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Seismic Response of RC Frame Building Considering Soil Structure Interaction

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ABSTRACT

Foundation is a load transferring part of structure to soil. Recent trends have made replacement of conventional practice of isolated and eccentric footing with Mat foundation. Necessity to choose Mat foundation over conventional isolated footing is when the bearing capacity of soil is considerably low. However, consideration of properties of soil in contact with the foundation has not been applied in detail practice which is also called soil structure interaction (SSI) will significantly affects the performance of structures. Our study has used Winkler's method to model the foundation soil as spring Moreover, three different buildings of five, seven and nine story were modeled using finite element method to incorporate the soil structure interaction effects. performance parameter to measure the performance of the structures was done using Roof displacement. This research reports the change in natural time period, roof displacement and base shear due to consideration of SSI and concludes with the urge of consideration of SSI in structural analysis and design.

1. INTRODUCTION

The response of a structure during earthquake event is affected by interaction between soil and structure. Soil Structure Interaction (SSI) is a collection of phenomena in the response of structures caused by the flexibility of the foundation soils, as well as in the response of soils caused by the presence of structure, the foundation, and the geologic media underlying and surrounding the foundation, to a specified free-field ground motion. The term free-field refers to motions that are not affected by structural Vibrations or the Scattering of waves at, and around, the foundation. SSI effects are absent for the theoretical condition of a rigid foundation supported on rigid soil. Accordingly, SSI accounts for the difference between the actual response of the structure and the response of the theoretical, rigid base condition. Conventional structure design methods neglect the SSI effects.

2. LITERATURE REVIEW

Sushan Prajapati (2019) has conducted thesis work titled "Comparison Between Dynamic Response of RC Building with Various Foundation Types" Considering SSI for different condition of soil for Combined Footing, Strap Footing & Eccentric Isolated Footing. He Concluded Eccentric isolated foundation shows poor performance and has Significantly high roof Displacement than other foundation types and gets more critical with increase in soil flexibility.

Santosh Niraula (2019) has conducted thesis work titled" Study on parametric Analysis of Piled Raft Foundation System using Finite Element Approach" with use of piles. He found out in his work that total settlement and differential settlement can be further reduced with increasing the number of piles. He also added keeping spacing of piles equal results in logarithmic decrement. for values in total and differential settlement shows

Pramod Kumar Shahi (2017) has conducted thesis work titled" Study of Response of RC Framed Building with lower Tie Beam and It's Necessity in Different Soil Condition". His main focus was consideration of SSI for different condition of soil for Isolated Foundation. His thesis work concluded necessity of lower tie beam is more significant in lower storey building than higher storey building.

Umesh Jung Thapa(2017) has conducted thesis work titled" Soil-pile-structure interaction effects on High-rise Building under Seismic Shaking: A case study of Chhaya Center,Thamel'' .He concluded that soil structure effects increase the time period of the structure whereas displacement, overturning moment and base shear decreases in SSI based which was modeled in Winkler approach model then fixed based model.

Nithya et al. (2014), studied the effects of Soil structure interaction on Reinforced concrete frame building with underground stories. The soil was modelled on continuum approach as well as Winkler Approach and the demands in each case was observed to decreased as compared to a fixed based model. The analysis results show that, basement walls and soil Structure interaction shows significant changes in the response of building during an earthquake which is not addressed by IS1893 explicitly. Moreover, Elastic continuum approach (FEM model) was found to be more effective than Winkler approach (Spring Model) as it considers elastic continuum below foundation which assists to get realistic behavior of structure.

S.A. Halkude, et al. (Halkude, Kalyanshetti, & Kalyani, 2014) concluded that the SSI significantly effects on the response of the structure. In that study the effects of soil flexibility on the performance of building frame was investigated. They also concluded that the fundamental time period, roof displacement, beam moment, column moment increases with increase in soil flexibility and the variation are less for low storey building

and goes on increasing with increasing in storey height.

3. METHODOLOGY

3.1 General Methodology

The Methodology used in the study of comparison of RC framed Building with Raft Foundation in different soil Condition will be as follows:

1. For the study, RC framed Buildings (five, Seven and Nine Storey) are selected.

2. The properties of Building and Soil are Collected and Specified.

3. The Winkler Model is Selected as the Method of Modeling the soil Structure interaction.

4. The Building is Modeled in SAP 2000 for Fixed support condition, for flexible support condition.

5. The results and Responses obtained from the analysis are compared for different soil Condition and results are Validated by comparing with other similar pervious researches.

