



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

EARTHQUAKE RESISTANT DESIGN OF FOUNDATIONS

Lecture 31: Introduction to Soil-Structure Interaction

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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. Major Effects of SSI and Methods of Analysis
3. SGM and Wave Propagation
4. Ground Response Analysis
5. Soil-Pile Interaction

Chapter -1: Introduction to SSI

- 1. Damage due to SSI in past Earthquakes**
- 2. Basic Objective of SSI**
- 3. Importance of SSI**
- 4. Steps of SSI: Free Field Motion,
Kinematic Interaction and Inertial Interaction**





**Liquefaction Induced Bearing Capacity Failure to Piles
(1964 Niigata, Japan Earthquake)**

Damage of Bridges in Past Earthquakes



SOFTENING OF PILE FOUNDATIONS IN LIQUEFIABLE SOILS
(NISHIOMIYA BRIDGE)

Kobe Earthquake, 1995



THE SHOWA BRIDGE WITH ONE SPAN OF ITS DECK FALLEN TO THE GROUND.

Niigata Earthquake, 1964



Damage of Bridges in Past EQs

**Damage to
Hanshin
Expressway
during 1995
Kobe EQ**



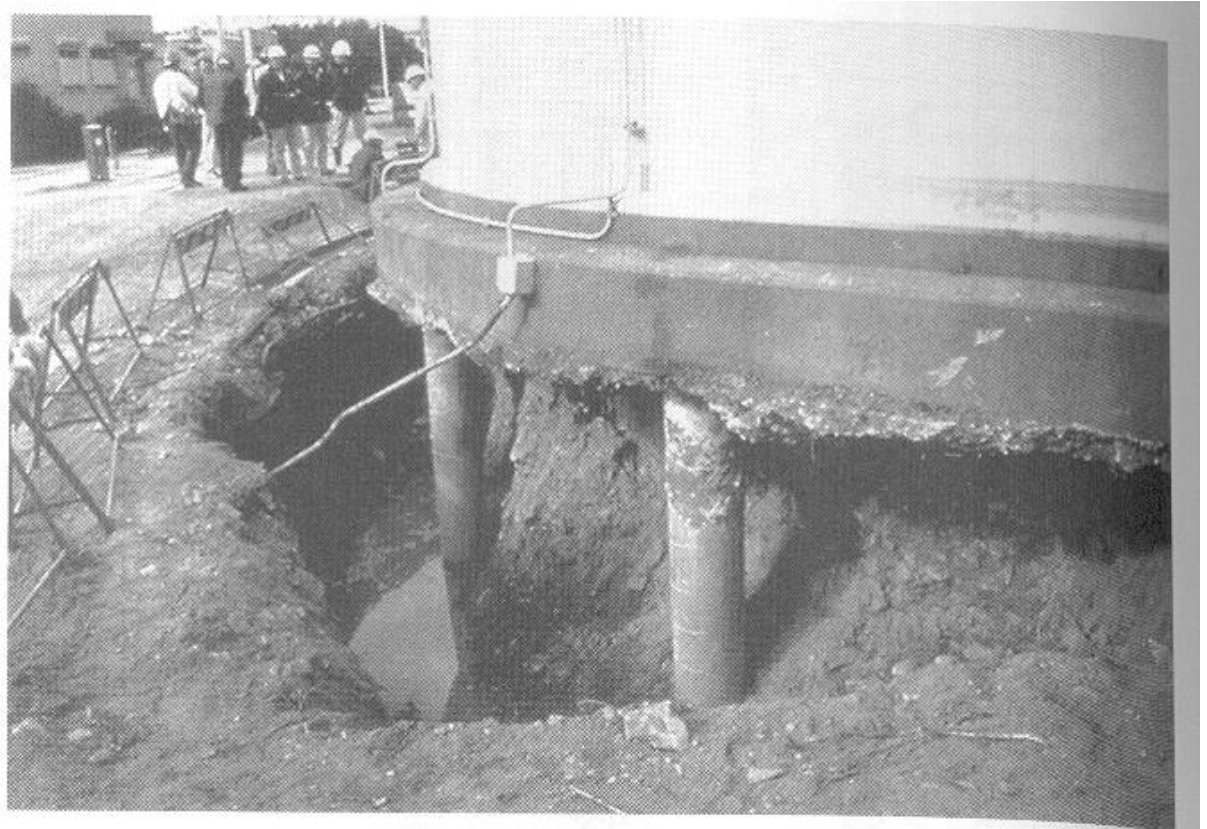
Damage of Bridges in Past EQs



Higashi-Nada Viaduct collapse in the 1995 Kobe Earthquake due to amplification of strong ground motion

