Seismic Response of RC Irregular Frame with Soil-Structure Interaction

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Abstract— **Seismic response of structure is extremely complex because of the non-linear behavior soil during earthquakes. Seismic design of structures is generally carried out assuming fixed base ignoring the flexibility of soil. The purpose of this study is to describe and investigate different approaches of considering soil flexibility in the soil structure interaction (SSI) with regard to the response in the super structure. In the present work, to illustrate the effects of soil-structure interaction on the seismic response of framed structures, irregular frames with 15 storey have been considered with base supported as fixed with and without considering the soil structure interaction. Buildings are modeled in SAP2000. Three types of soil i.e. hard, medium hard, and soft soil are used to SSI study. The soil is modeled as spring model or Elastic continuum (FEM), and stiffness is calculated by using the gerorge Gazetas equation. The effect of SSI on various structural parameters i.e. natural time period, base shear, roof displacement, are studied and discussed. The main objective in using this earthquake was, to find out the effect on structure when hit by long duration and see how the response is modified, when soil effects are taken into the consideration.**

Keywords— **Dynamic analysis, Time History, Soil Structure Interaction, Irregular frames, SAP2000.**

INTRODUCTION

Over the past 40 years, considerable progress has been made in understanding the nature of earthquakes and how they damage structures, and in improving the seismic performance of the built environment. During past and recent earthquakes, it is realized that the soil-structure interaction (SSI) effects play an important role in determining the behavior of building structures. The interactive response of a structure during an earthquake significantly depends on the characteristics of the ground motion, the surrounding soil medium, its properties and the structure itself. The soil structure interaction refers to the effects of the compression of supporting foundation medium on the motion of the structure. During an earthquake, seismic waves are transmitted through soil from the origin of disturbance to the structure; the wave motion of the soil excites the structure, which in turn modifies the input- motion by its movement relative to the ground. The movements of soil under foundation will interact with the deformations of the structure itself. The interaction phenomenon is generally affected by the mechanism of energy exchange between the soil and the structure, and the primary influence on the building is to modify the natural period of vibration and hence the response in terms of stress and strain.

Generally, conventional seismic design and analysis practice do not take into account the flexibility of the foundation and adjacent soil. The foundation and the superstructure are typically designed as two independent systems, and the superstructure is constrained at the bottom. The evaluated seismic performance of the building only depends on the superstructure. This method is simple and convenient, but the dynamic characteristics and seismic performances of buildings without considering the flexibility of the foundation and adjacent soil may be significantly different from those of the actual buildings, which may lead to an unsafe design, especially for the seismic design and analysis of important structures, such as super tall buildings.

This study is made to understand the effect of soil flexibility in the performance of building Irregular RC frames resting on isolated foundation. The purpose of this study is to describe and investigate different approaches of considering soil structure interaction analysis with regard to the response in the superstructure. For the study of soil structure interaction three types of soil are consider soft, medium and hard. The study is focused on SSI analysis of frame of 15 storey resting on isolated foundation with fixed and flexible base. The soil flexibility is including in the analysis using spring model and elastic continuum approach (FEM). Dynamic analysis is carried out using response spectra and Time History of IS: 1893-2000.These models are developed by using SAP2000 software. The effect of SSI on various structural parameters i.e. natural time period, base shear, roof displacement are studied and discussed.

METHODOLOGY

The steps involved may be summarized as follows: first, to study literatures of existing by different researchers. Next, selection of type of frame structure and plan of building, take different height of RC irregular frame structure. Three types of soil are considered hard medium and soft soil which the RC structures are to be resting. The property of soil are considered as per bowel or IS 1892.

For the interaction analysis, two approaches are considered.

