Control Science and Engineering
2017; 1(1): 4-6
http://www.sciencepublishinggroup.com/j/cse
doi: 10.11648/j.cse.20170101.12

Review Article

Study on Soil Structure Interaction: A Review

Ritu Rai

Department of Civil Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur, India

Email address:
ritsrai26@gmail.com

To cite this article:
Ritu Rai. Study on Soil Structure Interaction: A Review. *Control Science and Engineering*. Vol. 1, No. 1, 2017, pp. 4-6.
doi: 10.11648/j.cse.20170101.12

Received: April 1, 2017; **Accepted**: April 20, 2017; **Published**: June 28, 2017

Abstract: In this paper concept of soil structure interaction was introduced and methods involved in SSI were discussed. SSI evaluate the collective response of the structure, the foundation, and the soil underlying and surrounding the foundation to a specified ground motion. Furthermore study based on parameter on SSI behaviour by various scholar is tabulated. Brief summary of all the terms involved in study are enlisted. Various structures like Dam, soil embankment and waste landfill is affected by SSI so its effect is also examined.

Keywords: Soil Structure Interaction, Kinematic Interaction, Inertial Interaction, Dynamic Loading, Static Loading

1. Introduction

Most of the engineering structures are directly contact with the soil. When the external forces, such as huge weight, wind, wave or earthquakes, act on these structures, then the structural displacements and ground displacements effect each other. The earthquake ground motions caused from the three reasons, namely, source characteristics, propagation path of waves, and local site conditions. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as SSI or we can say that Soil Structure Interaction analysis evaluates the three linked systems; the structure, the foundation and the soil surrounding the foundation. SSI has become an important feature for the heavy construction on soft soils such as brides, nuclear power plants, etc. These types of massive construction require full attention to be given to the problems of SSI.

The assumption to be made in classical methods of structural analysis is that, the motion in the foundation of structure is quite similar to the ground free field motion. This assumption holds true for rigid base. Foundation motion is usually vary from the free field motion and rocking component caused by the flexibility at support on horizontal motion of foundation has been added, for the structures constructed on soft soils or flexible base. In the case of a soft soil structure, in addition to the added rocking component to the horizontal motion of the structure, a part of the structure's vibrating energy will transmit to the foundation level and can be dissipated due to radiation damping resulting from the wave propagation and hysteresis damping of the soil materials. However, this energy dissipation is not considered in the case of rigid structures of classical methods. In the dynamic response of structures of soil, it depends on the properties of soil, as well as structure and the nature of the excitation.

In the case of Flexible structures, motion in the foundation level differ from free-field motions for two main reasons: (1) the imposition of stiff foundation systems on (or in) a geologic medium experiencing non uniform shaking will result in foundation motions being reduced relative to those in the free-field and (2) inertial forces developed in the structure will cause base shear and moment, which in turn will induce relative foundation/free-field motions due to the foundation compliance. These process are commonly termed as Soil-Structure Interaction (SSI). Generally SSI problem is categorized into Kinematic SSI and Inertial SSI.

1.1. Kinematic Interaction

The presence of rigid foundation results in the Kinematic interaction which states to the deviation of foundation motion from free field motion. The main reason of Kinematic interaction is because of change in wave propagation media as a result of change in density and elasticity of the media. It leads to the property of reflection and refraction of seismic waves which is coming in addition to the changes in wave propagation velocity. When presence of structures is taken

into account then the change in response of structure using free field motions represent the Kinematic effect of SSI. It mainly depends on the geometry and configuration of structure, the foundation embedment, the composition of incident free-field waves, and the angle of incidence of these waves but it does not depends on the mass of the structures. For structures with no embedment, Kinematic Interaction is not considered.