Damage of Storage Tank in Kobe EQ

**Liquefaction of Soil, No
Damage to Tank due to
Pile Foundation**

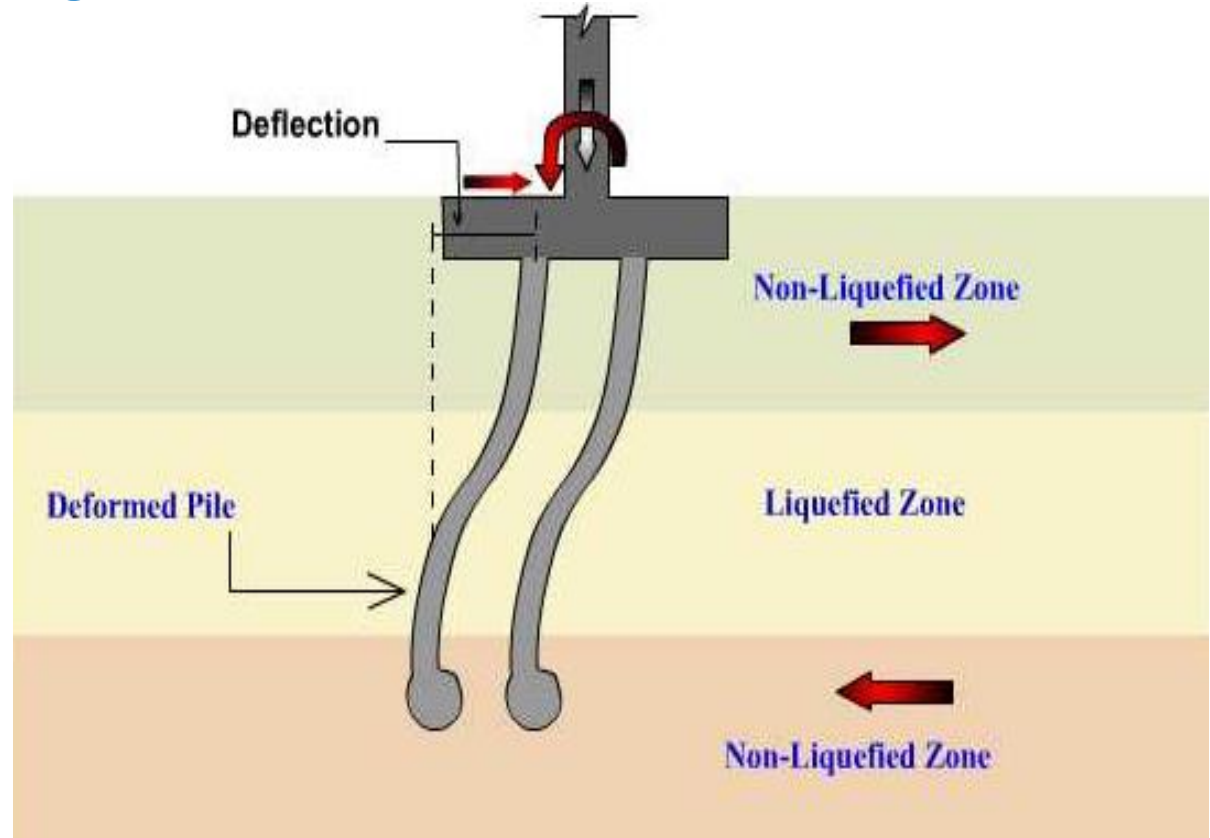


