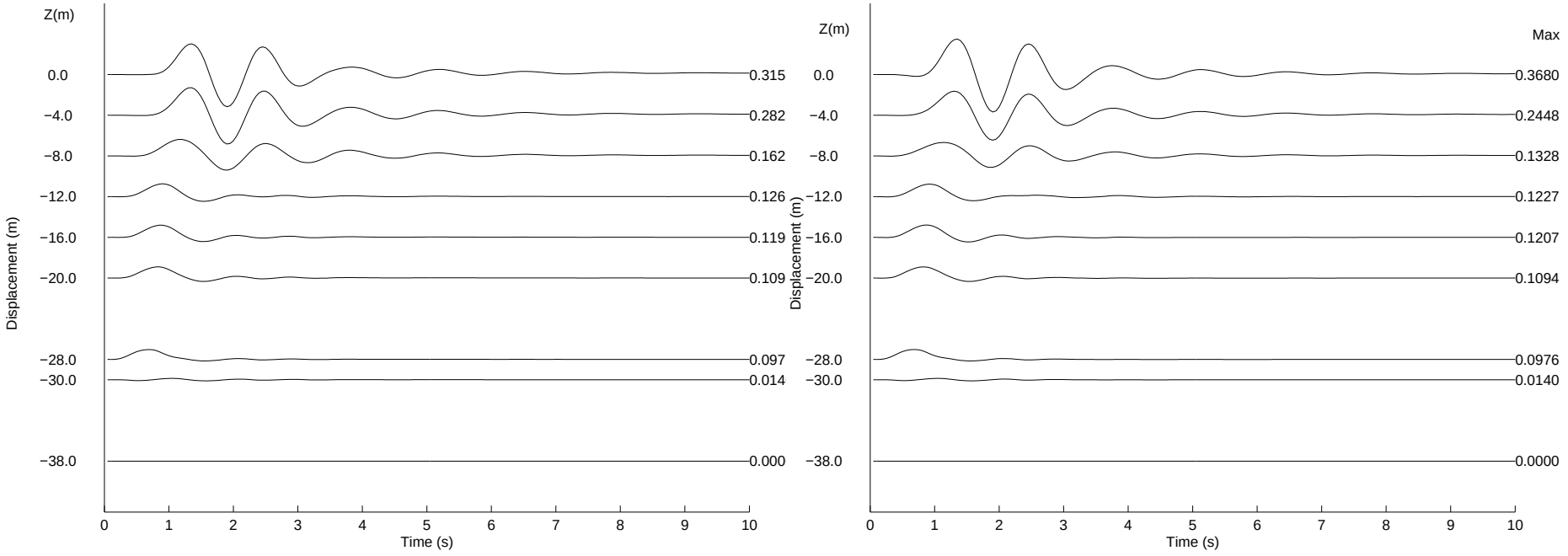


Free field



SFSI

SSI Model: Soft Soil



Free field

SFSI

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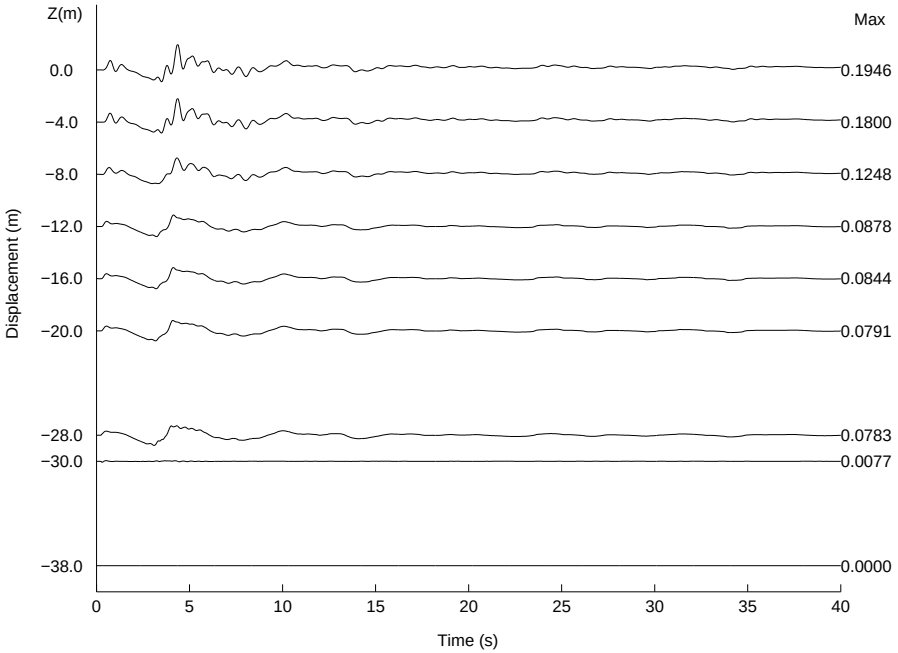
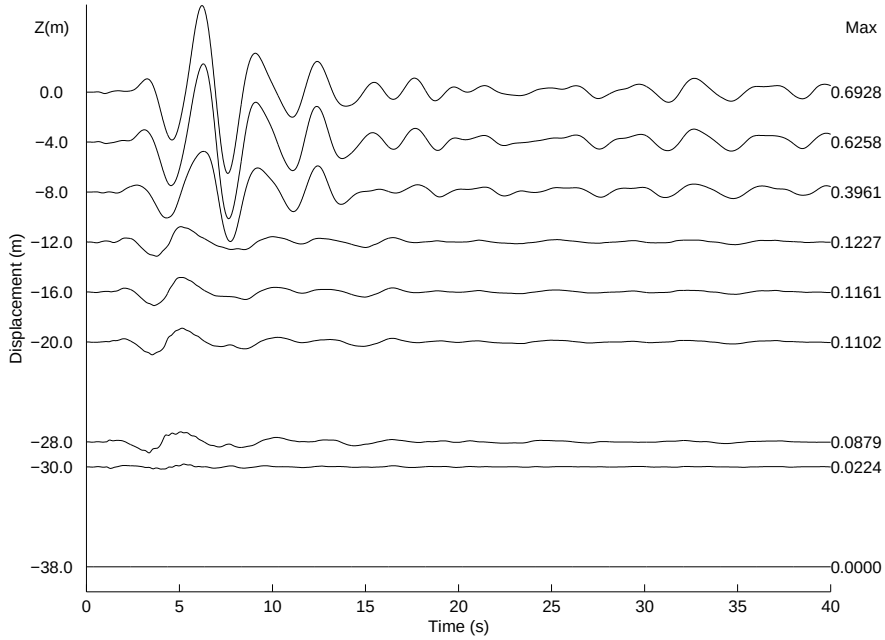
SSI Model: Seismic Amplification



Stiff soil



Soft soil

Currently in Works

- Generation of background wave fields from point seismic motions data

- Development of full soil–foundation–structure bridge model to investigate influences of
  - Local site amplifications
  - Coherency loss (stochastic variations)
  - Time lag (wave passage effects)