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Study of Soil Structure Interaction on RCC Building

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Abstract:- The response of a structure to an earthquake is influenced by the relationship between the structure, the foundation, and the three linked systems of soil beneath the foundation and adjacent soil. Soil structure interaction analysis estimates the combined response of these systems to well-defined ground movements. The terms Soil Structure Interaction (SSI) and Soil-Base-Structure Interaction (SFSI) are both used in the literature to define this effect. In this treatise, the foundation is measured as part of the structure and the term SSI is adopted.

Keywords:- *Soil Structure Interaction, Framed Structure, Behavior of Foundation, ETABS.*

I. INTRODUCTION

Soil-structural interactions can be defined primarily as a group of structural responses caused by the elasticity of the soil beneath the foundation, and soil response phenomena initiated by the development of structures. A complete soil foundation structural system consists of a superstructure frame, its foundation, and the soil above it, as shown in Figure 1. Both the axial force and the moment of the structural member can change due to different settlements (due to the causative soil characteristics) between different parts of the structure.

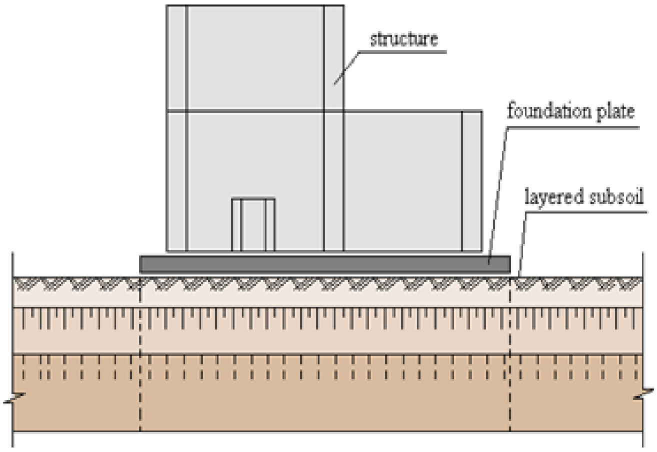


Fig -1: Interaction between structure, foundation plate and soil

Most civil engineering structures contain certain structural elements that come into direct contact with the ground. When external forces such as earthquakes act on these systems, structural and ground displacements do not remain independent of each other. The process by which the soil response affects the structural movement and the structural movement affects the soil response is called the soil-structural interaction (SSI).

Structural stiffness and soil load subsidence characteristics affect the amount of load redistribution acting on the structural members of the structure. Since then, there have been several studies in the literature conducted to estimate the effects of this factor. Traditional structural design techniques ignore this SSI effect. Ignoring SSI is suitable for light structures with relatively hard soil, such as low-rise buildings and simple hard retaining walls. However, the impact of SSI is more pronounced on heavy structures on relatively soft soils such as nuclear power plants, skyscrapers and highways. Ground-structure interaction analysis is a method of assessing the collective response of the above three linked systems to a particular ground motion. Soil-structure interaction can be defined as the process by which the response from the soil influences the movement of the structure and the movement of a particular structure influences the response from the soil. This is a phenomenon in which structural displacement and ground displacement are independent of each other.

II. RELATED WORK

Shehata E. Abdel Raheem et. al. (2014) studied that the effects of Soil Structure Interaction (SSI) can be detrimental to the seismic response of the structure, and ignoring the SSI in the analysis can lead to un-conservative designs. Nevertheless, normal design procedures assume that the foundation is fixed to the foundation, ignoring the requirements for foundation flexibility, mass compressibility, and consequent bending moments and shear forces. I will. Includes the impact of foundation subsidence on further redistribution. The impact of SSI is analyzed in a typical skyscraper on a raft foundation. Seismic resistance of the target. Seismic resistance of using frame frame building materials was evaluated using three analysis methods. Response spectrum (RS) method and nonlinear time history (TH) analysis. Three-dimensional finite element (FE) models have been constructed to analyze the effects of various soil conditions and floors on the vibrational properties and seismic response requirements of building structures. Numerical results obtained using the soil structure interaction model conditions are compared with those corresponding to the fixed floor support conditions. Layer shear, layer moments, layer displacements, layer drifts, peak response of beam end moments, and internal column forces are analyzed.

