Performance Based Analysis of Framed Structure Considering Soil Structure Interaction

Aravind I. Kolaki and Basavaraj M. Gudadappanavar

Abstract--- *Soil is a multiphase material, which is not linearly elastic or perfectly plastic for external loading and soil behaves nonlinear during earthquake. During seismic design, foundation is assumed as fixed which does not response for dynamic evaluation. An evaluated structure for lateral forces using SAP2000 software and ATC-40 earthquake data has been used. The effect of soil structure interaction as per code for analysis procedure is complexity and the soil parameter is considered as springs and the elasticity is presented in the form of fundamental natural period of vibration and base shear of the structure. The structure is analysed the performance of the structure by nonlinear static analysis in SAP2000 software. The performance of the structure is evaluated under immediate occupancy, life safety and collapse prevention levels as defined as ATC-40 for the respective performance point of structure.*

Keywords--- *Soil Structure Interaction, Performance Point, Fundamental Natural Period, Base Shear*

I. INTRODUCTION

DURING the seismic design the structural designer should think of about the soil behaviour during earthquake vibrations not only for foundation design. Soil structural interaction performs an important role in the design of foundation, for the structural components like beams, columns, foundations rather foremost to consider the deformational characteristics of soil and foundation flexural properties. It can be seen that when soil structure interaction is taken into account, the real design outcomes are noticeable and may be little unique from those worked without figuring out the soil structure interaction proposal. Soil structure interaction causes reduction in critical values of the shear and bending moments up to 20% compared to conventional method. But in some other cases there might be incremental in some of the elements. In some soil types there might be liquidity if any part of the soil meets water and the part of the foundation may settle or whole structure.

If whole structure settles the structure will stand without the failures but if the structural foundation settles then the structure might fail or the members gets cracked and the members fail. Rigidity of structure helps in reducing differential settlements, of course to realize the interactive analysis has to be carried out. There are many illustrations which explain that the soil beneath foundation can alter dynamic behaviour of the building.

Failures of structures during Bhuj (2001) and Sikkim (2011) seismic vibrations assisted for considering the importance of soil structure interaction and ensuring the protection. During the earthquake, the bedrock movements induce dynamic effect on the structure. In this case the influence of foundation flexibility is very important. The modeling of soil and structural foundations inherently accounts the interaction of soil on structure.

II. SOIL STRUCTURE INTERACTION

During earthquake vibrations, the structural response and the characteristics of the bottom motion or foundations are determined. The procedure where the response of the soil influences the movement of the structure and vice versa is referred as soil structure interaction. This method of analysis is explained by the following two approaches. One is direct method, which explains the response of the soil and structure is determined simultaneously by analysing the soil structure interaction in a single step and in this approach the soil and the structure is considered as a single unit. And another is indirect or sub structure method, which explains the structure and the soil are two different parameters or units and each unit in this method analyzed by best computational approaches. The soil structure interaction is explained by considering force displacement relationship of the soil with the motion of the structure which results within the ultimate system of the equations of the entire dynamic system.

Soil structure interaction (SSI) is an essential phenomenon within the design procedure of the structure and for systems and aspect housed within. The value of soil structure interaction determined on the basis and the type of soils. For conventional or traditional buildings with embedded foundations soil structure interaction is normally ignored. Soil structure interaction is most important for stiff structures with mat or raft foundations which significantly stiffened by way of the structure's load resisting process. In the Indian code (IS 1893(Part I):2002) there is no provision regarding the stiffness of infill and the soil structure interaction. By choosing table 1of IS-1893(Part I): 2002, which explains the adoption of percentage of permissible increase in allowable bearing pressure and as per ATC-40 explains the procedure for modelling and consideration of the stiffness of the soil.

