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Effect Of Soil Structure Interaction On The Dynamic Behavior Of Building - A Review

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Abstract:- *Soil Structure Interaction (SSI) is the response of soil that influence the motion of the structure. Soil structure interaction is prominent for heavy structure, especially for high rise building located on soft soil. Incorporation of soil interaction effect will reduce the base shear and flexibility of soil. Because of this the stiffness of the building is getting reduced resulting, increase in the natural period of the structure during earthquake.*

One cause of these deviations is base-slab averaging, in which spatially variable ground motions within the building envelope are averaged within the foundation footprint due to the stiffness and strength of the foundation system. Another cause of deviation is embedment effects, in which foundation-level motions are reduced as a result of ground motion reduction with depth below the free surface. Interaction of pile foundation with wave propagation below the base slab, which can further modify foundation-level motions at the base of a structure.

Keywords: *Soil structure interaction, flexibility, Kinematic interaction*

I. Introduction

SOIL STRUCTURE INTERACTION (SSI) - DEFINITION

During earthquakes, the structural elements in direct contact with the ground undergo structural displacement or ground displacement will take place in response to the movement of the structure during earthquake. Further, response of soil

influences the motion of the structure or motion of structure influences the response of soil.

CRITICAL ASPECTS OF SSI

There are three critical aspects influencing the soil structure interaction. They are:

• Inertia
• Free field displacement
• Free field rotation

Soil structure interaction is basically for heavy or high rise buildings located on the soft soil, compared to low rise buildings located on the stiff soil.

II. Literature Review

Jonathan et al. (1999) analyzed the procedure for evaluating inertial soil structure interaction effects with respect to seismic structural response. The analysis procedure data's are similar to provisions provided in standard building codes along with considering the influence of site conditions, foundation embedment, flexibility, and shape on foundation impedance. Implementation of analysis procedures and system identification techniques is illustrated using a data of Northridge earthquake (1994). A companion paper applies these analyses to empirically evaluate SSI effects using available strong motion data from a broad range of sites and then comes with general conclusions

Julio et al. (2008) investigated the influence of soil-structure interaction in the analysis and design of a 6-storey and basement reinforced concrete frame building. Models created with different support conditions which include soil-structure interaction (flexible base) and fixed-base behavior are considered. Inclusion of soil structure interaction effect influences dynamic behavior of the building resulting increase in the vibration period as well as increase in the system damping in comparison with the fixed-base model. The influence of the soil-structure interaction in the seismic design of the structure is reflected in a decrease of the horizontal spectral acceleration values. Creating artificial flexibility in the structural analysis provides results such as stress and displacement which are closer to the actual behavior of the structure than those provided by the analysis of a fixed-base structure.

Mylonakis et al. (2010) analyzed the effect of soil-structure interaction (SSI) in the seismic response of structures. Firstly, the way we treat the current seismic provisions with SSI effects is briefly discussed in this paper. Response spectrum specified in code book along with the increased fundamental period and effective damping due to SSI lead invariably to reduce base shear in the structure. In certain seismic and soil environments, an increase in the fundamental natural period of a moderately flexible structure due to SSI may have a detrimental effect on the imposed seismic demand. Further, an inelastic bridge pier which is a widely used structural model for assessing SSI effects on is also examined. Analyzing theoretical value with the numerical analysis, it is shown that inaccurate use of ductility concepts and geometric relations may lead to erroneous conclusions in the assessment of seismic performance. Numerical examples are presented which highlight critical issues of the problem.

Anand et al (2010) analyzed the seismic behavior of RCC buildings with and without shear wall under different soil conditions. One to fifteen storied space frames with and without shear wall were analyzed using ETABS software for different soil conditions (hard, medium, soft). The values of Base shear, axial force and Lateral displacement were compared between two frames. Lateral displacement, Base shear, axial force and Moment in the column value increases when the type of soil changes from hard to medium and medium to soft for all the building frames. Inclusion of soil structure interaction must be considered while designing frames for seismic forces.