Jonathan P. Stewart et. al. (2013) The analysis procedure and system identification method for evaluating the effect of inertial SSI on the seismic structure response were explained. The analytical procedure is similar to the provisions of some building codes, but more reasonably incorporates the effects of foundation embedding, flexibility, and shape on the site conditions and the impedance of the foundation. Implementation of analytical procedures and system identification techniques has been demonstrated using buildings that shook during the 1994 Northridge earthquake. The analytical procedure accurately predicts the observed SSI effect. Reliable papers have made these analyzes work, empirically assessing the SSI effect with strong motion data accessible from a wide range of sites, and disseminating the SSI effect on seismic structure excitation and response. Draw conclusions. This article describes two sets of analyses. (1) Simplified design procedure that can be used to predict the period extension ratio and foundation damping coefficient of structures with surface (MV) or embedded (MV or MB) foundations. (2) System identification procedure for evaluating modal vibration parameters of fixed and flexible bases from strong seismic data. The greatest uncertainty in using the MV and MB procedures for a given free field motion is related to the impedance function. Evaluation of shear wave velocity profiles, modeling of embedded foundations (MB procedure may not be appropriate if the basement wall is not continuous around the foundation), oval foundation, or flexible to support the central core The foundation should be carefully considered for rigid shear walls. The parametric system identification procedure provides a reliable basis for evaluating modal vibration parameters of structures under various basic fixed conditions. However, in order to reasonably interpret the results of such analyses, it is necessary to fully consider the disturbance of strong motion data and potential numerical errors in identification by proper characterization of nonlinear structural responses.

L. M. Anderson et.al. (2011) In this white paper, the SSI effect is measured by considering two models, one that contains the entire complex of structures and one that contains only the structures that show the most important SSSI responses. Amplification is quantified by comparing the transfer function with the required acceleration of the seismic component. Replacing the soil parameters at the Hanford Site with the soil parameters at the Savannah River Site (SRS) provides a realistic study of the sensitivity of the soil parameters. SRS is also a division of energy facilities. Since the site is located in South Carolina, the hardness of the soil is not very strict and a practical comparison is possible. Soil stiffness sensitivity is quantified by taking the ratio of the combined model's response to the individual model's response for both soil types. They concluded that the pre-treatment facility management building exhibits a significant increase in seismic demand load due to the SSSI effect of the adjacent larger structures. The weighted average ratio of maximum node acceleration shows that SSSI amplification is highest in the vertical direction, increasing seismic demand by 33%. Amplification of the response perpendicular to the building boundary is also important, increasing seismic demand by 15%. Amplifying the response parallel to the building interface is less important and only increases the demand load by 2%. The Savannah River Site soil profile applied to the pretreatment facility complex structure reduced the SSSI amplification apparent in the Hanford Site soil profile. Softer soils produce less SSSI effects than harder soils.

Barış Sevim et.al studied the blast response of a two-story reinforced concrete (RC) building under various charge weights of TNT explosives. In this study, a two-story RC building was numerically modeled with RC columns, beams, floors as structural elements, and walls and windows as non-structural elements. Blast modeling was configured using ANSYS AUTODYN (2016) software, and explicit analysis of the building was also performed with this software for a period of 3 ms. Use ANSYS Workbench to simulate a model of an existing building in Istanbul, Turkey, which was bombed in August 2015.Three explicit analyses were performed considering 0.1 ton, 0.25 ton and 0.5 ton TNT explosives. The results showed that the different charge weight of TNT explosives considerably affected blasting response of the two-storey RC building. Also, the main damages are obtained on the first storey slab. The pressure values obtained show that the building can resist against blast loading of 0.1 ton TNT explosive.

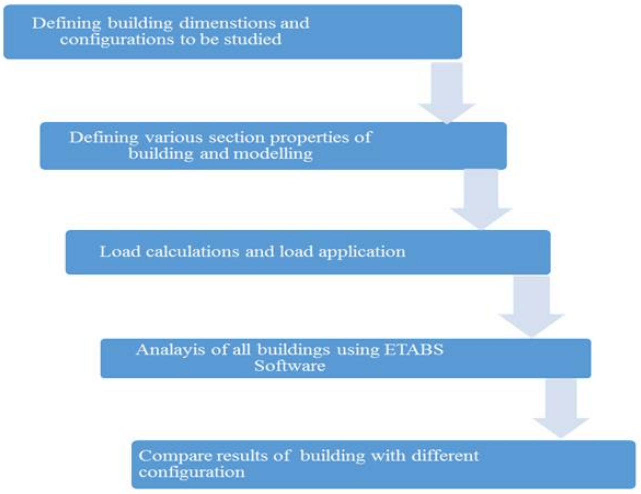
Objectives of investigation:

- To check the stability of structure with seismic load in seismic zones V.
- To understand the effect of soil structure interaction.
- To find the effect of SSI on structure.