Damage of Bridges in Past EQs

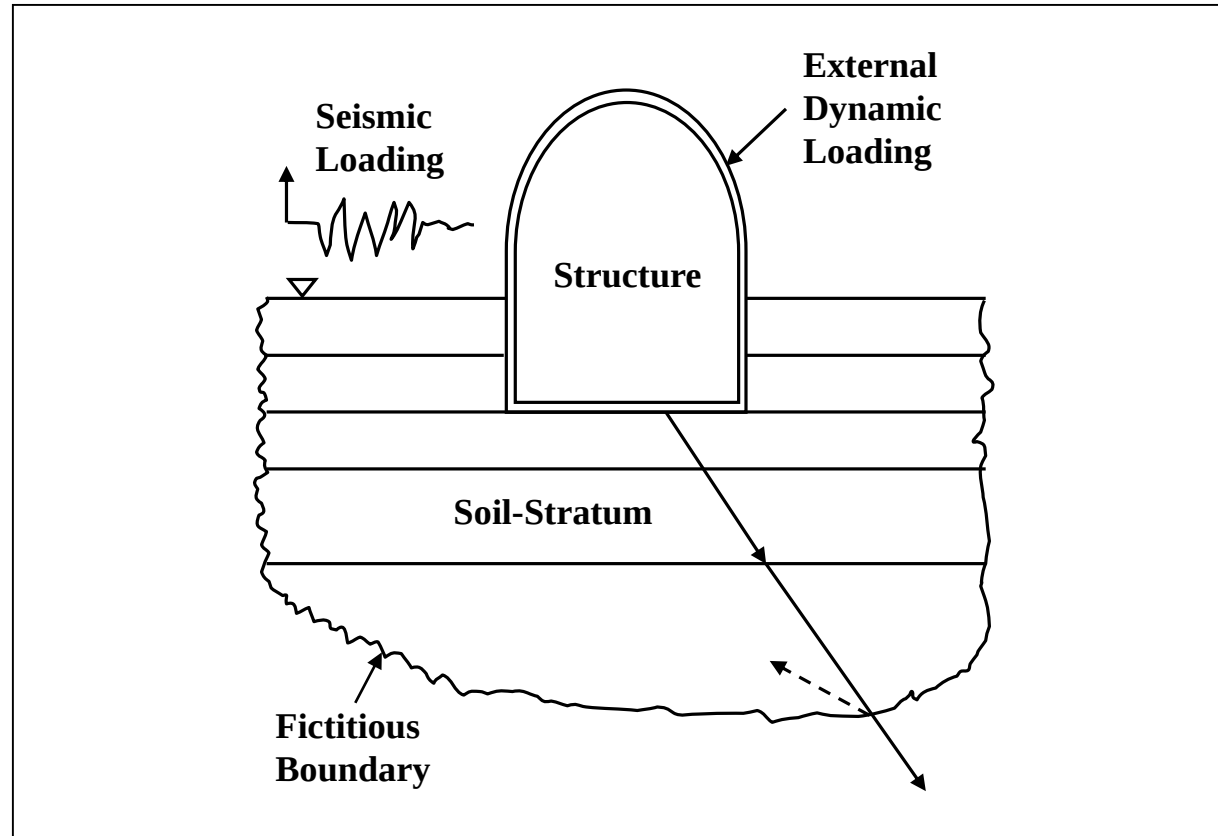
**Damage to Pier Cap of
a Bridge in Bhuj EQ of
January 26, 2001**