Matinmanesha et al. (2011) presented the idealized two dimensional plane strain finite element seismic soil-structure interaction analysis using Abacus V.6.8 program. Recording the ground motion with low, intermediate and high frequency content earthquakes. Inclusion of soil structure effect, results shown that sandy soils amplifies seismic waves on the soil-structure interface. During earthquakes, seismic waves propagate from the bedrock through the different soil layers beneath and cause damage to superstructure. Effects on strong ground motion is of particular importance for the mitigation of earthquake disasters as well as earthquake resistant design for local building design.

Pandey et al. (2011) presented the static pushover analysis and Response spectrum analysis (RSA)of the five different configuration of the building i.e. three step back buildings and two step backset back buildings with varying support conditions. These different configurations were analyzed for different soil conditions (hard, medium and soft soils) idealized by equivalent springs. The response spectra parameters includes total base shear (V), displacement from pushover analysis, displacement from response spectra method and response correction factor (R’) had been studied with respect to fixed base analysis to compare the effect of flexibility soil springs. In general it is found that response reduction factor decreases with increasing time period, but is expected to be constant beyond a certain value of time period.

Priyanka et al. (2012) studied the effect of Soil-structure interaction on multi storied buildings with various foundation systems. Dynamic properties of soil can affect seismic waves as they pass through a soil layer. When a structure is subjected to an earthquake excitation, it interacts the foundation and soil, and thus changes the motion of the ground. Response of the whole ground structure system is influenced by type of soil as well as by the type of structure. Also to study the response of buildings subjected to seismic forces with Rigid and Flexible foundations. Multi storied buildings with fixed and flexible support subjected to seismic forces were analyzed under different soil conditions like hard, medium and soft. The buildings were analyzed by Response spectrum method using software STAAD Pro. The response of building frames such as Lateral deflection, Storey drift, Base shear, axial force and Column moment values for all building frames were presented in this paper.

Mahadeva et al. (2014) studied the criteria for earthquake resistance design of structure. It gives spectrum analysis for different type of soil as hard medium and soft and also soil structure interaction with various foundation systems. Thispaper analyzed the 3D frame using SAP 2000 V14. The soil and the structure are considered as a single continuum model. It also gives the idea of the response of building subjected to seismic forces with raft foundation. The structure was analyzed by response spectrum method using software SAP 2000. Analysis of energy transfer mechanism from substructure to superstructure during earthquakes which is critical criteria for the design of earthquake resistant structures and for renovating the existing structures were focused. Thus the need for research into soil structure interaction problem is greater than ever.

Kuladeepu et al. (2015) studied the dynamic behavior of building frames over raft footing under seismic forces including soil structure interaction effect. The analysis is carried out using FEM software SAP2000 *Ver14. For the soil structure interaction analysis of building frame, foundation and soil are considered as parts of a single compatible unit and soil is idealized using the soil models for analysis. Soil under raft slab is replaced by providing a true soil model (continuum model). Soil is considered as homogeneous, isotropic and elastic of half space for elastic continuum model, for which dynamic shear modulus and Poisson's ratio are the inputs. Influence of number of parameters such as number of storey's, soil types and height ratio for seismic zone-V is considered in present study. Building responses are considered for bare frame with and without incorporating soil flexibility. Result parameters such as lateral natural period and seismic base shear, lateral displacement (story drift were evaluated.

Gaikwad et al. (2015) studied the behavior of bare frame & in-filled frame having soil beneath. In these cases three types of soils are considered, soft, medium stiff and hard. Also in-filled panel is of brick masonry only. Seismic analysis of a building frame, the columns at the foundation level are considered as fixed. But in real condition it is not the case. Incorporating the properties of soil building frame 100% fixity may not be ensured. Superstructure get altered because of the settlement and rotation of foundation, shear force and bending moment. This effect is called as "Soil Structure Interaction" .Various cases frames are studied. The following are the cases: 1] Analysis of bare frame with soil.2] Analysis of In-filled frame with Soil.3] Analysis of Bare frame without Soil.4] Analysis of In-filled frame without Soil Frame with different combinations mentioned above (with/without infill panel, with/without soil) is analyzed by using ANSYS 14.5. These results are comprised with SSI and without SSI.