1.2. Interial Interaction

The main cause of Inertial interaction refers to the vibration of superstructure which is caused by inertial forces at the foundation level. The inertial forces which are then distributed along structure height causing base shear and overturning moment which cause soil deformation initiates waves dissipated the energy from earthquake on structure into soil mass. Inertial effects is the combination of dynamic behaviour of structure, foundation, and soil supporting foundation. Elastic and inertial properties of soil media result in increases the degree of freedom of structure and makes it possible to emit energy from incoming seismic waves by the radiation of waves emerging from the structure and hysteretic deformation of soil media that support the structure. Relative flexibility of the soil media determines the inertial effect, it denotes that there is no significant effect of regular or heavy structures that is on rock or rigid base.

2. Resonance Between Soil and Structure

When the frequency of structure is similar to the frequency of soil, or if it is equal to n times of it which can increase the stresses in the structure, case of Resonance will occur. For these types of cases Soil Structure Interaction is used in detail and represented by converting the dynamic properties of the structure. Energy dissipation and changes in the vibration modes of the structure is the result of Soil Structure Interaction. The relationship between the fundamental frequency of both the structure and the ground, on which it is constructed, is important in getting destruction caused by earthquakes.

3. Effects of Nature of Soil on Resonance

3.1. Soft and Hard Soil

A structure constructed on soft soil has a delayed fundamental period than the period of the rigid base structure. The energy dissipated into supporting soil through wave propagation and hysteretic action is larger in the case of flexible base structure than that of rigid base structure.

3.2. Soil–Structure Interaction Under Static Loading

Number of studies have been made under static loading which resembles the effect of soil structure interaction. In this study various revised force quantities have been shown and effect is considered in a lucid manner. Less studies have been done on soil–structure interaction effect which consider 3-D space frames. The studies give us the clear indication that a 2-D frame analysis might overestimate or underrate the actual effect of interaction in space frames. From the studies we can conclude that considering the interaction effect significantly affect the design force quantities. These studies, may be quantitatively approximate, but clearly describe the need for studying the soil–structure interaction to enumerate the real value of force quantities in the structural members, accounting for their 3-D behaviour.

3.3. Soil–Structure Interaction Under Dynamic Loading

In designing and analysis of Structures under dynamic loading, structures are generally assumed to be fixed at their bases. When support flexibility is taken into account then the overall stiffness is lessened and period of system of structure increases. Change in spectral acceleration is considered with natural period is observed from the response spectrum curve. Seismic response of any structure can be altered by the change in natural period. In addition to this, soil medium imparts damping due to its characteristics. The increasing of natural period and involvement of high damping in soil due to soil structure interaction in structures has been studied. Moreover, the relationship between the supporting soil and the period of vibration of the structure is distinctly important in regard of the seismic response of the structure.

Different approaches have been employed in the past to give the solution of Soil-Structure interaction and incorporate the changes according to the studies made.

3.3.1. Direct Approach

It is the method in which both inertial and kinematic interaction is taken into account from which the soil and structure are modelled simultaneously. With its own vibrations development of inertial interaction takes place giving rise to base moment and base shear, which causes the foundation to be displaced. While kinematic interaction develops due to presence of stiff foundation elements on or in soil causing foundation motion to change from free-field motions.

3.3.2. Substructure Approach

In Substructure, the analysis is simplified into various steps in which principal of superposition is used to differentiate the two primary causes of the soil structure interaction that is foundation is not able to match the free field deformation and the effect of dynamic response of foundation system on the movement of supporting soil. In the past, it was assumed that the foundation of structure was fixed to a rigid underlying medium in the design and analysis of structure. In the last 10 years, however, it seemed that Soil Structure Interaction (SSI) affect the response characteristics of a structural system because of heavy and rigid nature of structure and, often, soil flexibility. Different studies have done in the literature to study the effect of SSI on dynamic response of structures such as nuclear power plants, high-rise structures and elevated highways.

