



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

EARTHQUAKE RESISTANT DESIGN OF FOUNDATIONS

Lecture 36: Soil-Pile Interaction (SPI)

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ERD of Foundations - Modules

1. Introduction
2. Shallow Foundations
3. Pile Foundations
4. Well Foundations
5. SSI for Deep Foundations
6. Miscellaneous

Module - 5

SSI for Deep Foundations



Module - 5: Chapters

1. Introduction to Soil-Structure Interaction
2. Effects of Soil-Structure Interaction
3. SGM and Wave Propagation
4. Dispersion & Attenuation of Waves, Damping
5. Ground Response Analysis (GRA)
6. Soil-Pile Interaction

Chapter-6: Soil-Pile Interaction (SPI)

- 1. Recent Advances in Soil-Structure Interaction**
- 2. SPSI using Kelvin Elements at Boundary**
- 3. Evaluation of Soil Parameters in Laboratory**

Recent Advances in SSI

Significant advancement has been made in SSI studies in last three decades. With the advances in computer technology now it is possible to model and analyze SSI problems more rigorously. Most of these advances are on two major and very important issues.

- (1) Though the soil is an unbounded domain, still its precise modeling is possible
- (2) The behavior of soil during strong excitation is highly nonlinear and for saturated loose sands even the liquefaction may occur

However, till today no commercial software such as SASSI, FLUSH, FLEX, CLASSI, FLAC3D, DYNA4, PLAXIS3D adequately deals with these important issues.

Recent Advances in SSI

Our Research Group including Ph.D. students (Emani, Sarkar, Syed) worked extensively in the area of SSI and SPSI.

- Maheshwari (1997) introduced Material & Geometrical Nonlinearity in the theory by Kaynia and Kausel (1982) for Pile Dynamics
- Maheshwari (2003) used Kelvin Elements to model the Boundary and HiSS soil model to deal with Nonlinearity
- Emani (2008) carried out Nonlinear SSI analysis using CIFEEM for Boundary and used Hybrid methods
- Sarkar (2009) considered Liquefaction for SSI analysis
- Syed (2014) modeled the Boundary using SBFEM and Nonlinearity of Soil using HiSS soil model

Modeling of Boundary: Approximate

These boundaries are local in space and time

- **The Elementary Boundaries**
- **The Viscous Boundaries**
- **Kelvin Elements**
- **Transient Transmitting Boundary**
- **Infinite Elements**

Soil-Pile-Structure Interaction using Kelvin Elements at Boundary

Soil-Pile-Structure Interaction

For structures supported on pile foundations

problem of SSI => Soil-Pile-Structure interaction (SPSI)