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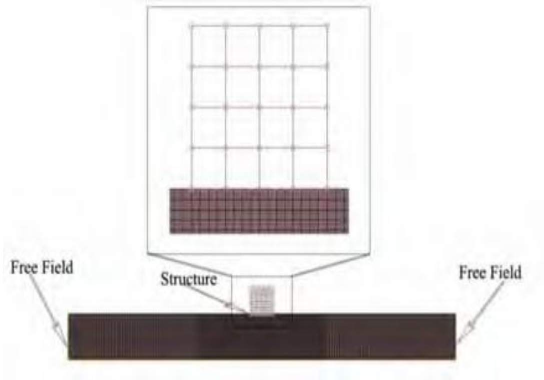

Figure 1: Representation of SSI

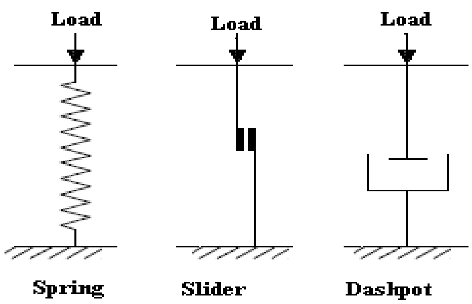

Figure 2: Basic Models for Types of Soil

III. Objectives of the Study

The objectives of the present study is,

a. To produce an easier but a design procedure for practical purpose which enables structural engineers to consider major effects of SSI in seismic design for moment resisting framed structure to ensure the life safety and reliability;
b. To evaluate the effect of SSI on infill frame and bare frame;
c. To evaluate the effect if SSI on different types of frames considering different types of soils;

IV. Methodology

Model of soil structure interaction in dynamic analysis falls into 2 essential classes specially; multistep approach and direct approach. The previous description of SSI phenomenon is the bottom for the multistep parameter ways and helps to exemplify soil structure interaction outcomes separately. In the direct procedure the whole system is analyzed in one step in view that the interaction wholly. The study will be done in the following ways: 1) The effects of soil structure interaction base over the conventional fixed base of the building structures. 2.) To study parameters such as time period, base shear, storey shear, displacements, and drifts. 3.) To compare the above said parameters for conventional fixed case against flexible base.

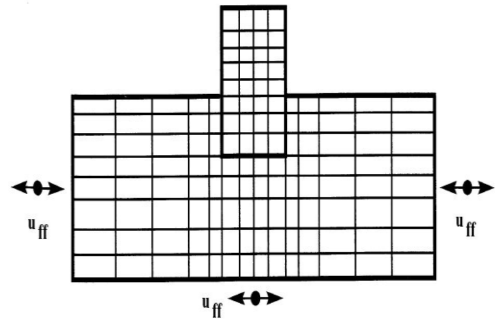

Figure 3: Modeling of Direct Method and Solving the Equations

V. Modeling and Analysis

In the present study, a regular building with size 36mX36mX46m with beam size 0.3mX0.6m and column size 0.6mX0.9m. This 15 storey building is analyzed for fixed and flexible base condition. The slab thickness is taken as 150mm and analyzed as membrane. Firstly, the structure is analyzed as fixed base condition and then the springs are applied as per footing size as in the fixed base condition for counteracting the soil structure interaction. The structure is analysed for different load cases as per code specification in SAP2000 software.

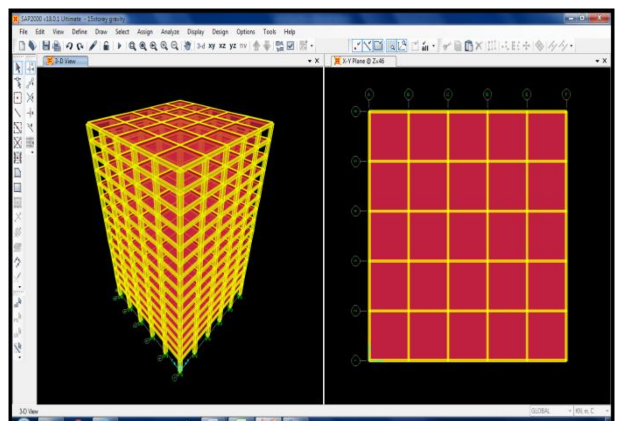

Figure 4: 3d and Plan View of the Storey with Fixed End Condition with Beam and Column Sections

