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STUDY ON INFLUENCE OF INTERACTION OF SOIL AND STRUCTURE – A REVIEW

A.A. Gudadhe[1], P.P. Saklecha[2]

Abstract - The majority of the structures are having enduring contact of one or more elements with the soil. Neither structural nor the ground displacements are independent of each other after the application of motions. Usually, the effect of Soil-Structure Interaction is avoided for the light structures and becomes important for heavy structures. This paper represents the comparative study of the effect of influence of Soil-Structure Interaction (SSI) on different structures like bridges, dam, laterally loaded pile, etc. An immeasurable loss is expected when the bridges or dam are damaged due to earthquakes which occurs due to break away of surrounding soil of the structures. This effect leads to the importance of study of Soil-Structure Interaction for heavy structures and the same is presented through comparative study of different structures.
Keywords - Soil-structure interaction, Earthquake, Seismic response

1. INTRODUCTION

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 soil-structure interaction [1]. Almost all seismic structural response is caused by SSI forces, whereas in certain situations only the effect of SSI is considered. The analysis of SSI is a unique area of earthquake engineering. Substructure method and Direct method are the two main methods of analysis of SSI [3]. Though most of the codes have given the provisions for torsion resistant structures and asymmetry structures, but soil structure interaction can change the seismic behavior of the asymmetric structure [4]. That's why it has now been widely accepted that during analysis and design for seismic, the effect of SSI should be taken into consideration. The most important methods for understanding the behavior of structure with foundation and of foundation with soil are laboratory test and numerical simulation [5].

2. CONSIDERATIONS IN SOIL-STRUCTURE INTERACTION EFFECTS

When a structure is designed by considering its foundation to be rigid, it is supposed to have no effect of SSI. The soil motion influence by the interaction forces will depend upon the magnitude of the force and flexibility of soil foundation. Interaction forces can be evaluated from base acceleration and inertia of the structure. The SSI effects for a particular soil site increases with the increase in weight of structures which includes dams, bridges, etc.. Also, the chance of occurrence of SSI effect is more for softer soil [6].

3. ADVANTAGES OF SOIL-STRUCTURE INTERACTION

It is used in heavy structures like hydraulic structures and nuclear structures.
ii. For those structures where the P delta effects are prominent, the analysis based on soil structure interaction is helpful.
iii. The study of SSI has a significant role in the deep – seated foundations, structures supported over soft soil, tall or slender structures which have an average shear velocity of 100m/sec [6].
Dynamic Analysis in Soil-Structure Interaction
In past two different methods had been adopted for the analysis of structures considering SSI effects.
Direct Approach
Substructure Approach
Direct Approach

[1] Department of Civil Engineering, Datta Meghe Institute of Engineering, Technology & Research, Wardha, Maharashtra, India
[2] Department of Civil Engineering, Bapurao Deshmukh College of Engineering, Wardha, Maharashtra, India

