Review Paper on Study on Soil Structure Interaction & Its Various Effects on Shear Wall Structure

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Abstract— Soil Structure Interaction (SSI) is an interdisciplinary field of endeavor. It lies at the intersection of soil and structural mechanics, soil and structural dynamics, earthquake engineering, geophysics and Geo mechanics, material science. Soil flexibility has to be considered in the analysis of massive structures to avoid failure and ensure safe service. This study focuses on a review of the influence of soil-structure interaction phenomena and its importance to various recipient roles in design and planning consideration of shear wall structures. It is a well-established fact that the soil-structure interaction effect considerably influences the design of multi-storey buildings subjected to seismic loads. The shear walls are often provided in such buildings to increase the lateral stability and to resist seismic lateral loads. Conventional analyses of the buildings is done by taking the base of the structure to be fixed but in the real life the scenario will be different as compared to a fixed end condition because the soil beneath the foundation will vary the earthquake forces and thus varying the lateral forces acting on the structure. The effect of shear walls which when placed at different locations and different shapes is also the important part. The effect of shear walls and also the soil structure interaction influences the behavior of multi-storied buildings subjected to seismic forces.

Key words: Soil Structure Interaction, Geo Mechanics, Structure Dynamics, Shear Wall

I. INTRODUCTION

Soil–structure interaction plays an important role in the behavior of structure under static or dynamic loading. It influences the behavior of soil, as well as the response of pile under loading. The analysis is highly essential for predicting a more accurate structural behavior so as to improve the safety of structures under extreme loading conditions.

Soil Structure Interaction origins trace back to the late 19th century, evolving and maturing gradually in the ensuing decades and during the first half of the 20th century. SSI progressed rapidly in the second half stimulated mainly by the needs of the nuclear power and offshore industries, by the debut of powerful computers and simulation tools such as finite elements, and by the desire for improvements in seismic safety.

The importance of soil-structure interaction both for static and dynamic loads has been well established and the related literature covers at least 30 years of computational and analytical approaches for solving soil–structure interaction problems. Since 1990s, great effort has been made for substituting the classical methods of design by the new ones based on the concept of performance-based seismic design. In addition, the necessity of estimating the vulnerability of existing structures and assessing reliable methods for their retrofit have greatly attracted the attention of the engineering community in most seismic zones throughout the world. So that maximum benefit can be derived.

The shear walls are often provided in such buildings to increase the lateral stability to resist seismic lateral loads. Further, the position of shear walls in a building alters the response of structure. It is desirable to decide the position of the shear walls judicially adopting realistic approach for structure foundation soil behavior, a flexible approach analysis considering soil structure interaction, also alters the response of structure. If the building is founded in the soft soil the effects will be high.

II. CONCEPT OF SOIL STRUCTURE INTERACTION

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 (SSI). Most of the civil engineering structures involve some type of structural element in direct contact with ground. When the external forces, such as earthquakes, act on these systems, neither the structural displacements nor the ground displacements, are independent of each other. Conventional structural design methods neglect the SSI effects. Neglecting SSI is reasonable for light structures in relatively stiff soil such as low rise buildings and simple rigid retaining walls. The effect of SSI, however, becomes prominent for heavy structures resting on relatively soft soils for example nuclear power plants, high-rise buildings and elevated-highways on soft soil.

III. EFFECTS AND RESPONSE OF SOIL STRUCTURE INTERACTION

It has conventionally been considered that soil- structure interaction has a beneficial effect on the seismic response of a structure. Considering soil-structure interaction makes a structure more flexible and thus, increasing the natural period of the structure compared to the corresponding rigidly supported structure. Moreover, considering the SSI effect increases the effective damping ratio of the system. The smooth idealization of design spectrum suggests smaller seismic response with the increased natural periods and effective damping ratio due to SSI. With this assumption, it was traditionally been considered that SSI can conveniently be neglected for conservative design. In addition, neglecting SSI tremendously reduces the complication in the analysis of the structures which has tempted designers to neglect the effect of SSI in the analysis. In fact, the SSI can have a detrimental effect on the structural response, and neglecting SSI in the analysis may lead to unsafe design for both the superstructure and the foundation.