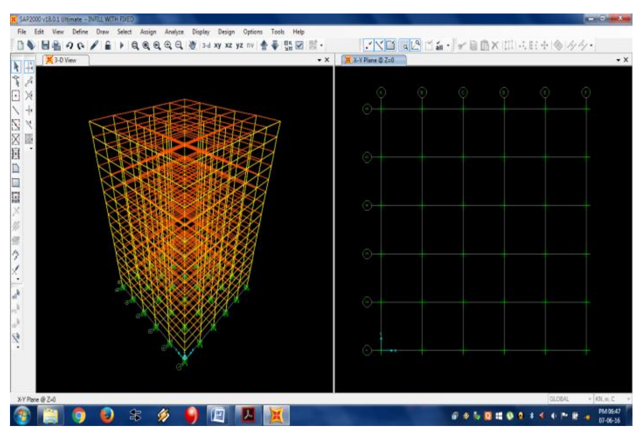

Figure 5: 3d and Plan View of the Storey with Fixed end Condition

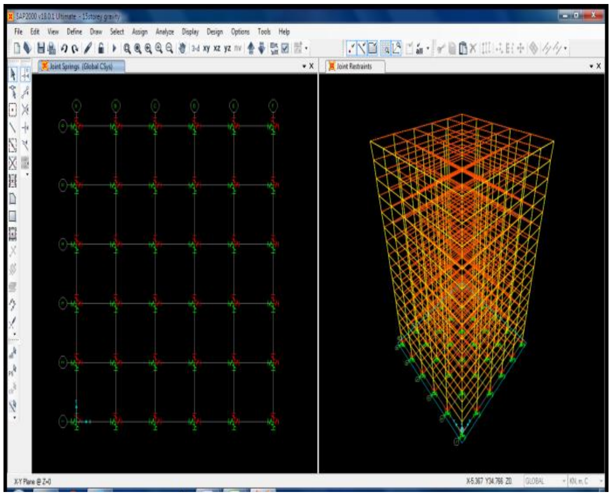

Figure 6: 3d and Plan View of the Storey with Flexible End Condition

VI. RESULTS

Following are the tables and graphs which are shown after the analysis in the software, the tables and graphs are shown are 15 storeys building. The results and the graphs shown are of base shear, storey displacement, storey drifts for different soils.

The different models are explained below;

Model I- Building with no walls in the structure supported on stiff clay;

Model II- Building with no walls in the structure supported on medium clay;

Model III- Building with no walls in the structure supported on soft clay;

Model IV- Building with open storey in the ground storey supported on stiff clay;

Model V- Building with open storey in the ground storey supported on medium clay;

Model VI- Building with open storey in the ground storey supported on soft clay.

Table 1: Base Shear for Different Models

Model	*Model I*	*Model II*	*Model III*	*Model IV*	*Model V*	*Model VI*
Fixed	2207.37	3002.02	3685.35	6536.78	8888.03	10916.9
Flexible	2840.508	3863.091	4437.05	8211.37	11167.03	13721.36