III. METHODOLOGY

For present work seismic analysis is carried out for reinforced concrete moment resisting building frame G+12 Storey, is considered for the present study to investigate SSI effects on tall buildings. The plan dimension of the building is 28.20 m by 16.10 m and the height of the building is 43 m from the ground level. The stilt height is 4m from the base level and all other stories are 3 m. Two types of buildings considered in the study, which are:

1) Buildings without fixed base (soft and hard)
2) Buildings with flexible base with SSI



ETABS 9.7.4 facilitating modeling a 12-story building modeled using software. The entire building is modeled as a 3D RC frame model. Beams and columns are modeled using R.C 3-D beam elements with 6 degrees of freedom at each node. The slab is modeled as an infinitely rigid membrane in its own plane and provides a diaphragm action to transfer horizontal loads to columns and shear walls. Shear walls are modeled using R.C3-D shell elements. 3D R.C beam elements are used to model the frame of the structure. Steel is modeled as a bar element, concrete is modeled as a beam element, and it is assumed that the two materials are perfectly bonded. The frame section of the modeling process contains beams and columns. Sections of various columns used in modeling. All pillars are made of M35 grade concrete and Fe 500 grade steel. Table 1 details the beam and column sections used in the modeling.

Table 1 Sections properties of all structural members

Beams	**Columns**	**slab**	**shear wall**
230mm0x450mm for all floors	350x750 for first 5 floors	125mm for all floors	150mm for all floors
	350x450 for remaining floors		

Slabs and shear walls are modeled with R.C shell elements. Shell elements are stacks of monolayers of varying thickness and eccentricity. Shell elements can withstand bending, shearing, and membrane forces. Floor slabs are modeled with membrane elements because they are supposed to be rigid diaphragms. Shear walls are modeled using 3D quadrilateral shell elements, and all shell elements are assigned M35 grade material.

Buildings with fixed base: The co-ordinate points are the placements of columns according to the base plan layout of the structure. All the points will be constrained with ux, uy, uz, rx, ry and rz coordinates for fixed base condition, which means no linear and rotational Displacements are allowed. Storey 1 being a Master storey, remaining stories modeled according to it. The complete building has been modeled using appropriate elements of beams, columns, slabs and shear walls in each storey. as shown in Fig. 2.

Building on Raft foundation: The 29.8x17.7x0.5m raft foundation is modeled using a thick R.C. Shell elements, to facilitate simulation of Soil Structure Interaction effects for the clayey soil. The building with raft foundation model is as shown in the Fig. 3. The properties of clayey soil have adopted and calculated, are shown in Table-2. Spring stiffness values for vertical, horizontal, rocking and twist motion are calculated according to the Richart and Lysmer models. The entire area is meshed with quad shell elements and a soil spring is applied.