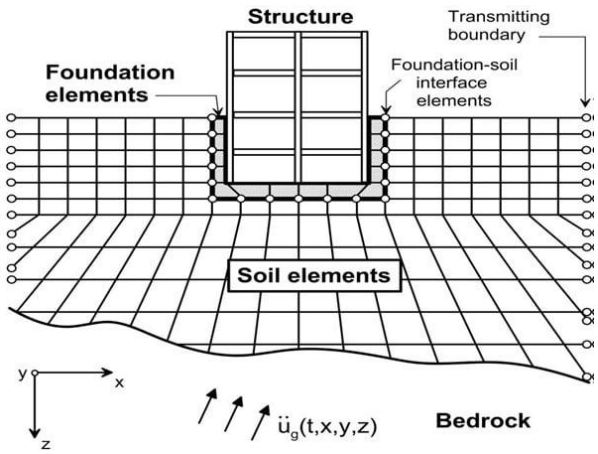

Fig.1

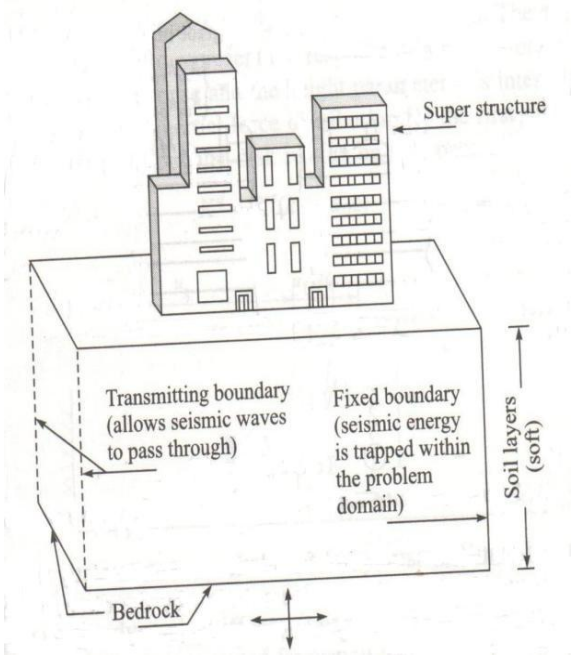

Fig.2

This approach includes consideration of both soil and structure for the analysis and is considered as one complete part as shown in Fig.1. The total system is characterized as continuum and is represented through finite element [6]. The special boundary elements are necessary to simulate the effects of unbounded soil medium which requires that the seismic energy should radiate away from the vibration source as shown in Fig.2 [7].

Substructure Approach

In this approach, the analysis is divided into several parts as shown in Fig.3 and then to combine, principle of superposition is used [6]. Earlier, for analysis & design of engineered structures it was understood that the base of the structure is fixed to rigid underneath medium. But, in last few decades it has been acknowledged that SSI altered response characteristics of structural system because of colossal weight of the structure and also soil softness [8].

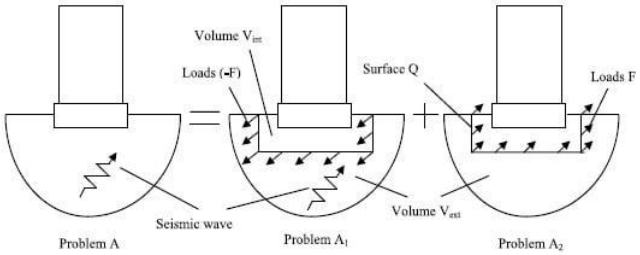

Fig.3

4. INFLUENCE OF SSI ON VARIOUS STRUCTURES

4.1 Bridges

Enormous losses are observed when bridges are destroyed during earthquakes [9] and for that genuine work is required. Non-linearity is seen in soil once it is influenced by earthquake [10]. To study the influence of SSI on bridges, Wenliang Qiu, Mei Hu and Yuefang Zhou in 2011 analyzed three models of soil by m-method, p-y curve method and p-y curve considering separation of soil and pile as shown in Fig.4 and Fig.5. [11].

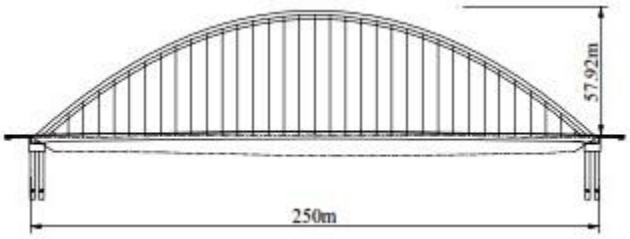

Fig.4

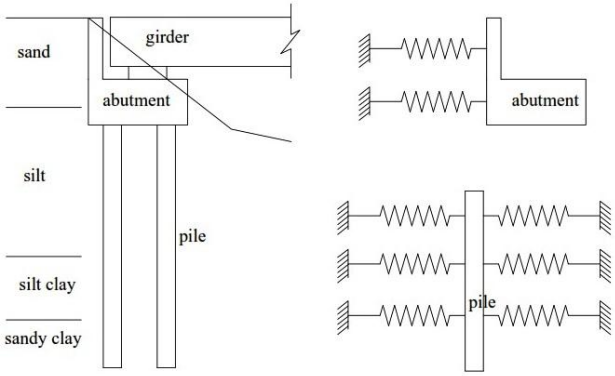

Fig.5

The El-Centro seismic waves were used for seismic analysis and peak accelerations of the wave 0.1g and 0.4g were the inputs to stimulate in the horizontal direction (Fig.6).