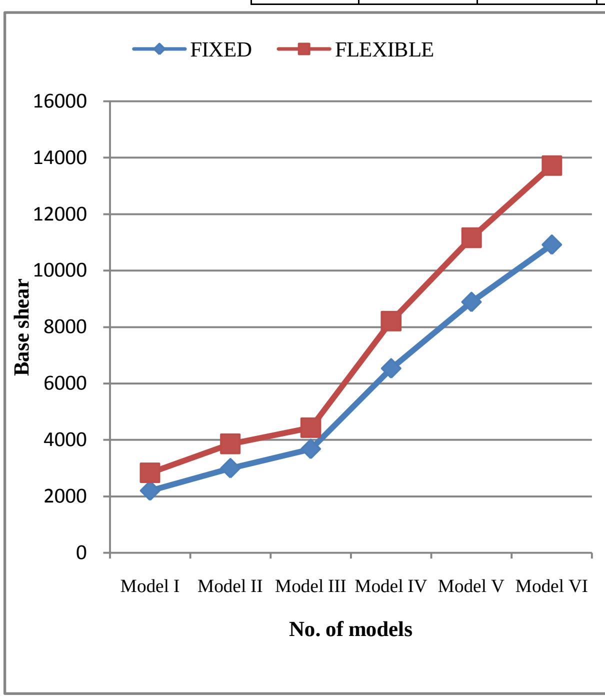

Figure 7: Graphical Representation of Base Shear

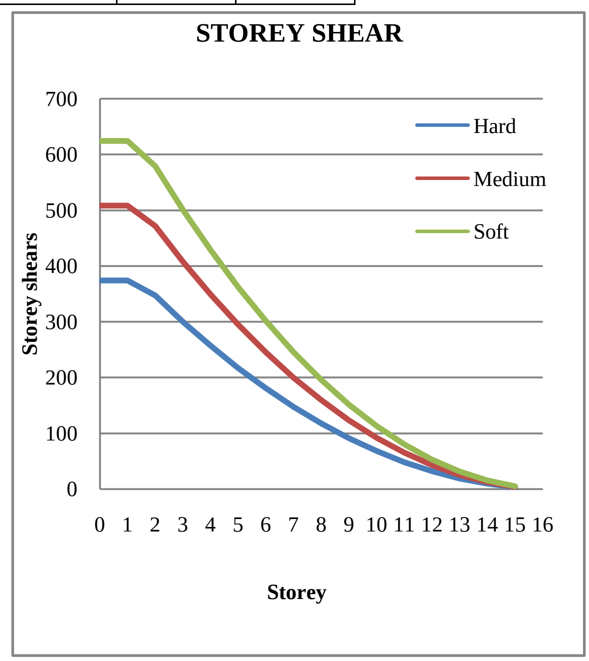

Figure 8: Graphical Representation of Storey Shear for Fixed base

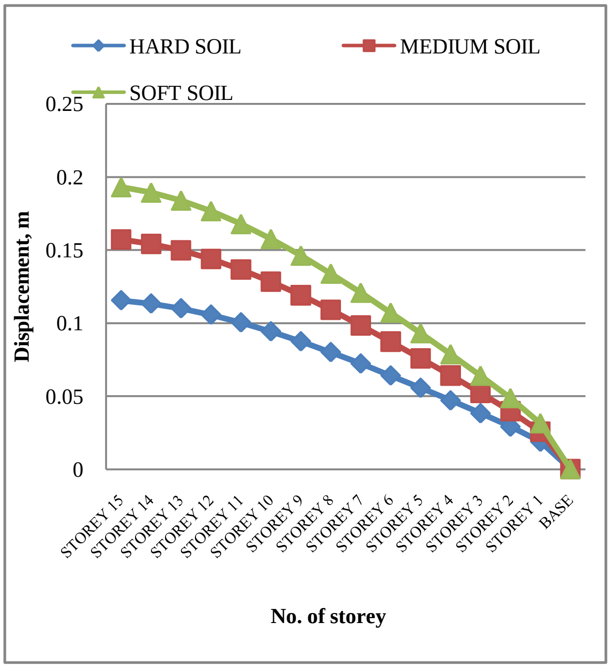

Figure 9: Graphical Representation of Storey Displacement for Fixed Base Along Longitudinal Direction

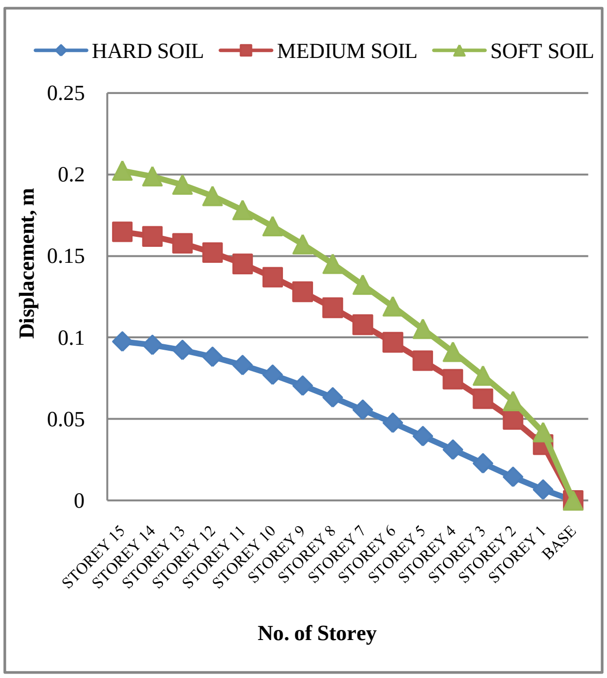

Figure 10: Graphical Representation of Storey Displacement for Fixed Base along Transverse Direction