1) Winkler approach (spring model)
2) Elastic continuum approach (FEM)

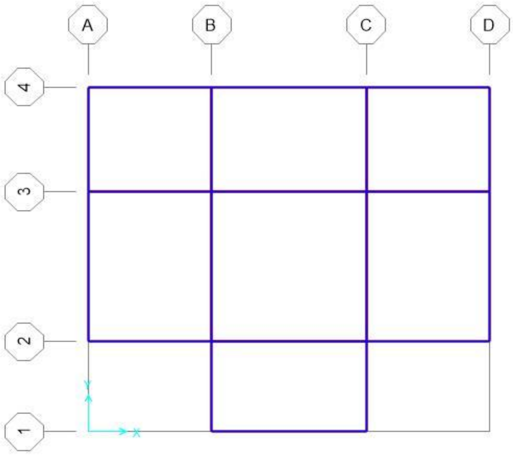
The analysis has been carried out for two different cases

1) Fixed base without considering SSI
2) Flexible base with considering SSI

For the seismic analysis the static and dynamic analysis are carried out for seismic zones V. the effect of SSI on various structural parameters i.e. Natural Time Period, Base Shear, Roof Displacement, are studied and discussed.

GEOMETRIC MODELING OF STRUCTURE

A three-dimensional RC irregular frame structure is considered for soil structure interaction. Figure 1 shows the plan, considered for the analysis. The plinth area of the building is 13m X 11.5m, the total height of building is 45.5m. As per IS 1893:2002 cl no. 7.1 and table 4 and 5 taking plan irregularity.



Details of frame:

1) Plan area of building : 13m X 11.5m
2) Number of floor : 15
3) Height of 1st floor : 3.5 m
4) Height of other floors : 3m
5) Thickness of slab : 0.15m
6) Size of column : for 1st to 7th floor : 0.35m X 0.95m
   : for 8th to 11th floor : 0.35m X 0.85m
   : for 12th to 15th floor : 0.35m X 0.75m
7) Size of beam : 0.23m X 0.45m
8) Footing Size : 3.4m X 2.9m X 0.8m
9) Internal wall thickness : 0.115m
10) External wall thickness : 0.23m
11) Intensity of live load : 4 kN/m2
12) Floor Finish load : 1.5 kN/m2

Details of Soil:

Soil type	Designation	Modulus of Elasticity (kN/m^2)	Shear modulus(G)	Passion Ratio(μ)
Hard Soil	E-65000	65000	26000	0.25
Medium Soil	E-35000	35000	13461.53	0.3
Soft Soil	E-15000	15000	5357.14	0.4

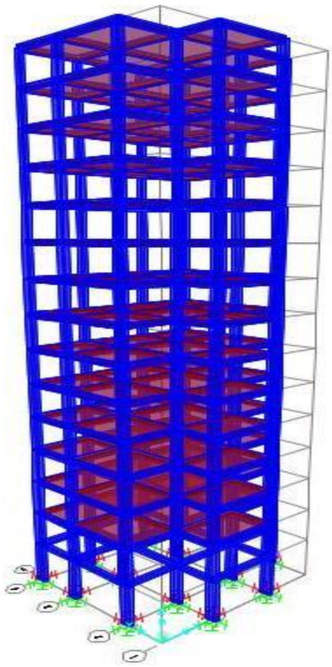


Figure 2 RC frame with spring

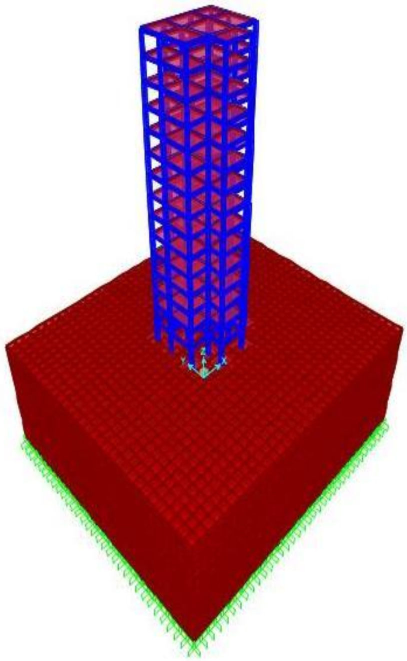


Figure 3 RC Frame with soil model

RESULT AND DISCUSSION

Analysis has been done on above mentioned models with Bhuj earthquake and Response spectrum for zone-V and results are shown. Base shear for building on Fixed based and Flexible base frames are shown in Figure 4 to Figure 6. Roof Displacement is shown in Figure 7 to Figure 9