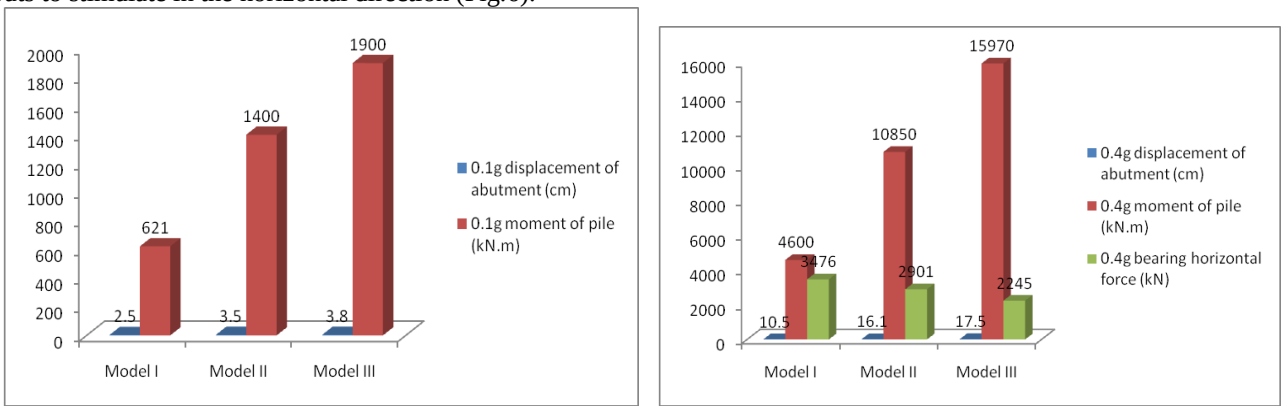

Fig.6

4.2 Dams

Bycroft G.N. and Mork P.N. in 1987 present that an optimum seismic design is achieved when the cross section of the dam is triangular instead of trapezoidal section and also the effect of SSI lowers the strain occurring in the dam. Fig.7 shows the considered cross-section of dam for analysis.

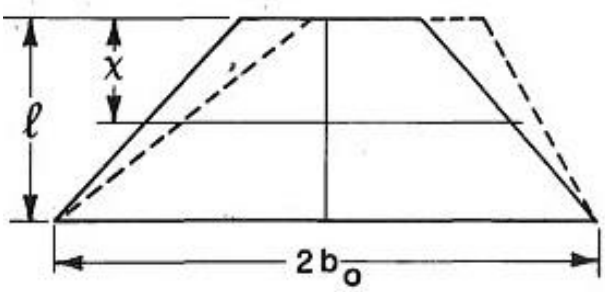

Fig.7

For a long trapezoidal-section dam consisting of an elastic half-space on a foundation subjected to seismic motion, an analytical solution is developed. This analysis is applicable to both symmetrical as well as unsymmetrical case as shown in dotted line in Fig.7 where, l=height of dam, 2bo=width of dam at bottom. The width of dam at depth x from top of dam is given by the expression:

$$\frac{2b_0}{(1+\lambda)}\left(1+\frac{\lambda x}{l}\right) \tag{1}$$

For horizontal translation, the equation of motion of the dam is given by:

$$\frac{\partial}{\partial x}\left[\left(1+\frac{\lambda x}{l}\right)\frac{\partial y}{\partial x}\right]=\frac{\rho_1}{Gg}\left(1+\frac{\lambda x}{l}\right)\frac{\partial^2 y}{\partial t^2} \tag{2}$$

The non-dimensional strain w.r.t. dam variables is given by:

$$R_0=\frac{RG^{3/4}g^{3/4}}{S_0^{1/2}b_0^{1/2}\rho_1^{3/4}} \tag{3}$$

Fig.8 shows the strain at three different heights as the function of the SSI parameter λ3 for a cross-section which is almost triangular [13].

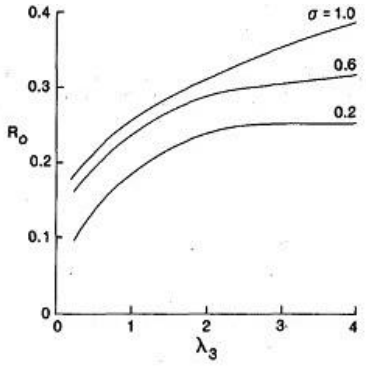

FIG. —Nondimensional Strain as Function of σ and λ_3; $\lambda = 10$; $\lambda_1 = 2.5$; $\lambda_2 = 1.0$

Fig.8

5. CONCLUSION

The cases of bridge and dam as discussed, represents that Soil Structure Interaction parameter is essential and needs to be considered. Though all three methods are all of significance but to overcome the non-linearity in soil, p-y curve method found to be convenient. In case of dam, soil structure interaction decreases the strain and also triangular cross-section minimizes the strain at the base and thus gives the minimum volume.

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