Distortion of Piles during Seismic Loads

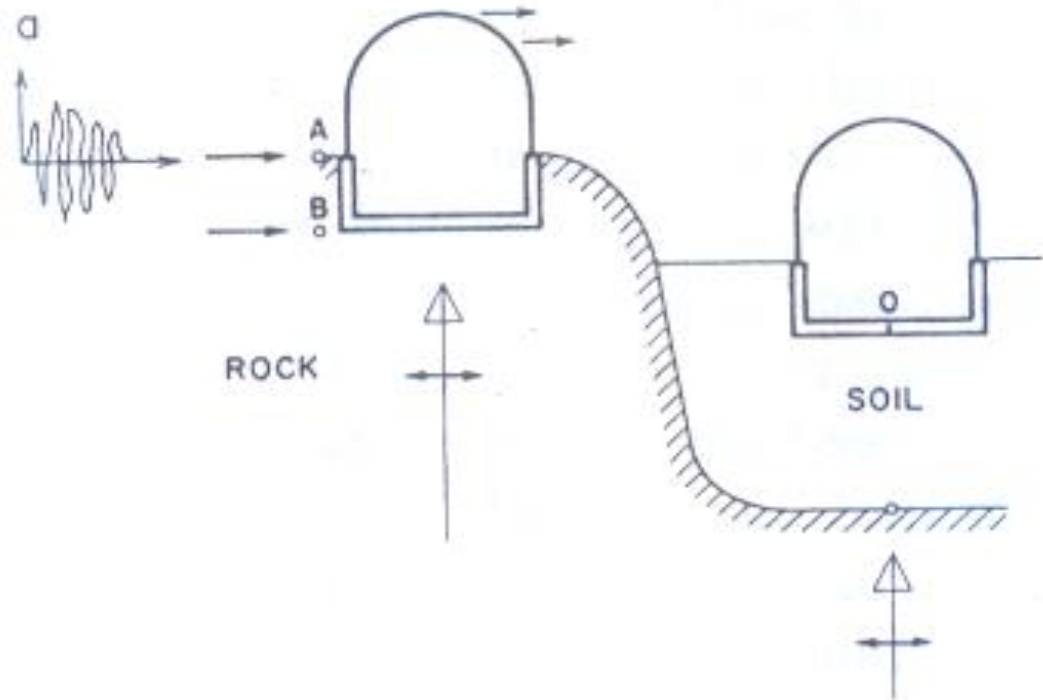


Basic Objective of SSI: Modeling of Unbounded Domain



Importance of SSI – Two Different Sites

Seismic response of structures founded on rock site and on soft soil site



For the Structures founded on Rock

- The horizontal motion can be applied directly to the base of the structure. The input acceleration resulting in the applied horizontal inertial loads will be constant over the height of the structure.
- During the earthquake, an overturning moment and a transverse shear acting at base will develop. As the rock is very stiff, these two stress resultants will not lead to any (additional) deformation at the base.
- The resulting horizontal displacement of the base is thus equal to the control motion; no rocking motion arises at the base.
- For a given control motion, the seismic response of the structure depends only on the properties of the structure.



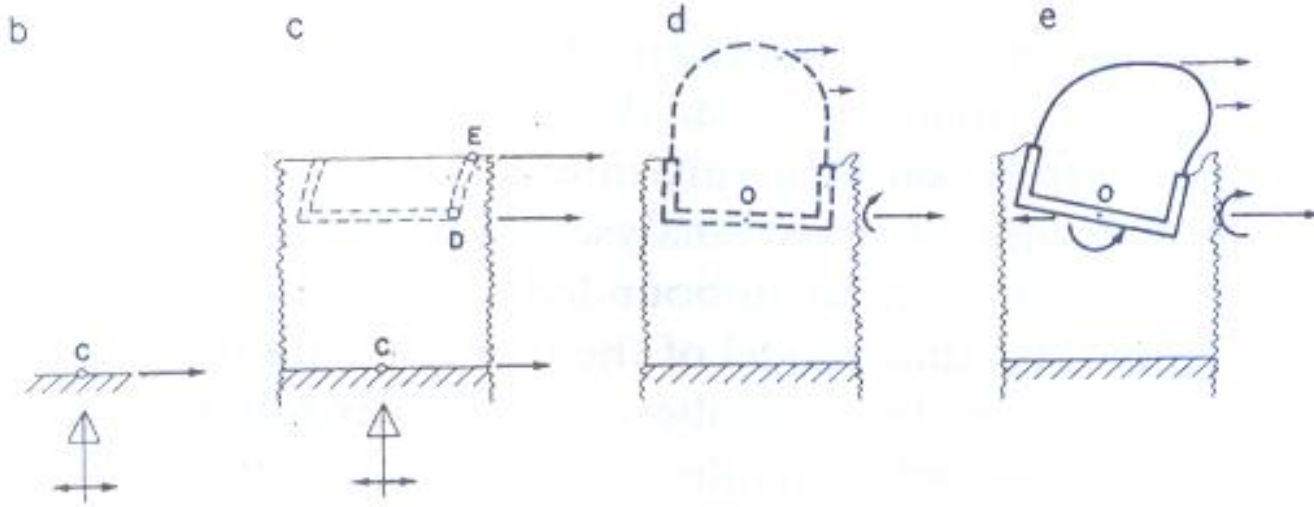
For the Structures founded on Soft Soil

The motion of the base of the structure in point O will be different from the control motion in the control point A because of the coupling of the structure-soil system. The soil affects the dynamic response of the structure in 3 ways:

- (a) It modifies the free-field motion (i.e. the motion of the site in the absence of the structure and of any excavation). If there were no soil on top of the rock in point C of Fig. 2c, the motion in this fictitious rock outcrop shown in Fig. 2b would be same as the control motion of the rock in point A. The presence of the soil layer will reduce the motion in point C (Fig. 2c). This wave will propagate vertically through the soil layer, resulting in motions in points D and E which differ from that in C. Points D and E are nodes in the free field which will subsequently lie on the structure-soil interface when the structure has been built. In general, the motion is amplified, but not always (depending on its frequency content), thus resulting in horizontal displacements that increase towards the free surface of the site.



