An Overview of Foundation Structure Interaction

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Abstract: ***During earthquake the behavior of any structure is influenced not only by the response of the superstructure, but also by the response of the soil beneath. Structural failures in past have shown the significance of Soil-structure interaction (SSI) effects. The present study focuses on SSI analysis of a symmetric 13 story RC Space frame shear wall building over soft soil and subjected to seismic loading. The transient analysis of structure -soil-foundation system is carried out using ETAB software. Earthquake motion in time domain corresponding to Zone Vof IS 1893:2002 designs. Seismic coefficient method is used to excite the model of soil-structure system. For integrating the SSI effect, one type of soils based on values of elastic modulus of soil, Poisson ratio and shear modulus are considered. Responses in terms of variation in natural period, base shear, deflection, and column forces, obtained from the analysis of the SSI model are compared with that obtained from conventional method assuming rigidity at the base of the structure. The results show that the SSI effects are significant in altering the seismic response full shear wall at central bay and basement wall below plinth in combination is the alternative for minimizing the effects of SSI.***

Keywords: Soil-Structure Interaction, natural period, Base Shear, column forces, masonry building, RC building

1. Introduction

Definition: Generally Building rest on fixed base condition if fixed supports are replaced by multi linear spring then that interaction is called 'Soil –Structure Interaction'.

Response of structure depends on properties of soil, structure and nature of the excitation. The process in which the response of soil influences the motion of structure is referred as 'Soil Structure Interaction'. The scales of socio–economic damages caused by an earthquake depend to a great extent on the characteristics of the strong ground motion. It has been well known that earthquake ground motions results primarily from the three factors, namely, source characteristics, propagation path of waves, and local site conditions. Also, the Soil-Structure Interaction (SSI) problem has become an important feature of Structural Engineering with the advent of massive constructions on soft soils such as nuclear power plants, concrete and earth dams. Buildings, bridges, tunnels and underground structures may also require particular attention to be given to the problems of SSI. If a lightweight flexible structure is built on a very stiff rock foundation, a valid assumption is that the input motion at the base of the structure is the same as the free-field earthquake motion. If the structure is very massive and stiff, and the foundation is relatively soft, the motion at the base of the structure may be significantly different than the free-field surface motion. For code design buildings it is important to consider the effect of the SSI. The objective of this chapter is to understand the basic concept of the Soil-Structure Interaction, following the different methods of analysis with some solved examples.

2. Soil Structure Interaction

2.1 Free Field Motion and Fixed Base Structures:

Ground motions that are not influenced by the presence of structure are referred as free field motions.

Structures founded on rock are considered as fixed base structures. When a structure founded on solid rock is subjected to an earthquake, the extremely high stiffness of the rock constrains the rock motion to be very close to the free field motion.

2.2 Soil-Structure Interaction

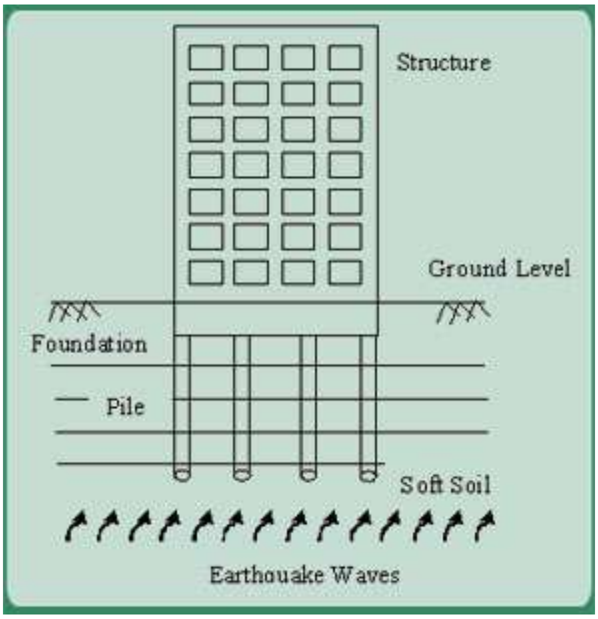

Figure 1: Seismic Soil-Structure Interaction

If the structure is supported on soft soil deposit, the inability of the foundation to conform to the deformations of the free field motion would cause the motion of the base of the structure to deviate from the free field motion. Also the dynamic response of the structure itself would induce deformation of the supporting soil. This process, in which the response of the soil influences the motion of the structure and the response of the structure influences the motion of the soil, is referred as SSI as shown in Figure. 6.1.

These effects are more significant for stiff and/ or heavy structures supported on relatively soft soils. For soft and /or light structures founded on stiff soil these effects are generally small. It is also significant for closely spaced structure that may subject to pounding, when the relative displacement is large.

In order to understand the SSI problem properly, it is necessary to have some information of the earthquake wave propagation through the soil medium for two main reasons. Firstly, when the seismic waves propagates through the soil as an input ground motion, their dynamic characteristics depends on the modification of the bedrock motion. Secondly, the knowledge of the vibration characteristics of the soil medium is very helpful in determining the soil impedance functions and fixing the boundaries for a semi-infinite soil medium, when the wave propagation analysis is performed by using numerical techniques. To understand the influence of local soil conditions in modifying the nature of free field ground motion it is very essential to understand the terminology of local site effect. Therefore, in this chapter, the terminology of local site effect is discussed first and then, seismic SSI problems are presented.