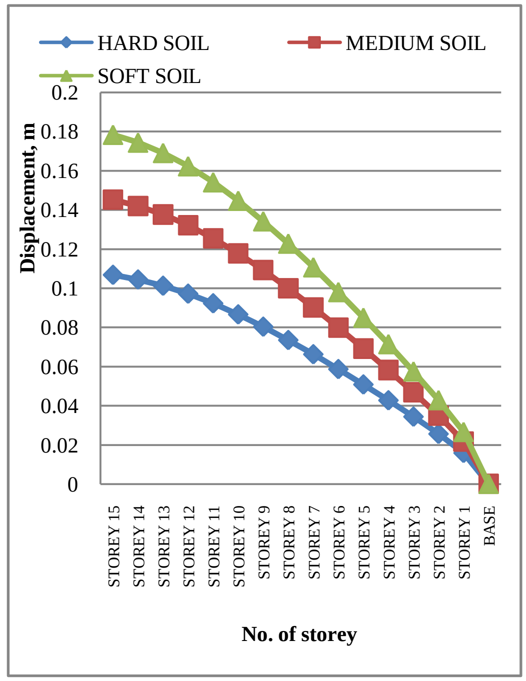

Figure 11: Graphical Representation of Storey Displacement for Flexible Base along Longitudinal Direction

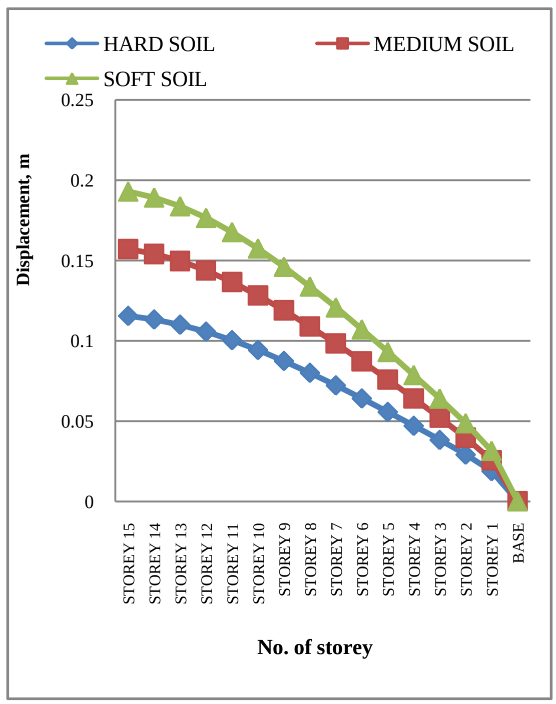

Figure 12: Graphical Representation of Storey Displacement for Flexible Base along Transverse Direction

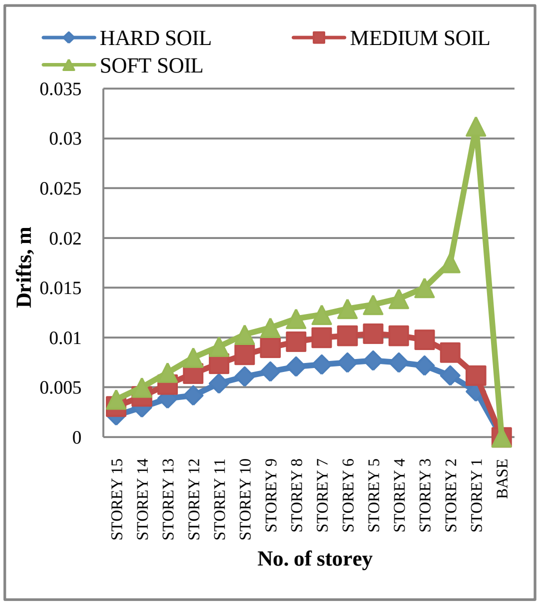

Figure 13: Graphical Representation of Storey Drift for Fixed Base along Longitudinal Direction

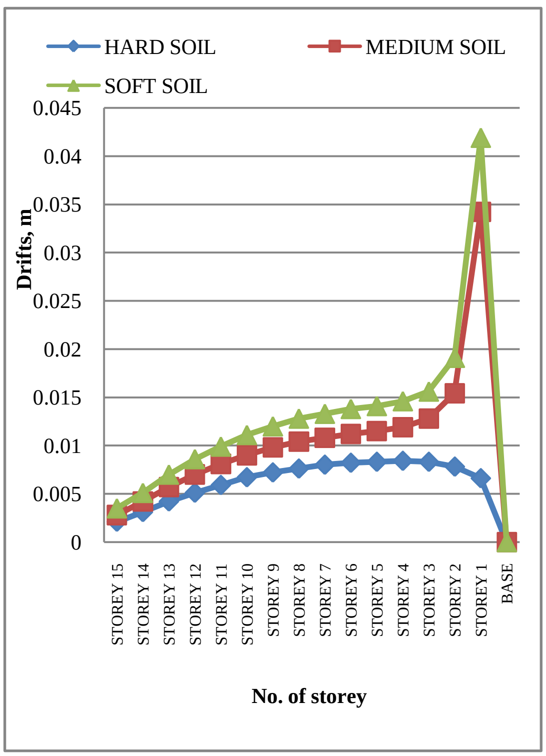

Figure 14: Graphical Representation of Storey Drifts with Fixed Base in Transverse Direction