Response of SPSI System =

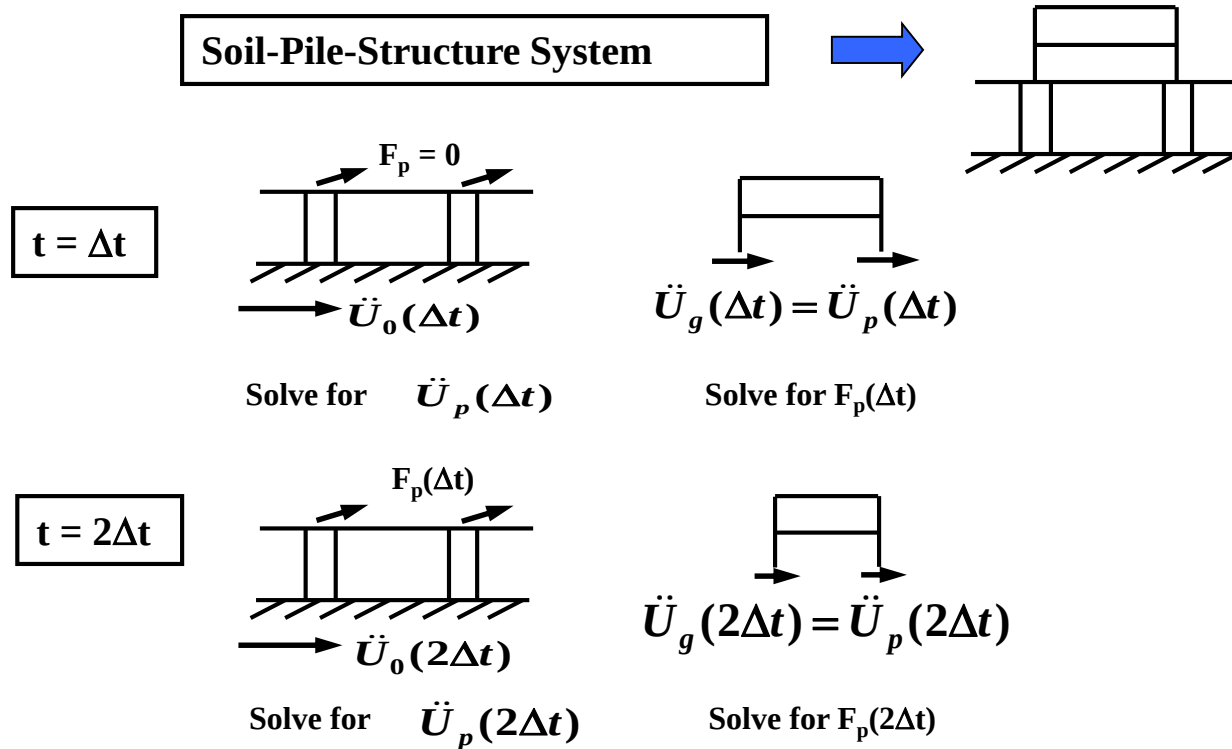
Kinematic Interaction + Inertial Interaction

For SPS System 2 Types of Interaction Effects

(a) Soil-Pile Interaction (Pile-Soil-Pile for Group)