IV. Review on Analytical Studies of Soil Structure Interaction

The analytical soil modeling in SSI problem can be achieved by adopting different simplified methodologies like springs, dashpots and masses with frequency independent, Formulations based on one-dimensional wave propagation theory. Some analytical modes have been described in this section. Very few study have been addressed on the analytical approach to solve the due the complexity invoved in the interaction solution. The one of the popular techniques to solve the interaction problem analytically is cone mode (Bahreh, 2009). Cone model is efficient for the layered soil for embedded foundation system and gives agreeable results for both forced and displacement based methods and sufficiently captures the all degree of freedoms.

In this model the equilibrium equation for an infinitesimal element can be solved both directly in time and frequency domains. Consequently the equivalent spring stiffness and damper constants can be determined. The soil will be then replaced by a spring and a damper in the vertical direction.

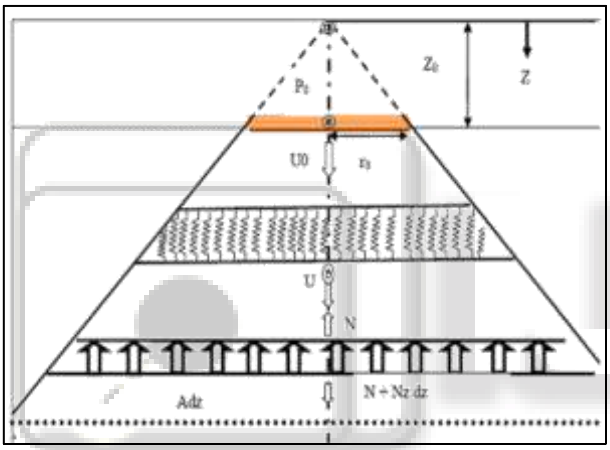

Fig. 1: Structure of the Soil Strata based on Cone Model

Cone models satisfy physical features like a layer fixed at its base, no radiation damping occurs below the cut-off frequency. Thus cone models can be used for sites with general layering. The cone models have postulated the wave pattern clearly. The wave reflections and refractions at the material discontinuities such as of a layer on a half-space are captured using cones. The concept of elastic half space soil structure coupled analysis is started with this model. The dynamic behavior of soil during an earthquake is well captured by this model using wave propagation theory. Apart from the cone model Wolf (1985), Krammer (2004) proposed a analytical equations to solve the kinematic interactation in terms of wave prapogation have been addressed.

V. Review on Experimental Studies of Soil Structure Interaction

The response of structures to dynamic loads (e.g. Strong earthquake shaking, strong winds, explosions etc.) are often estimated using mathematical models as it represent some idealization of real structure in spite of its complexity. There are different experimental approaches like Ambient Vibration Tests, Forced Vibration Tests, Shake Table Tests and Laminar box test which describes the soil structure interaction effect. Their success in representing the response of real structures is best evaluated by experiments on full scale structures such as ambient and forced vibration tests and recording of earthquake response (Ivanovic, 1995). These experimental models have been extended to the geotechnical applications to study the soil behavior with the structure coupling under the dynamic load.

VI. Literature Review on Previous Work

Various literature reviewed on soil-structure interaction analysis of RC framed shear wall building is presented in this section. A brief summarizing of the work done by different scholars and researchers on soil-structure interaction analysis of RC framed shear wall building structures is presented here.

Cai et al, (2000) carried out analysis, which includes fixed boundary conditions neglecting the effect of damping in the foundation subsystem. Moreover, the effects of soil nonlinearity were not analyzed. Lehmann and Antes (2001) used the FEM BEM coupling model to investigate the structure, soil structure phenomenon by giving a vertical load in the soil between the two structures. The study reveals that finding the hybrid numerical model is suitable for analyzing the structure soil structure interaction problems. Emphasis was also outlined for the application of FEM-BEM coupling methods to SSI problems when more than one structure is present.