The first significant structure where the dynamic effect of soil was considered in the analysis in industry in India was the 500MW turbine foundation for Singrauli (Chowdhary, 2009).

2.3 Objective

Following are objectives of present study to analyze the structure:

1) To study the literature available regarding soil-structure interaction (SSI), base isolation and understanding the effects of both on structural performance.
2) To study the structure without considering soil-structure interaction.
3) To study the structure considering soil-structure interaction

2.4 Types of SSI

Soil-structure interaction broadly can be divided into two phenomena:
a) Inertial interaction
b) Kinematic interaction.

- Earthquake ground motion causes soil displacement known as free-field motion. However, the foundation embedded into the soil will not follow the free field motion.
- This inability of the foundation to match the free field motion causes the kinematic interaction
- The mass of the super-structure transmits the inertial force to the soil causing further deformation in the soil, which is termed as inertial interaction.

Inertial Interaction
a) Springs used to represent soil-foundation interaction
b) Complex-valued
  - Real part represents stiffness
  - Imaginary part related to damping

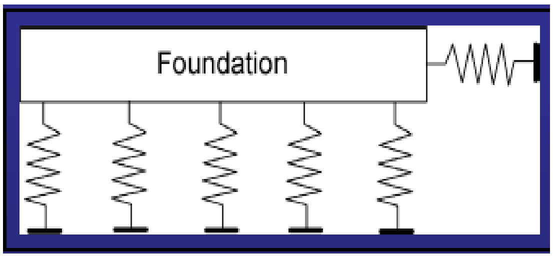

Figure 1: Shows the effect of inertial interaction

If rigid foundation simplifies to:
- 3 springs for 2D system
- 6 springs for 3D system

2.5 Methods of SSI

Two different approaches have been adopted in the past to investigate the problem of soil-structure interaction and incorporate the effect of soil compliance in the dynamic analysis:

1) The Direct approach.
It is based on including the soil medium in the mathematical model developed for dynamic analysis.

2) The Substructure approaches.
In the substructure approach the SSI problem is divided into three distinct parts which also demonstrates the basic concept of substructure method of soil-structure interaction analysis.

2.6 Formulae's Used

The formulas for soil-structure interaction analysis is given by Pais and Kausel are given below which are modified by Gazetas.

- Translation along X-axis=$GB/(2-\nu)[3.4(L/B)^{0.65}+1.2]$
- Translation along Y-axis=$GB/(2-\nu)[3.4(L/B)^{0.65}+0.4(L/B)+0.8]$
- Translation along Z-axis=$GB/(1-\nu)[1.55(L/B)^{0.75}+0.8]$
- Rocking about X-axis=$GB^3/(1-\nu)[3.2(L/B)+0.8)$
- Rocking about y-axis=$GB^3/(1-\nu)[3.73(L/B)^{2.4}+0.27)$
- Torsion about Z-axis=$GB^3\,[4.25(L/B)^{2.45}+4.06]$

Where
G=shear modulus
=$E/2(1+\nu)$
E=Modulus of Elasticity of Soil
ν =Poisson's ratio
B=width of rectangular Footing
L=length of rectangular footing

References

[1] Abrahamson, N.A., 1985, Estimation of Seismic Wave Coherency and Rupture Velocity Using the SMART 1 Strong-Motion Array Recordings, Report No. UCB/EERC-85/02, Earthquake Engineering Research Center, University of California, Berkeley, California.
[2] ACI, 2008, Building Code Requirements for Structural Concrete, ACI 318-08, American Concrete Institute, Farmington Hills, Michigan.

[3] Allotey, N., and Naggar, M.H.E., 2003, "Analytical moment–rotation curves for rigid foundations based on a Winkler model," Soil Dynamics and Earthquake Engineering, Vol. 23, pp. 367-381.
[4] Andrus, R.D., Stokoe, K.H. II, and Juang, C.H., 2004. "Guide for shear-wave-based liquefaction potential evaluation," Earthquake Spectra, Vol. 20, No. 2, pp. 285-308.
[5] ASCE, 2007, Seismic Rehabilitation of Existing Buildings, ASCE/SEI 41-06, American Society of Civil Engineers, Reston, Virginia.
[6] Cox, W., Reese, L., and Grubbs, B., 1974, "Field testing of laterally loaded piles in sand," Proceedings, Offshore Technology Conference, Houston, Texas, Paper 2079.
[7] Fadum, R.E., 1948, "Influence values for estimating stresses in elastic foundations," Proceedings, 2nd International Conference on Soil Mechanics and Foundation Engineering, Rotterdam, Netherlands, Vol. 3, pp. 77-84.
[8] Fleming, W.G.K., Weltman, A.J., Randolph, M.F., and Elson, W.K., 1992, Piling Engineering, 2nd Edition, John Wiley & Sons, New York, New York.
[9] IS 1893