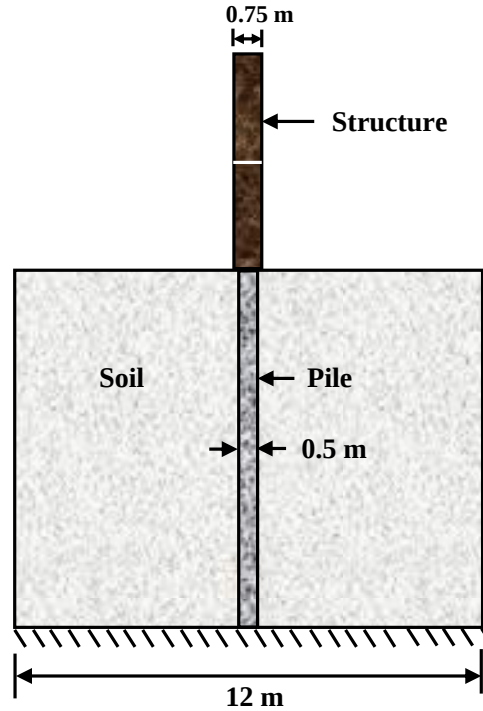
(b) Foundation-Structure Interaction

Linear Analysis: Successive Coupling Scheme

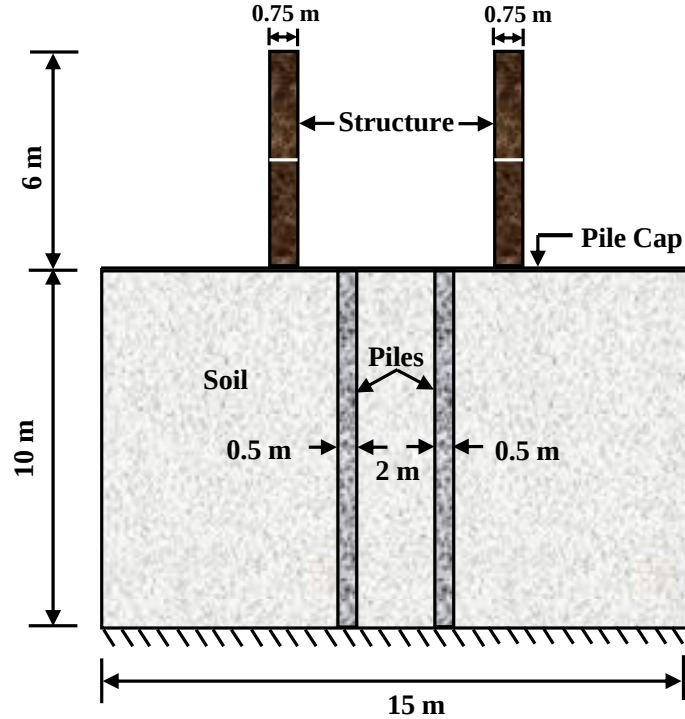


Soil Dynamics and Earthquake Engineering (2004), 24(4), 345-358

SPS Systems Considered



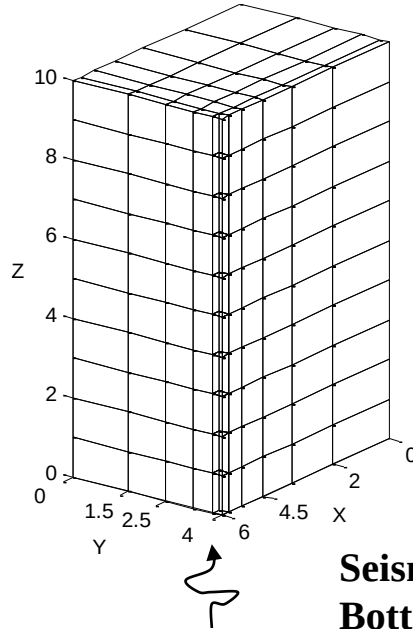
Single Pile System



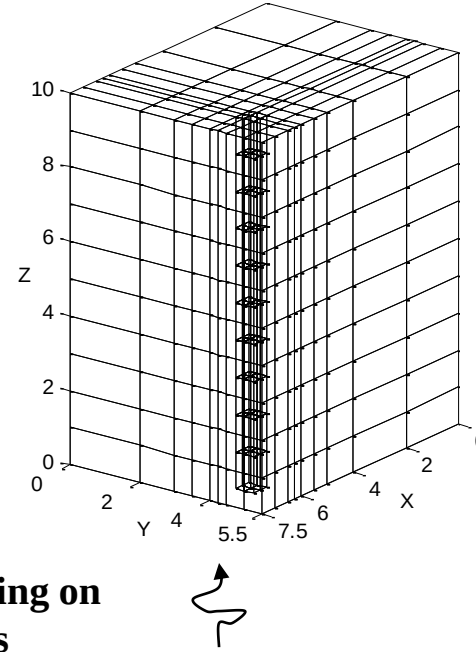
2*2 Pile Group System ($s/d=5$)

