NIST 2012 Soil-Structure Interaction Guidelines for Applications to Buildings

Jonathan P. Stewart

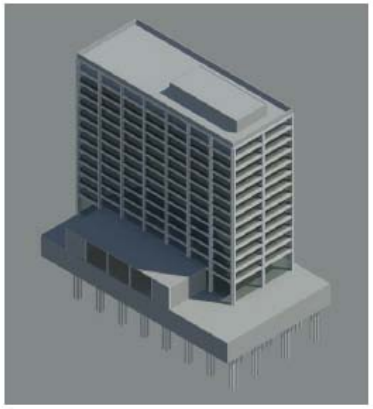
Professor and Chair, C&EE Dept., UCLA

SCEC an NSF+USGS center

SCEC Workshop on Soil-Structure Interaction of Complex Systems

January 29, 2015

NIST GCR 12-917-21



Soil-Structure Interaction for Building Structures

NEHRP Consultants Joint Venture
A partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering

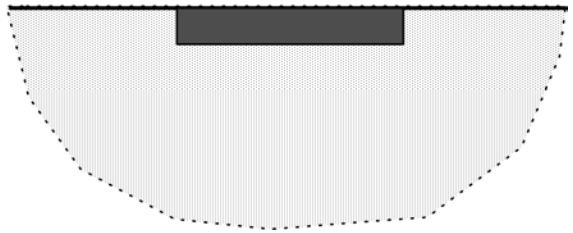
Available at: http://www.nehrp.gov/pdf/nistgcr12-917-21.pdf

Outline

- Technical issues addressed by project
- Under what conditions SSI effects are significant
- SSI applications and state of practice
- Example applications (problem-focused studies)

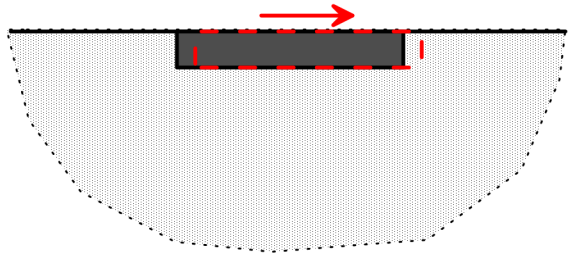
Technical Issues Addressed

- Flexibility from foundation-soil interaction



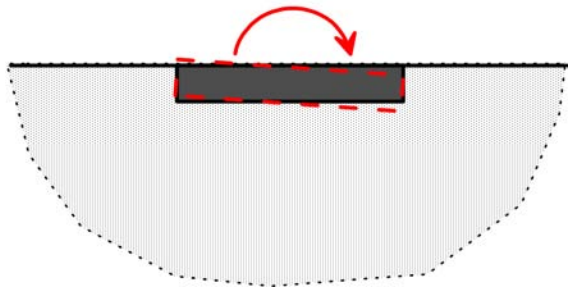
Technical Issues Addressed

- Flexibility from foundation-soil interaction



Technical Issues Addressed

- Flexibility from foundation-soil interaction

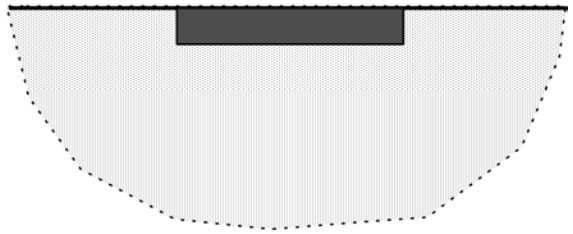


Major elements:

- Impedance equations for rigid rectangular foundations on uniform soil
- Adapting for realistic soil profiles
- Adapting for non-rigid foundations
- Limiting spring capacities and nonlinear effects
- Effects of piles and pile groups
- Role of field testing