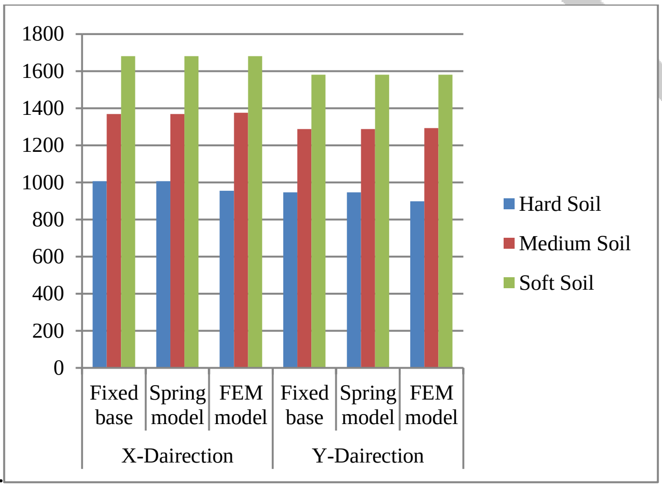


Fig. 4 Comparison of base shear for Static analysis

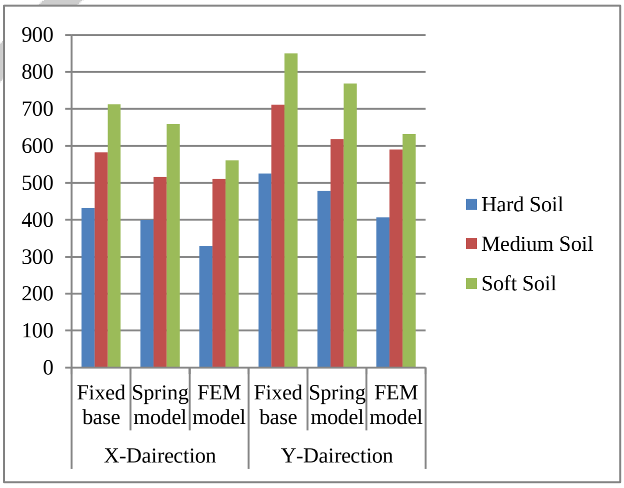


Fig. 5 Comparison of base shear for Response Spectrum

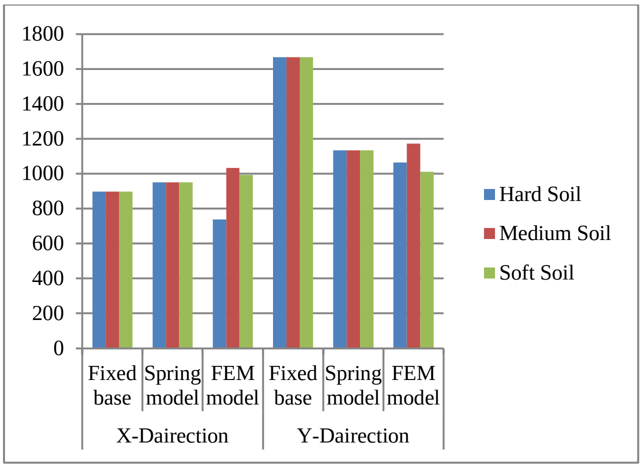


Fig. 6 Comparison of base shear for Bhuj Time History

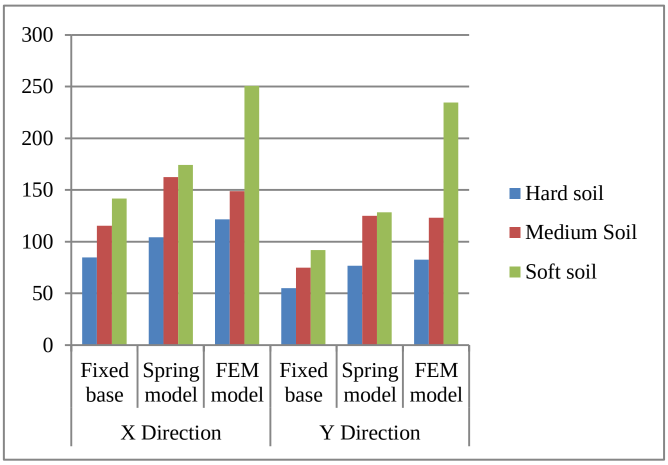


Fig. 7 Comparison of Roof Displacement for Static analysis

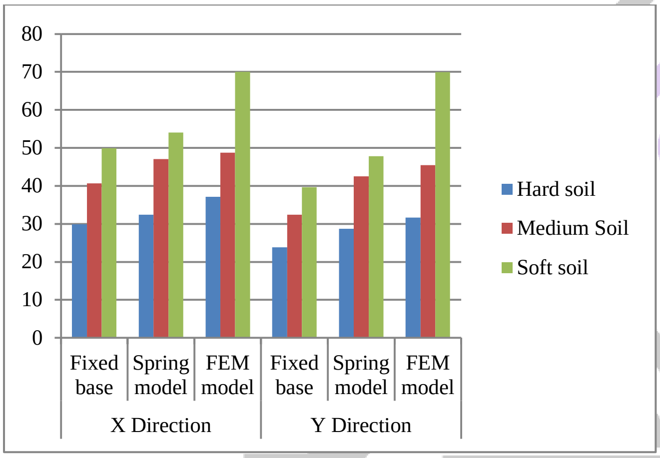


Fig. 8 Comparison of Roof Displacement for Response Spectrum

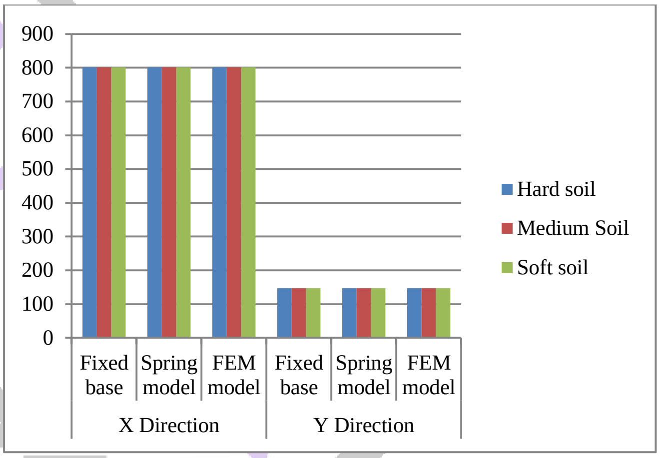


Fig. 9 Comparison of Roof Displacement for Bhuj Time History

CONCLUSION

[1] During analysis of structure, using fixed base at foundation but it is replace by spring or if we model soil as a FEM the response of structure changes in case of soft soil the base shear increases approx. 9-30 % compare to the spring and FEM model

[2] In case of soft soil the effect of soil is predominant so, must considered soil structure interaction in case of soft soil in savior earthquake zones.

[3] Form the study, observed that the percentage of displacement in X and Y direction are increased with increased in soil flexibility.

[4] From the study, observed that the percentage of displacement in X and Y direction for FEM is more compare to the spring and fixed base models.

[5] As the number of storey increases in the building the base shear and displacement are increases.

[6] In case of soft soil, soil structure interaction has been recommended as the height of building increases.

[7] FEM method is useful method for studying the effect of soil structure interaction.

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