Foundation Subsystem: 3D FE Models

Single Pile

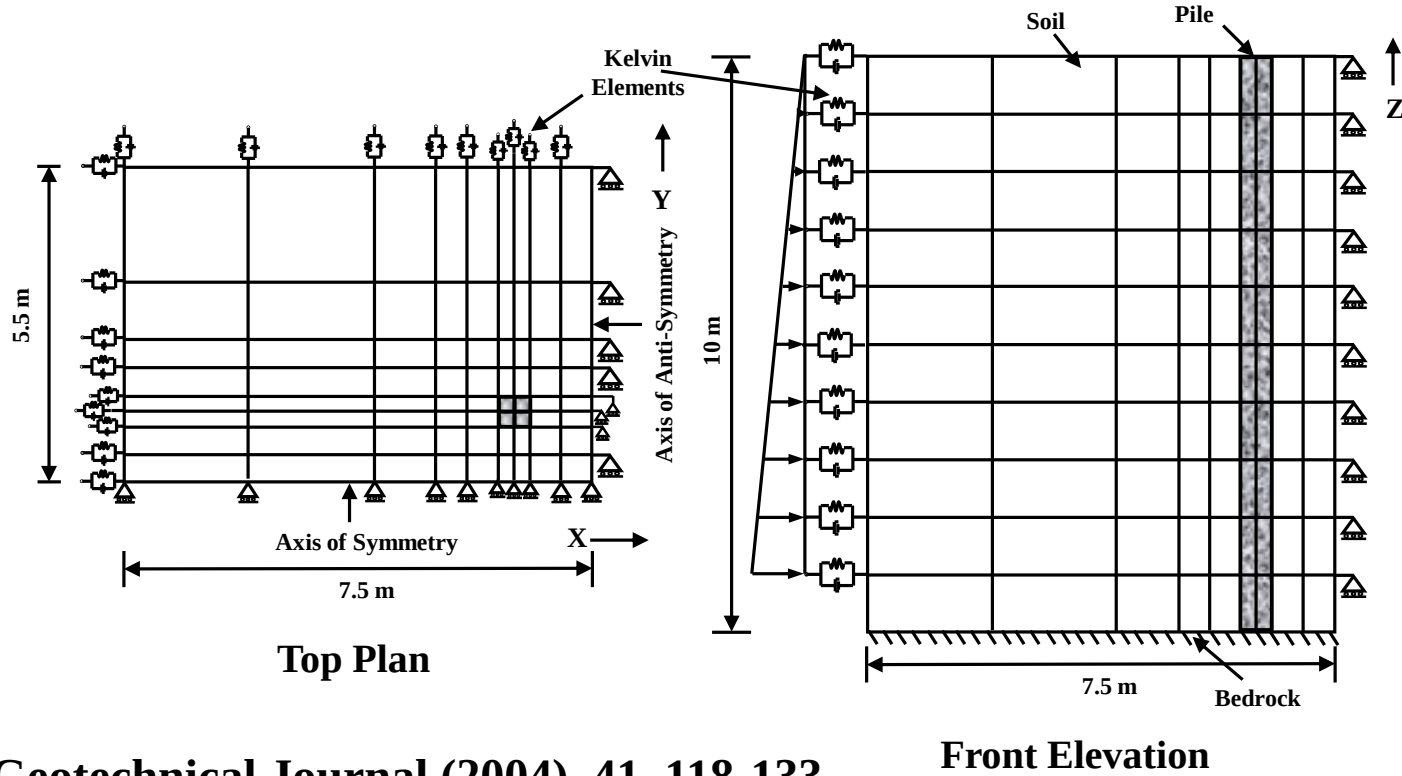


Pile Group



**Seismic Loading on
Bottom Nodes**

Finite Element Mesh for Pile Group Model



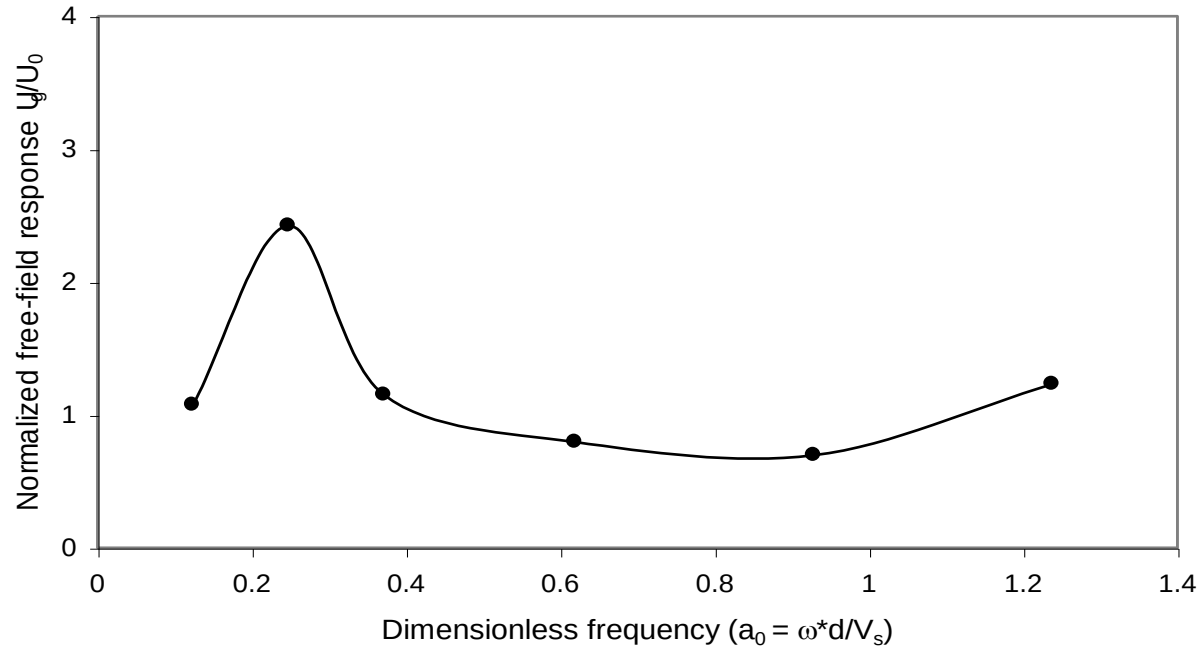
Canadian Geotechnical Journal (2004), 41, 118-133