Effects of SSI - Structures on Soft Soil



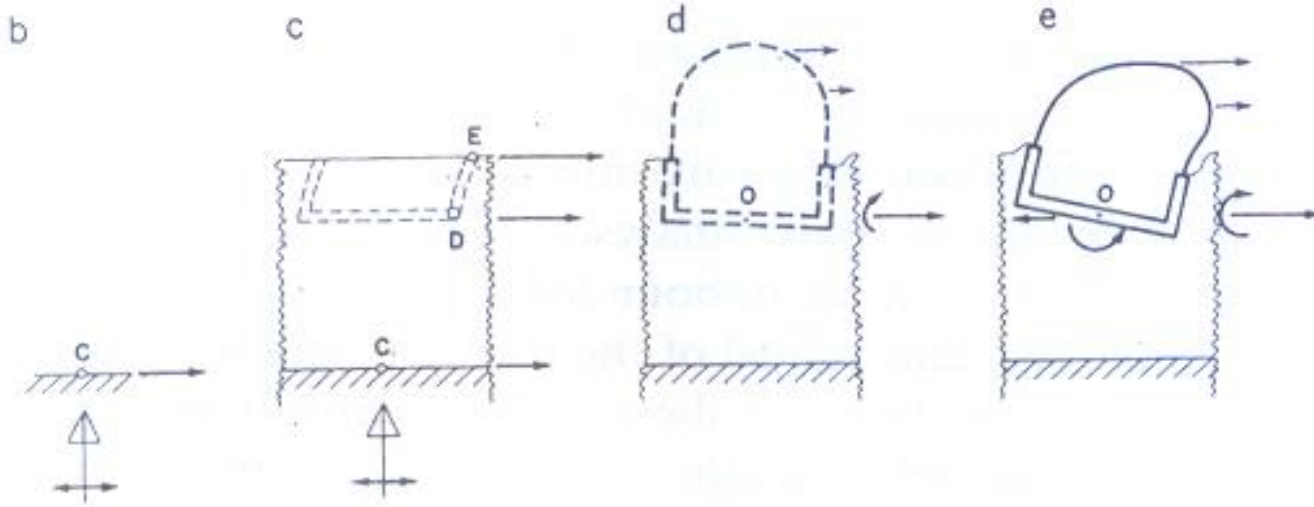
Seismic response of structure founded on soft soil
(b) Outcropping rock; (c) Free field response;
(d) Kinematic interaction; (e) Inertial interaction

For the Structures founded on Soft Soil (continue)

- b. Excavating and inserting the rigid base (say foundation) into the site will modify the motion (Fig. 2d). The rigid base will experience some average displacements and a rocking component. This rigid body motion will result in accelerations (leading to inertial loads) which will vary over the height of the structure, in contrast to the applied accelerations in the case of a structure founded on rock. This kind of interaction between soil and base in the absence of superstructure is called kinematic interaction.
- c. In the presence of structure, the inertial loads applied to the structure will lead to an overturning moment and a transverse shear acting at point O. This will cause deformation in the soil and thus once again modify the motion at the base. This part of the analysis is referred as inertial interaction.



Effects of SSI - Structures on Soft Soil



Seismic response of structure founded on soft soil
(b) Outcropping rock; (c) Free field response;
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Schematic Effects of Presence of Soft Soil

Control Motion + Effect of Soil



Modified Free-Field Motion
+ Effect of Base (e.g. Foundation)



Kinematic Interaction (K.I.)
+ Effect of Structure (e.g. Structure)



Inertial Interaction (I.I.)

References:

**Wolf J.P. (1985), “Dynamic Soil-Structure Interaction”,
Prentice-Hall, Inc., Englewood Cliffs, N.J., USA**

Thank You