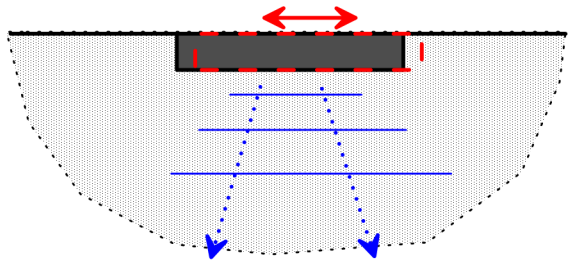
Technical Issues Addressed

- Flexibility from foundation-soil interaction
- Foundation damping



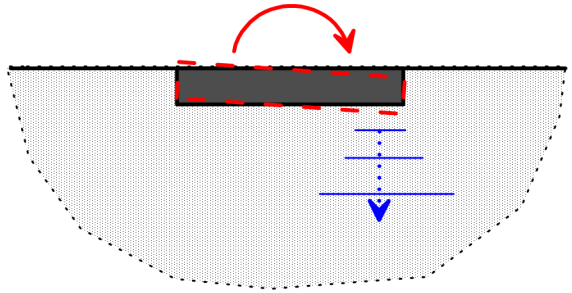
Technical Issues Addressed

- Flexibility from foundation-soil interaction
- Foundation damping



Technical Issues Addressed

- Flexibility from foundation-soil interaction
- Foundation damping

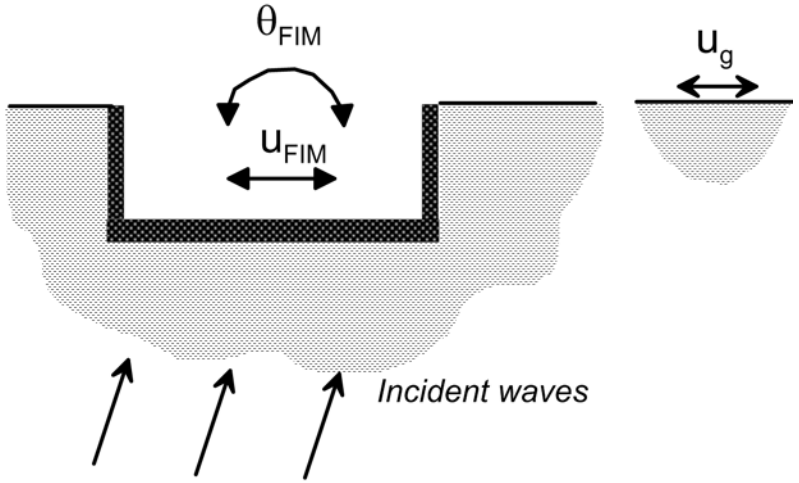


Highlights:

- Damping expressed in form of ratios instead of more traditional dashpots or complex component of impedance
- Relative importance of radiation damping from shear and rotational vibration modes
- Effects of nonlinearity on soil and radiation damping terms
- Important roles of field testing

Technical Issues Addressed

- Flexibility from foundation-soil interaction
- Foundation damping
- Ground motion modification from free-field to foundation



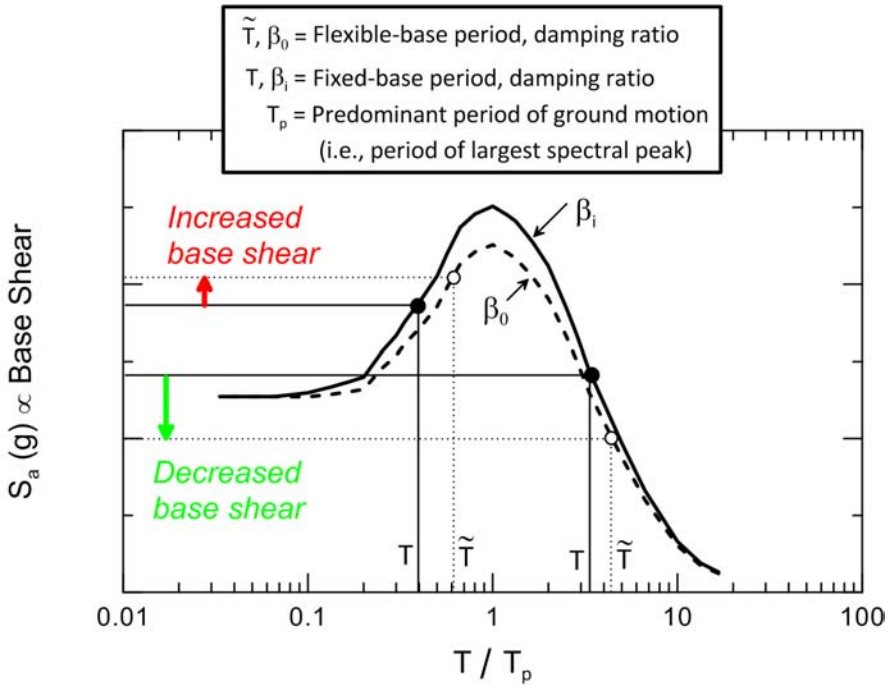
(b) Kinematic Interaction

Important role of field case histories.

Limited and conflicting information for pile-supported foundations

When Is SSI Significant?