Chore et al. (2009) presented an interaction analysis for the building frame resting on the pile group using a coupled approach, i.e., by considering the system of building frame - pile foundation - soil as a single unit. Although such an analysis is computationally uneconomical, fair agreement has been observed between the results obtained using coupled and uncoupled approaches.

Mao et.al. (2009) modeled a real time building in Fujian province of China and the effect SSI has been cofigurated. The peak response of absolute acceleration, storey drift, moments at beam ends, as well as an inner force of columns and shear walls are analyzed under two orthogonal horizontal directions seismic excitations. The SSI effect with nonlinearity on seismic response of high-rise building is summarized and the rationality of the reduction fa ctor for soil-structure interaction calculation specified. Pitilakis (2010) proposed an equivalent linear substructure approximation of the soil foundation structure interaction system. A numerical code MISS3D has been developed to perform soil foundation structure interaction analyses in the three-dimensional linear elastic or viscoelastic domain, based on the substructure method.

H. K Chinmayi and B. R Jayalekshmi (2013) This study focuses on the soil-structure interaction analysis of RC frame shear wall building over raft foundation subjected to seismic loading. Multi story building symmetric in plan of height below 45m, located in seismic zone V. The stress resultants in the structure and raft foundation considering SSI are compared with stress resultants obtained by the conventional method of analysis assuming rigidity at the base of the structure. Influence of variation of the parameters such as, different soil conditions and number of stories were also considered in the study for which the buildings were modeled by four alternate approaches, namely, (1) bare frame with fixed supports, (2) bare frame with supports accounting for soil-flexibility, (3) frame-shear wall with fixed supports and (4) frame-shear wall with supports accounting for soil-flexibility. The study shows, for a 12 story building the increase in lateral natural period by 27% and 61% and increase in seismic base shear by 67% and 68%. Reduction in bending moment and shear force by 37% and 20% in structure and 29% and 26% in foundation due to the effect of soil flexibility is seen in bare frames and building with shear wall on soft soil.

Jayalekshmi B.R, Chinmayi H.K (2013) In this study, an attempt has been made to find the effectiveness of shear wall locations on RC frame buildings of varying height with raft foundation by noting the effect of soil flexibility on change in lateral natural period. Free vibration analysis of the three dimensional models of these buildings with five different shear wall positions founded on different soils has been carried out using finite element software. It is observed that variation in natural period by inclusion of shear wall is reduced with increase in height of the building as well as increase in flexibility of soil. And the best location for the least spectral acceleration in the structure is identified. The building configuration SW2 (i.e) shear wall placed at the centre causes the maximum average response acceleration coefficient resulting in higher values of design base shear.

Sachin Hosamani and R. J. Fernandes (2015) This paper demonstrates the soil-structure interaction and the effects of shear walls which when placed at different locations. The effect of shear walls and also the soil structure interaction is studied for different heights of buildings using ETABS software to study the difference in parameters like time period, spectral acceleration co-efficient (Sa/g), base shear, storey shear, storey displacement and storey drift when considered against conventional fixed base analyses. The adding of shear walls which is required for stiffness in lateral direction, increases the stiffness but also increases Spectral acceleration coefficient value. In this study the shear walls are provided in two ways. In first case the shear walls are provided at the four corners and the second case the shear walls are provided at four corners along with shear wall at the centre. Study shows the base shear value increases for the building with shear wall provided at four corners along with the centre with considering soil structure interaction effects.

VII. Conclusion

Structural failures during earthquakes in the past demonstrated the importance of soil-structure interaction (SSI) effects and its consideration to avoid failure and ensure safety.

- The effect of SSI is should be considered in the buildings which are located in the earthquake prone areas. The shear walls are often provided in such buildings to increase the lateral stability to resist seismic lateral loads.
- The inclusion of shear walls significantly alters the response of the structure and also the location and shape of the shear wall also the most important phenomenon for the response of the structure with considering the soil-structure interaction effects.
- From the literatures location and shape of the shear wall is not a constant factor it is varying according to the type of building structures.
- The buildings designed without the consideration of SSI effects will be less safe during the time of earthquakes.

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