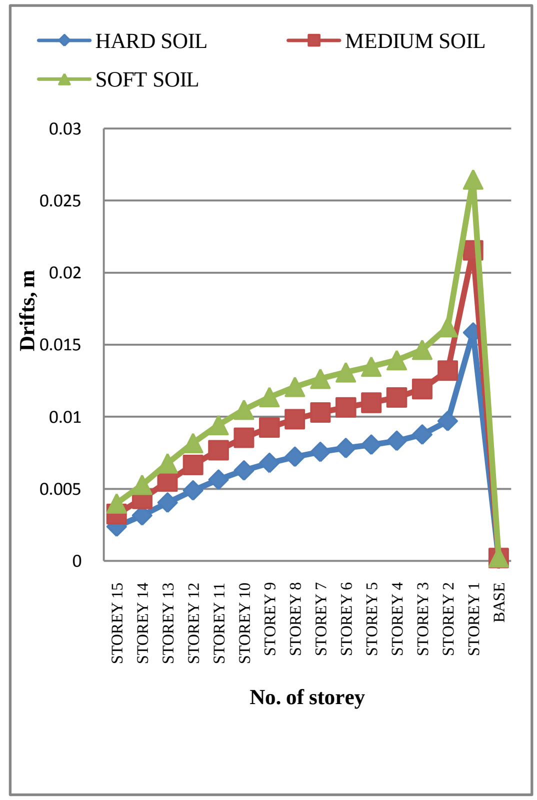

Figure 15: Graphical Representation of Storey Drifts with Flexible Base in Longitudinal Direction

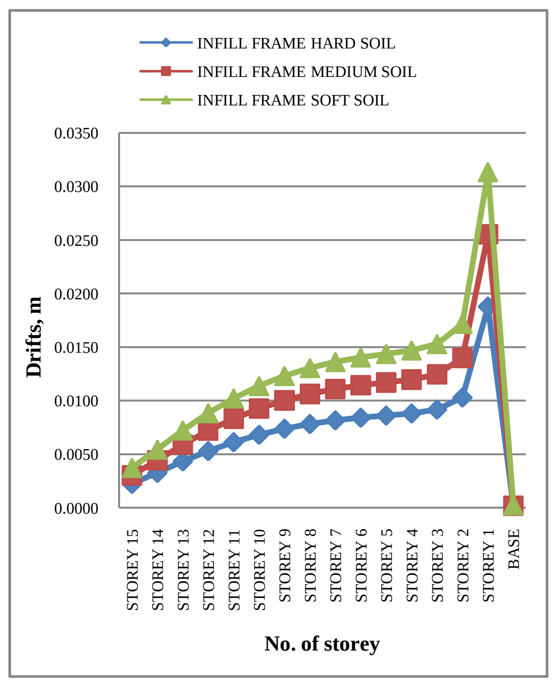

Figure 16: Graphical Representation of Storey Drifts with Flexible Base in Transverse Direction

VII. CONCLUSION

In this present study, the reinforced 15 storey building is analyzed by including and not including soil structure interaction. The results are lead in the following conclusions.

1) The base shear for bare structure, flexible base is more than fixed base condition.
2) The base shear for infill structure, flexible base is more than fixed base condition.
3) Storey displacement is more in case of bare frame building with or without soil structure interaction.
4) Storey displacement even more in case of infill frame building with or without soil structure interaction.
5) Storey drift is more in case of bare building with or without soil structure interaction.
6) Storey drift for infill building is more, with or without soil structure interaction.
7) The storey shears for fixed condition is more for soft soil as far as flexible condition too in soft soil.

VIII. FUTURE ENHANCEMENT

Soil structure interaction is evaluated for various types of frames like composite frames, shear wall frames, steel frames too. It can be analyzed by various dynamic methods like response method and time history method. Even for different irregularities such as mass, plan, and vertical irregularities.

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