Front Elevation

Effects of SSI: Frequency Response

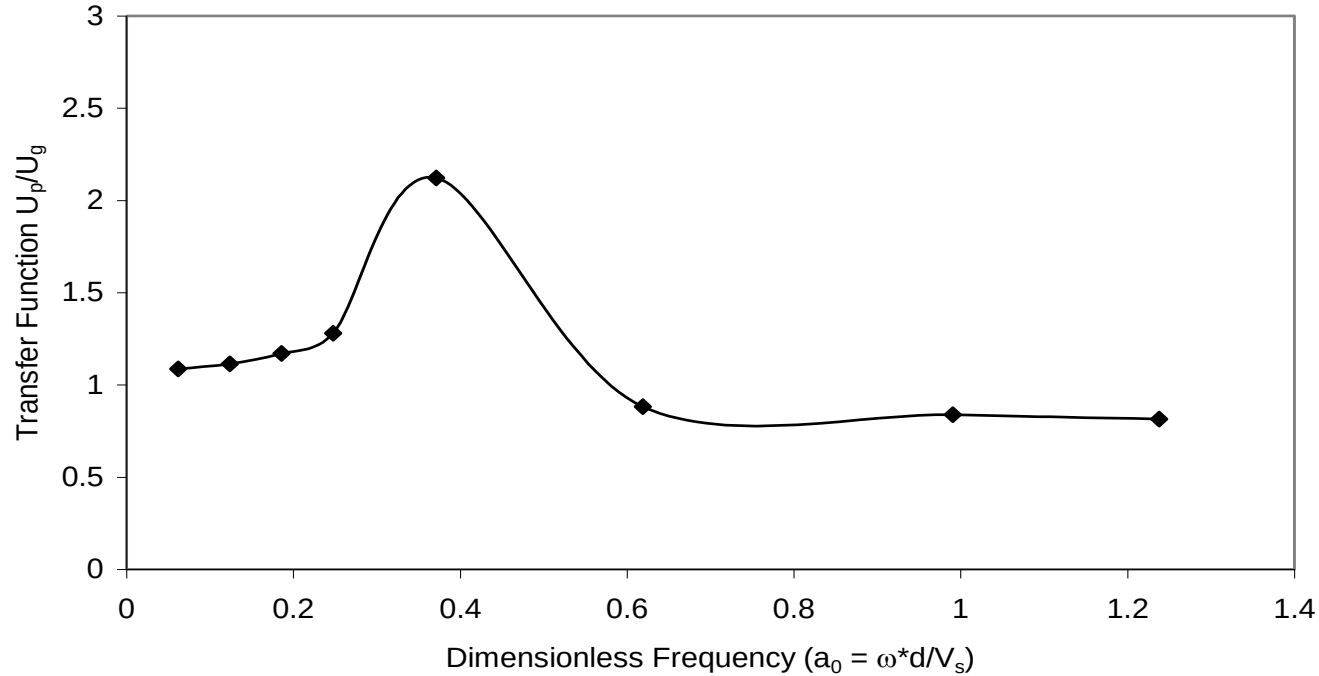
- **Free-Field Response**
- **Response of a Single Pile: Soil-Pile Interaction**
- **Response of Pile Group: Pile-Soil-Pile Interaction**
- **Soil-Pile-Structure Interaction**