Singh et al. (2016) analyzed the performance of RC frame buildings with and with-out infill walls. In structural construction, RC framed structures are frequently used due to ease of construction and rapid progress of work. Both stiffness and strength of the frame is enhanced by the use of infill panels and it behaves like compression strut between column and beam and compression forces are transferred from one node to another. Response of building during Bhuj earthquake clearly illustrates that the presence of infill walls has significant structural failure. Equivalent diagonal strut concept analysis is used in-order to assess their response in seismic resistance of reinforced concrete buildings. Comparing the results, which are obtained from the computerized model analysis (with and without infill structures).Parameters included are base shear, lateral floor displacement, story drift, and beam and column reactions by buildings for the comparison of results.

Kumar et al. (2016) investigated the seismic performance of superstructure considering the interaction between substructure and superstructures. Comparing the dynamic responses offixed base with that of dynamic base. solve this problem, a Finite Element Method is used to model soil structure interaction analysis of raft foundation supported framed structures by programming in SAP 2000 V14 software. Results are obtained by considering the parameters like time period, lateral displacement, storey drift, bending moment in X-X and Y-Y direction. Time history analysis has been carried out and the parameters like base shear and roof top displacement of the building frames resting over raft foundation and soil media has been studied. Soil-structure interaction effect plays a significant role to increase the time period, bending moment in X-X direction, bending moment in Y-Y direction, lateral displacement. As the flexibility of the soil increases the bending moment also increases.

Magade et al. (2016) analyzed the common design practice for dynamic loading assumes the building to be fixed at their bases. In reality the supporting soil medium allows movement to some extent due to its property to deform. Foundation flexibility may decrease the stiffness of the structural system and resulting increase the natural periods of the system. Such an interdependent behavior of soil and structure regulating the overall response is referred to as soil structure interaction. Soil structure interaction effect is suggested to be accounted through consideration of springs of specified stiffness. Thus the change in natural period due to effect of soil structure interaction may be an important issue from the viewpoint of design considerations.

Hosseinzadeh et al. (2017) analyzed the response characteristics of embedded building using experimental tests (shaking table) and finite element analysis. Soil Structure-Interaction (SSI) is the response of structures caused bythe flexibility of the foundation soils as well as in the free field response of soils media caused by the presence of structures. The effects of this phenomenon in dynamic behavior of building structures can be changed by embedment of foundation. For this study, four scaled models of steel building structures with 5, 10, 15, and 20 stories have been designed and studied as common representative buildings in urban areas. Both soft and relatively soft soil media with geometric scale model of 1/100 have been designed and considered in this study. These models subjected to earthquake records of El Centro, USA (1940), and Tabas, Iran (1981) using

International Institute of Earthquake Engineering and Seismology (IIEES) shaking table. Result such as building aspect ratio, shear wave velocity, frequency content, damping ratio, and acceleration of structural models. Also, the results of finite element analyses of soil-structure system have been compared with shake table results. It can be concluded that SSI effects reduces by increasing of the foundation embedment.

III. Conculsion

1. From the literature review, performance of the multi-storied buildings of ten (G+10) and twenty storey (G+20) with ground floor, located under fixed support and over raft foundation of varying depth 0.8 m, 1 m, and 1.2 m respectively.
2. Area springs are included in the local 'z' axis to make the foundation flexible there by creating the effect of soil structure interaction.
3. The response of the building is analyzed in terms of fundamental natural period, lateral displacement, storey drift, lateral deflection and seismic base shear.
4. This study shows that, the SSI will have an influence on dynamic behavior of the building needs to be considered in the design of earthquake resistant buildings.

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