- Flexibility lengthens period: $T \rightarrow \tilde{T}$
- Foundation damping (b_f) contributes to structural system damping: b_i b_0
- Good metric for significance: $h/(V_S T)$. Controls $\tilde{T}/T$ and b_f

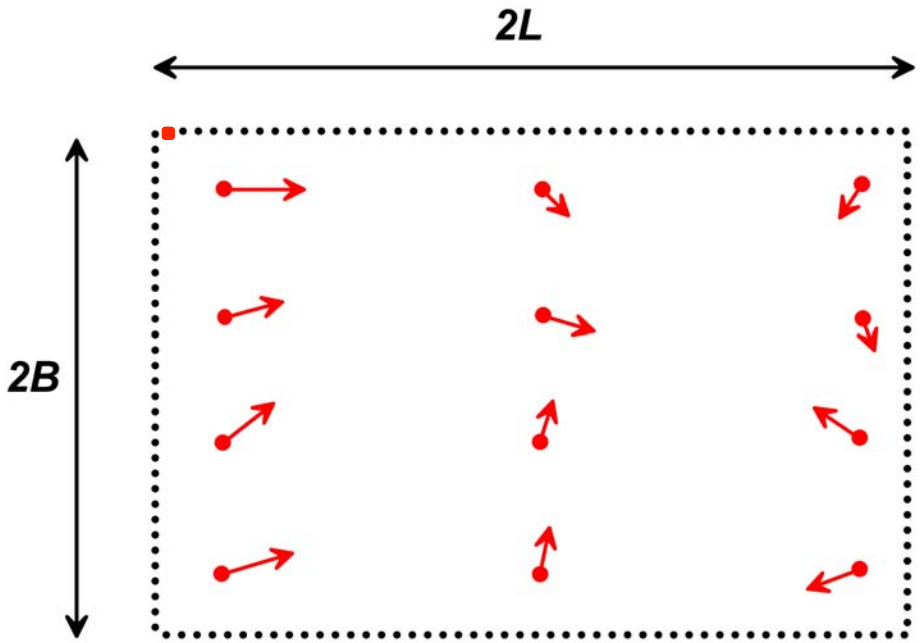


When Is SSI Significant?

- Drivers of 'Kinematic SSI' independent of those for 'inertial SSI'

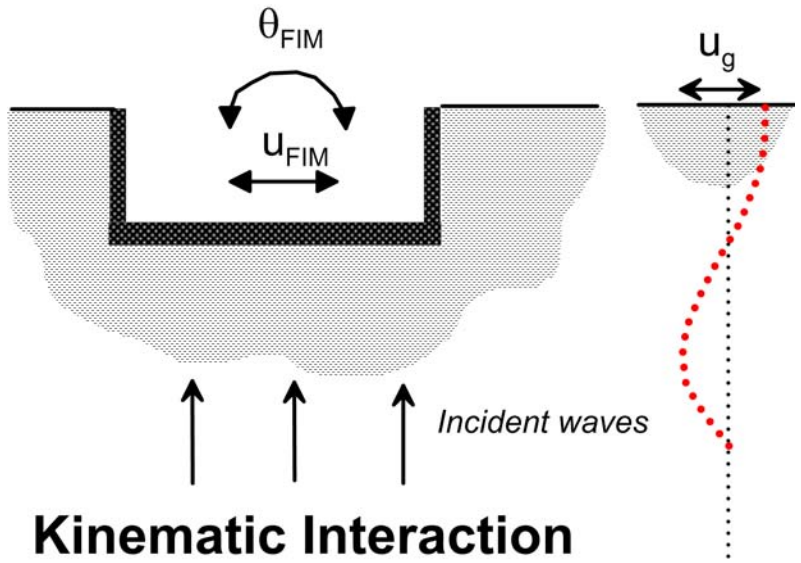
When Is SSI Significant?