Effect of Soil on Free Field Response



Free-Field Response at Different Frequencies

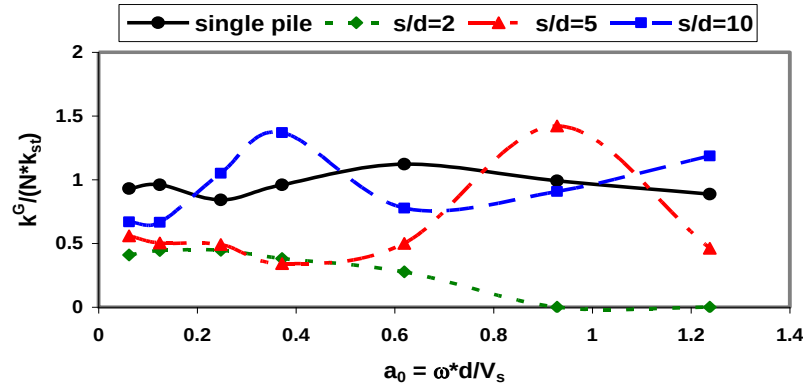
Effect of Soil-Pile Interaction



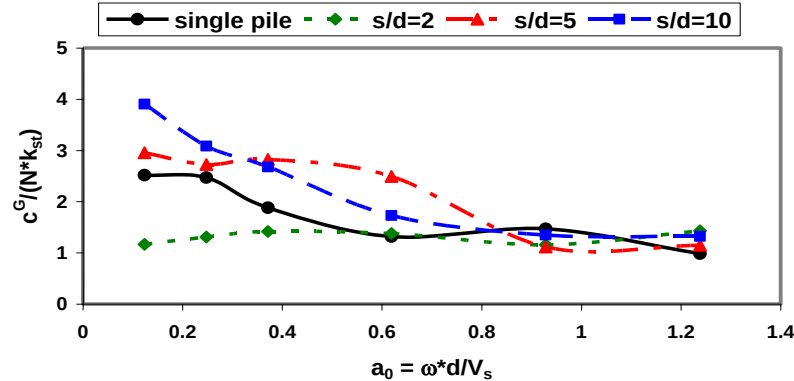
Pile Head Response at Different Frequencies