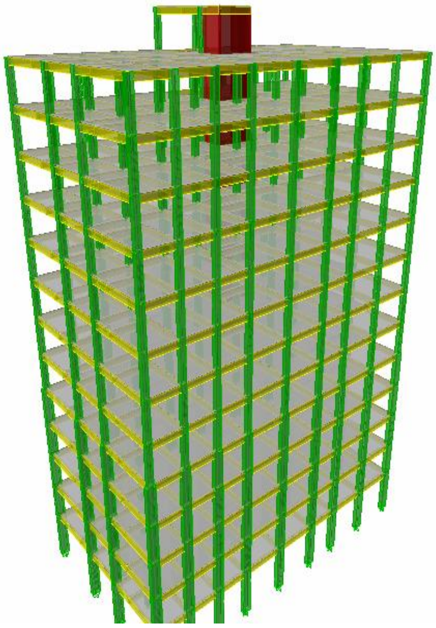


Fig. 2: 3D rendering view of building with fixed base in ETABS

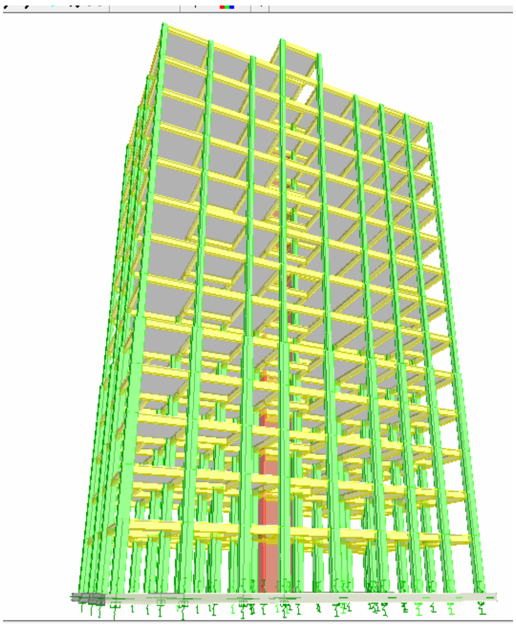


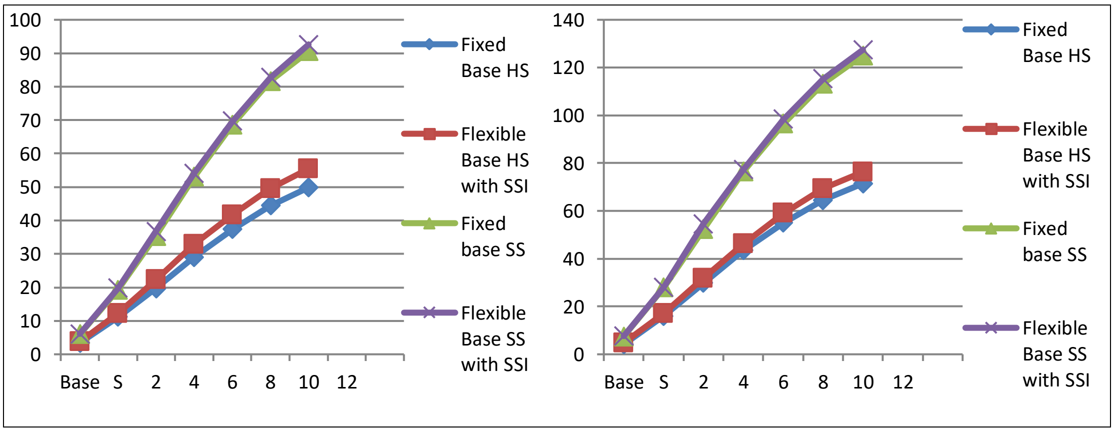
Fig. 3: 3D rendering view of building with raft foundation and applied soil springs in ETABS

Table 2: Soil Spring Values as Per Richart and Lysmer

Direction	Spring Values	Equivalent Radius
Vertical	$K_z = \frac{4Gr_z}{(1-\theta)}$	$r_z = \sqrt{\frac{LB}{\pi}}$
Horizontal	$K_x = K_y = \frac{32(1-\theta)Gr_x}{(7-8\theta)}$	$r_x = \sqrt{\frac{LB}{\pi}}$
Rocking	$K\varphi_x = \frac{8Gr_{\varphi x}^3}{3(1-\theta)}$	$r_{\varphi x} = \sqrt[4]{\frac{LB^3}{3\pi}}$
	$K\varphi_y = \frac{8Gr_{\varphi y}^3}{3(1-\theta)}$	$r_{\varphi y} = \sqrt[4]{\frac{LB^3}{3\pi}}$
Twisting	$K\varphi_z = \frac{16Gr_{\varphi z}^3}{3}$	$r_{\varphi z} = \sqrt[4]{\frac{LB^3+BL^3}{6\pi}}$