- Drivers of 'Kinematic SSI' independent of those for 'inertial SSI'
- *Base slab averaging*: depends mostly on foundation area



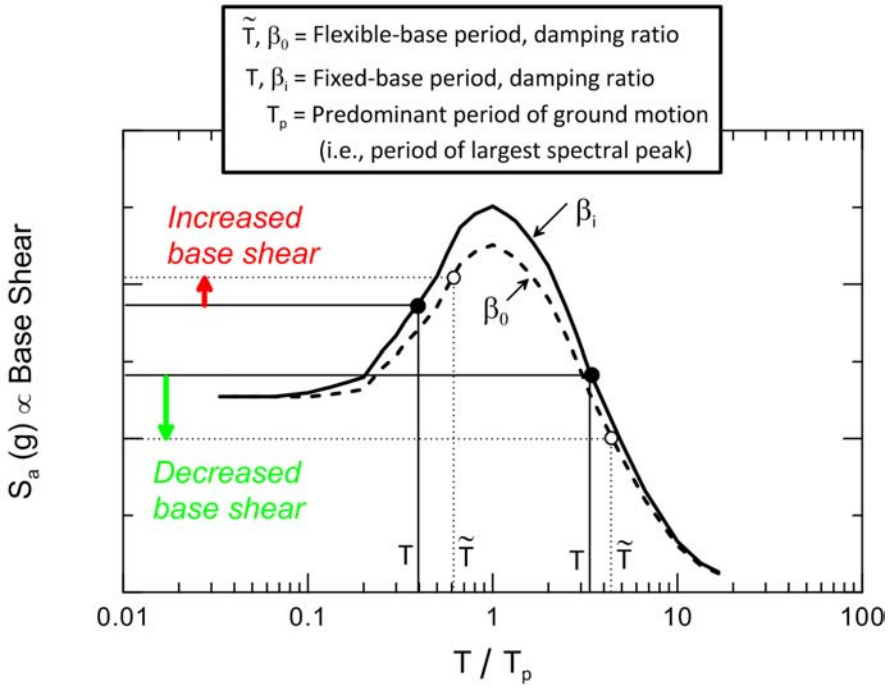
When Is SSI Significant?

- Drivers of 'Kinematic SSI' independent of those for 'inertial SSI'
- *Base slab averaging*: depends mostly on foundation area
- *Embedment*: depends mostly on foundation depth



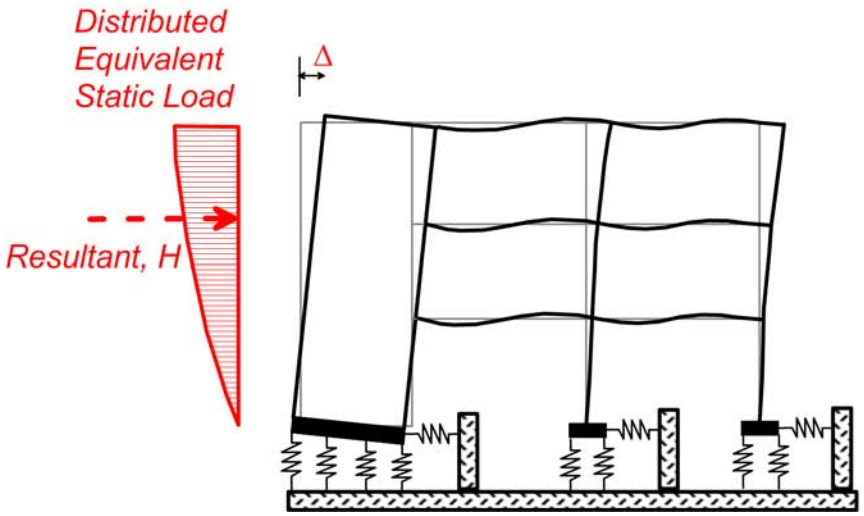
SSI Applications

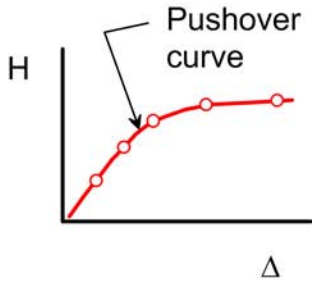
- Equivalent lateral force procedures: change in base shear. ***New:*** change in spectra.



SSI Applications

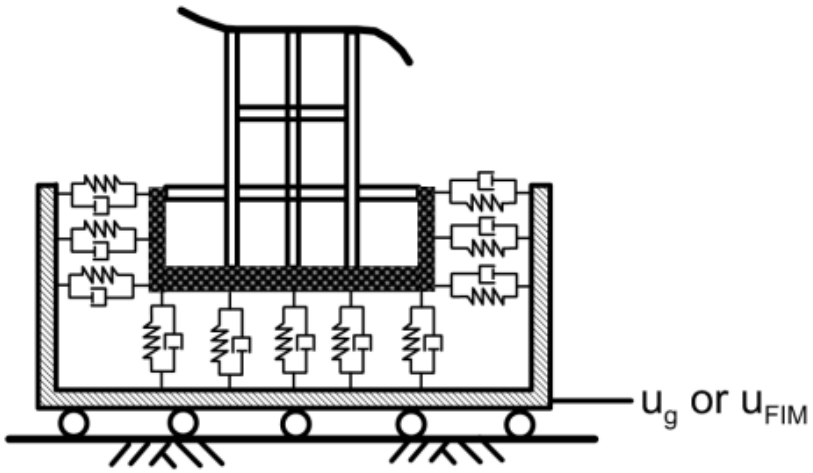
- Equivalent lateral force procedures: change in base shear.
- Pushover procedures: flexibility, foundation damping, SD change