Effect of Pile-Soil-Pile Interaction

Real Part

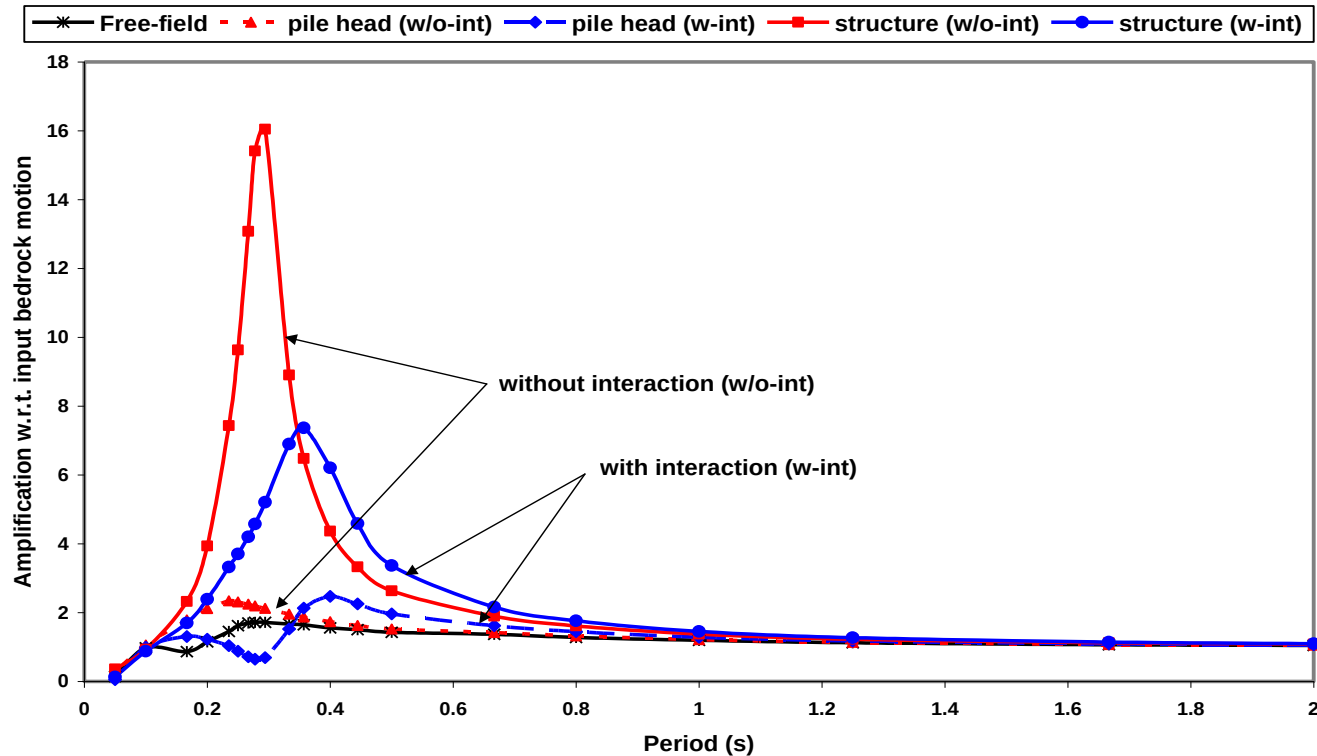


Imaginary Part



Dynamic Stiffness at
Different Frequencies:
Canadian Geotechnical
Journal (2004), 41, 118-133

Effects of Soil-Pile-Structure Interaction



Effect of Successive Coupling on the Response of Pile and Structure:
Soil Dynamics and Earthquake Engineering (2004), 24(4), 345-358

Evaluation of Soil Parameters in Laboratory



Cyclic Triaxial Testing Apparatus@IITR for High Strain



Resonant Column Test Apparatus@IITR for Low Strain



References:

1. Maheshwari B.K., “Three-Dimensional Finite Element Nonlinear Dynamic Analyses for Soil-Pile-Structure Interaction in the Time Domain”, Research Report Submitted to Mid America Earthquake Center (NSF), Dept. of Civil Engineering, Washington University, St. Louis, Missouri, March 2003.
2. Wolf J.P. (1985), “Dynamic Soil-Structure Interaction”, Prentice-Hall, Inc., Englewood Cliffs, N.J., USA

Thank You