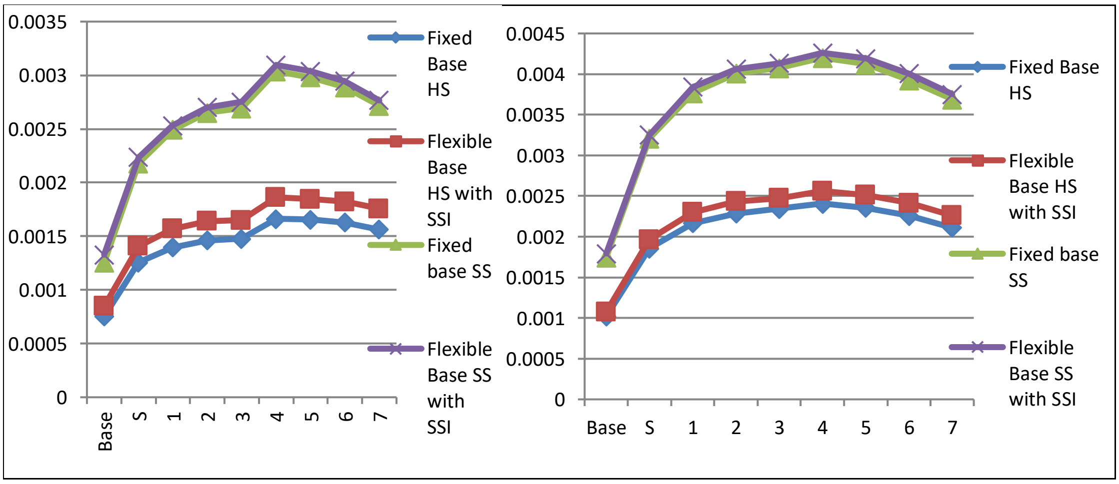
IV. RESULTS AND DISCUSSIONS

After analysing all the models with response spectrum analysis we found that values of lateral displacement (mm) with floor level in X direction increased slightly around 4-10% with soil structure interaction as compared to fixed base. The values of lateral displacement (mm) with floor level in Y direction increased slightly around 4-7% with soil structure interaction as compared to fixed base. Values of time period of building with mode no for zone V increased slightly around 1-2% with soil structure interaction as compared to fixed base. Values of Story Drift with floor level in X direction for zone V increased by 7-8% with soil structure interaction as compared to fixed base case. Values of Story Drift with floor level in Y direction increased by 6-10% with soil structure interaction as compared to fixed base case. It is found out that, base shear in X and Y direction is almost similar in both cases as there is no increase in seismic weight of the building.



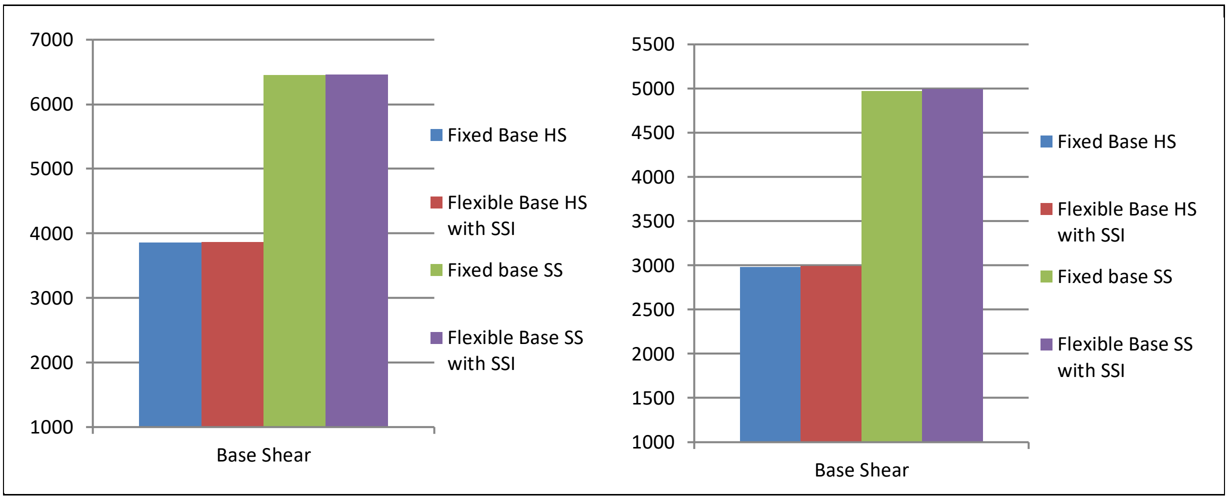
(a) (b)

Fig.: 4 (a) & (b) shows the variation of lateral displacement (mm) with floor level in X & Y direction for zone V



(a) (b)

Fig.: 5 (a) & (b) shows the variation of Story Drift with floor level in X & Y direction for zone V



(a) (b)

Fig.: 6 (a) & (b) shows the variation of base shear (kN) of buildings in X &Y direction for zone V

V. CONCLUSION

Variation of storey drift in both the cases is parabolic with middle storeys showing maximum drift. When SSI is considered there is a magnification of storey drift in the middle storeys. Variation of lateral displacement in both the cases is maximum at top stories showing maximum displacement, also the displacement value increases when SSI is taken into consideration. The base shear for with soil structure interaction case is almost same as compared to fixed base case as there is no increase in seismic weight of the building.

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