4. Analytical Methods

Analytical methods to predict lateral deflections, rotations

and stresses can be grouped under the following four headings

a) Winkler Approach
b) P-Y Method
c) Elastic Continuum Approach
d) Finite Element Method

5. Conclusion

The review of the current practice as applied in soil structure interaction analysis leads to the following broad conclusions.

a) To accurately estimate the response of structure, the effect of soil structure interaction is needed to be considered under the influence of both static and dynamic loading.
b) The forces in superstructure, foundation and soil mass are significantly altered due to the effect of soil structure interaction. For accurate estimation of the design force quantities, the interaction effect is needed to be considered.
c) Load redistribution significantly modifies the total and differential settlements. Settlements are found more in the non-linear analysis.
d) Numerous investigators analysed the interaction behaviour considering foundations as raft foundation, isolated footing, grid foundation and pile foundation etc.
e) The investigators have considered the soil mass as homogenous, isotropic and behaving in linear and nonlinear manner in the interaction analysis.
f) A limited number of studies have been conducted considering the soil mass as elasto-plastic, visco-elastic and visco plastic in interaction analyses.
g) The finite element method has proved to be a very useful method for studying soil-structure interaction effect with rigor. In fact, the technique becomes useful to incorporate the effect of material nonlinearity, non-homogeneity and interface modelling of soil and foundation.
h) To perform nonlinear soil-structure interaction analysis, incremental iterative technique is found to be the most suitable and general one.
i) For practical purpose, Winkler hypothesis should at least be employed instead of carrying out an analysis with fixed base idealization of structures.
j) Soil-structure interaction may cause considerable increase in seismic base shear of low-rise building frames resting on isolated footings.

References

[1] Fundamental principles of seismology, ground motion, dynamics and soil behaviour and application of the principle involved by Kramer, S. L. “Geotechnical Earthquake Engineering”, Prentice Hall, Inc., Upper Saddle River,New Jersey (1996).

[2] Interactive analysis of a space frame-raft-soil system considering soil nonlinearity by M. N. Viladkar, J. Noorzaei, and P. N. Godbole, Interactive analysis of a space frame-raft-soil system considering soil nonlinearity Comput. Struct., 51, (1994), 343-356.

[3] Structure interaction analysis: Deformable structures in multilayered soil mass, Engineering Computations by J. Noorzaei, M. N. Viladkar, and P. N. Godbole, Nonlinear soil-structure interaction in plane frames, Eng. Comput., 11, 1994, 303-316.

[4] The concept of soil–structure interaction was introduced, and the research methods were discussed by H. M. Rajashekhar Swamy, Krishnamoorthy, D. L. Prabakhara, and S. S. Bhavikatti, Relevance of interface elements in soil structure interaction analysis of three dimensional and multiscale structure on raft foundation, Electron. J. Geotech. Eng., 16, 2011, 199-218.

[5] A critical review on idealization and modeling for interaction among soil–foundation–structure system by R. Roy, and S. C. Dutta, Differential settlement among isolated footings of building frames: the problem, its estimation and possible measures, Int. J. Appl. Mech. Eng., 6(1), 2001, 165186.

[6] Development of numerical tools for solutions of nonlinear analysis problems in soil mechanics by. C S. Desai, H. V. Phan, and J. V. Perumpral, Mechanics of three-dimensional soil-structure interaction, J. Eng. Mech., ASCE, 108(5), 1982, 731-747.

[7] The physical modelling is achieved via use of finite element method, which requires the use of variety of isoparametric elements with different degrees of freedom by M. Hora, Nonlinear interaction analysis of infilled building frame-soil system, J. Struct. Eng., 33(4), 2006, 309-318.

[8] Soil Structure Interaction and Flexible Analysis of shallow foundation by P. T. Brown, and Si K. R. Yu, Load sequence and structure-foundation Interaction J. Struct. Eng., ASCE, 112(3), 1986, 481-488.

[9] An idealized 2-dimensional plain strain finite element seismic soil-structure interaction by M. Kutanis, and M. Elmas, Non-linear seismic soil structure interaction analysis based on the substructure method in the time domain, Turk. J. Eng. Environ. Sci., 25, 2001, 617626.

[10] Resonance effect on structures subjected to earthquake loads due to soil structure interaction by SajaMokhles Al Smadi 2, No 1, 2011.