ABSTRACT

Super structures are mostly founded on layers of soil unless bedrock is very close to the ground surface. It is clear that seismic waves pass through kilometers of bedrock and usually less than 100 meters of soil; soil layers play a significant role in assigning the characteristics of the ground surface movement. When the ground is stiff enough, the dynamic response of the structure will not be influenced significantly by the soil properties during the earthquake and the structure can be analyzed under the fixed base condition. When the structure is resting on a flexible medium, the dynamic response of the structure will be different from the fixed base condition owing to the interaction between the soil and the structure. This difference in behavior is because of the phenomenon, commonly referred to as soil-structure interaction (SSI), which if not taken into account in the analysis and design properly; the accuracy in assessing the structural safety, facing earthquakes, could not be reliable.

During some past earthquakes several damages have been observed due to not accounting the effect of interaction in the analysis. The 1985 Mexico earthquake high rise building collapsed due to the partial bearing capacity failure of foundation soil and increase in a fundamental time period of soil from about 1.0 s to nearly 2.0 s induced due to the interaction phenomenon. In the 1995 Kobe earthquake (M=6.9) the interaction effect played a vital role in the sudden increase of natural period where the collapse and overturning of Hanshin expressway is observed. During the 2001 Bhuj earthquake (MW= 7.6) caused extensive damage to life and property due to the attenuation effect of the wave travelling through the soil layers with a high impedance contrast of the supporting soil layers. Coming to the Indian scenario, Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. The seismic risk in the country has been increasing rapidly in the recent years as there were large magnitude earthquakes in recent times even in the stable continental region.

Performance-based engineering (PBE) is a technique for seismic evaluation and in design using performance level prediction for safety and risk assessment. Soil structure interaction, particularly for unbraced structures resting on relatively soft soils may significantly amplify the lateral displacements and inter-storey drifts. This amplification of lateral deformations may change the performance level of the building frames. Thus a comprehensive dynamic analysis to
evaluate the realistic performance level of a structure should consider the effects of SSI in the model.

In the present study the research has been primarily motivated to reduce the complexity in the modeling a soil structure foundation interaction model. In interaction problem the flexible interface is needed to implement in the model between soil to raft and soil to pile in order to achieve the continuity in the analysis and to obtain the model nearest to the reality. The soil half space can be represented in two ways like near field and far field. The near field behavior can be considered as the nonlinear and the far filed is modeled as the linear with the application of the non reflecting viscous boundary to avoid the multiple wave reflection during the dynamic analysis. The soil structure interaction problem is computationally very expensive due to big size which includes interfaces, nonlinear soil behavior, and structure. This cost has been exponentially increasing with the volume of soil, interfaces area and structure geometry is increasing. In case of pile foundation the soil domain is needed to consider deeper and wider thus it is essential to reduce the model with some techniques. In the present study the focus has been given to reduce the soil domain by replacing the pile group with the equivalent pier method. This approach for soil-structure interaction analysis has been fully investigated. With this the volume of the interfaces can be reduced up to a certain extent and the solution can be obtained within the shortest time. The finite element program for dynamic analysis has been developed using a versatile low level object oriented language C++. The time domain displacement and stress histories have been estimated for the given set of dynamic loading of the original pile configuration and the equivalent pier. The applicability of the equivalent pier method has been checked for different set of location of a pier in the plan area and the suitable pier combination has been obtained which gives the optimum deviational response of the superstructure. The results are estimated with the view of the significance of SSI analysis for the particular loading and local soil condition, applicability of the Equivalent Pier Method to reduce the computational efforts and the complexity in modeling, soil structure interaction effect on the responses of the superstructure. The study covers the typical complex plans of asymmetrical buildings to understand the effect of shape on the response of the superstructure. In this regards the C, L and T shape buildings are considered for dynamic soil structure analysis.
The study concluded that the Equivalent Pier Method (EPM) can be well applied to asymmetrical pile group and it reduces the numerical cost and complexity in SSI modeling. The approach has been checked for other asymmetrical shapes like C and T and it has been found that the EPM approach is applicable with some deviation in the responses of the superstructure. The variation in the response estimated for the asymmetrical superstructure with regards of different Equivalent piers configuration is in the 12 to 20%.

The EPM approach proposed in the present study for the asymmetrical pile group shows the numerical efficiency and provides overestimated (sometimes) responses of the superstructure which provides the more conservative approach in the SSI. The time of the analysis is found to be enhanced with the application of the EPM methodology to the asymmetrical pile layout. Thus the method suggested in this study gives the computational efficiency of the analysis.

The detailed SSI analysis has been carried out to understand the behavior of the asymmetrical superstructure by altering the key parameter in the seismic analysis. The response of the superstructure is estimated for the different soil type of the supporting domain, the magnitude of the earthquakes and the pile L/D ratios. The study observed that the each asymmetrical structure responds differently depending upon the complexity of the plan. The displacements vary with the different soil type, different dynamic loading. The kinematic interaction transferred through the piles is different for the each aspect ratio of the pile foundation system.
LIST OF REFEREED PUBLICATIONS BASED ON THIS RESEARCH

Journal Articles


Peer-reviewed Conference Papers

1. **Pallavi Ravishankar** and Neelima Satyam, 2013,"Numerical modeling to study dynamic soil structure interaction effects on asymmetrical buildings”, Proceedings in International Conference on Earthquake Geotechnical Engineering, from Case Histories to Practice; In the Honor of Prof.Kenji Ishihara (ICEGE2013), Turkey .


8. **Pallavi Ravishankar** and Neelima Satyam, 2014, “Study on Interfaces effect on SSI analysis of asymmetrical pile supported building” 4th International Conference on Civil Engineering and Building Materials (CEBM2014), Hong Kong.

Communicated

1. **Pallavi Badry** and Neelima Satyam, “An Efficient approach for assessing the dynamic soil structure interaction analysis for asymmetrical pile group”, International Journal of Innovative Infrastructure Solutions (Springer). (**Paper Accepted**).

2. **Pallavi Badry** and Neelima Satyam, “Dynamic nonlinear analysis of asymmetrical buildings”, Indian Geotechnical Conference (IGC 2015), Pune, India, December 2015, (**Paper Accepted**).


6. **Pallavi Badry** and Neelima Satyam, “Seismic Soil structure interaction analysis of pile supported asymmetrical building using Equivalent Pier Method” 6th International conference on Geotechnical Engineering and soil dynamics (6ICGESD), Delhi NCR, INDIA. (**Paer accepted**).