SSI Applications

- Equivalent lateral force procedures: change in base shear
- Pushover procedures: flexibility, foundation damping, SD change
- Response history procedures: flexibility, damping, time series



(4) Rigid bathtub model

Summary of Key Points

What field and laboratory investigations are required to develop soil springs and dashpots for SSI analysis?

Characterization of site profile

Shear strength parameters (undrained below water table)

Seismic velocities

Under what conditions are the use of soil springs/dashpots important and what structural response parameters are affected?

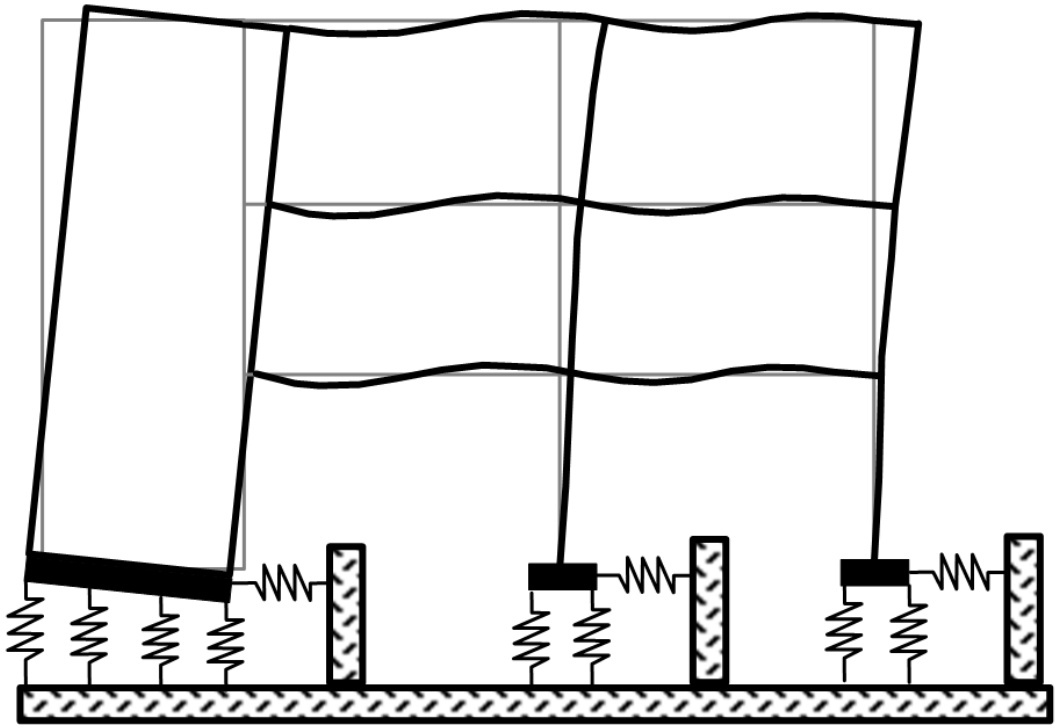
Under what conditions are the use of soil springs/dashpots important and what structural response parameters are affected?

Stiff structures (shear walls, braced frames, etc.)

$h/(V_s T) > 0.1$

Dual systems (esp. if one is stiff)

Dual System: Wall-frame



Under what conditions is the use of soil springs/dashpots important and what structural response parameters are affected?

Structural period

System damping

Vertical distribution of EDPs

EDPs for lateral elements in dual systems

Subterranean demands

For what conditions is consideration of the differences between foundation and free-field ground motions important?

Buildings with multi-level basements

Large plan areas

Structures with short fundamental mode periods or significant contributions from higher modes

Do not:

- Use conventional coefficients of subgrade reaction for dynamic spring stiffnesses
- Use limiting foundation pressures derived from settlement considerations or factored bearing capacity to develop limiting spring forces
- Reserve consideration of SSI only for “important” (often tall) buildings
- Assume that ignoring SSI is always conservative