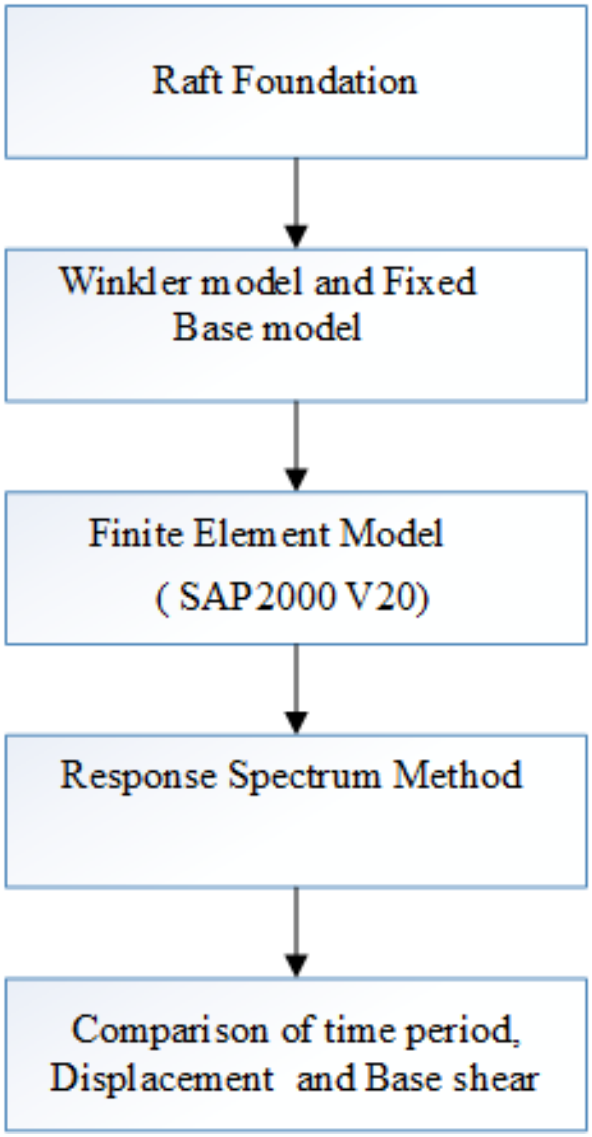

Figure 3-1: Flowchart of Methodology

3.2 Building Selection and Description

For the study, Regular Symmetrical five Storey, Seven Storey and Nine Storey buildings have been selected. Analysis has been done in bare frame structure with mat foundation by Response Spectrum Method using tool SAP2000. Here are some details of the buildings selected for the study

Table 3.1: Description of Five Storey Building description of Five Storey Building

Component	Description	Data (m)
Frame	Number of storey	5
	Number of bays in X direction	3
	Number of bays in Y direction	3
	Storey height (m)	3
	Bay width in X direction (m)	4
	Bay width in Y direction (m)	4
	Size of beam (m)	0.35x0.23
	Size of column (m)	0.35x0.35
	Thickness of slab (m)	0.125
Foundation	length of mat footing(m)	14
	width of mat footing (m)	14
	Thickness of mat (m)	0.5

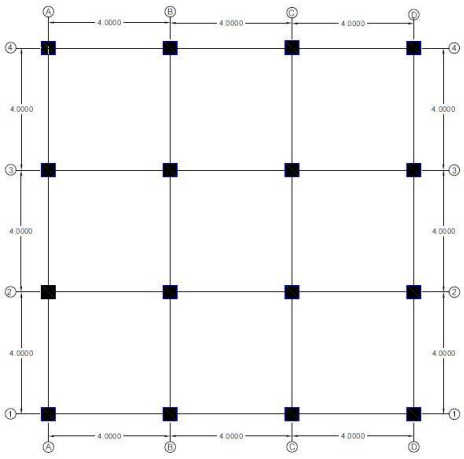

Figure 3-2: Floor Plan

4. MATERIAL PROPERTIES OF FOOTING AND SOIL MASS

Foundations are considered to be resting on three types of soil namely, Hard soil, Medium soil and Soft Soil. The categorization of soil as soft, medium and hard is done based on the IS 1893(part 1),2002. These soils have been designated as E-65000(hard Soil), E-35000(Medium Hard Soil) and E-15000(Soft Soil). The Elastic Constant of these soils are considered as per Bowels. (Bowels,1998)

- **Hard soil**

The soil categorized under hard soil are well graded gravel and sand gravel mixtures with or without any clay binder, and clayey sands poorly graded or sand clay mixtures. The soil whose standard penetration value(N) is greater than 30 are hard soil.

- **Medium Soil**

All soils with standard penetration value(N) between 10 and 30, poorly graded sands or gravelly sands with little or no fines with N value greater than 15 are comes under medium soil category.

- **Soft Soil**

All the soils other than hard soil and medium soil having standard penetration value less than 10 comes under soft soil category.

Finite Element Model of Five storey building is shown below.

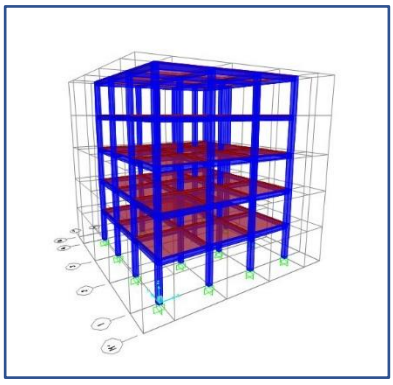

Figure 3-5 : FEM model of five Storey building with fixed Based condition

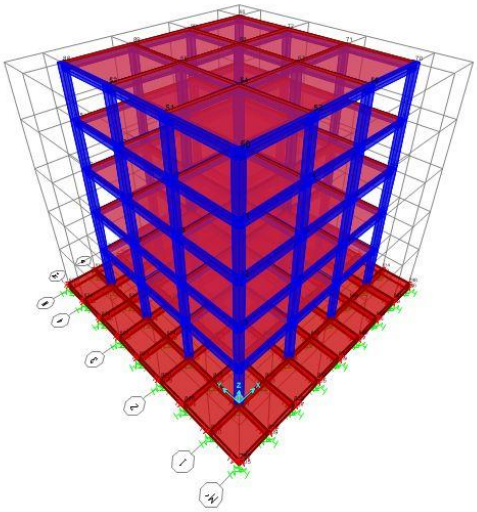

Figure 3-6: FEM model of Five Storey Building with Spring Support Condition

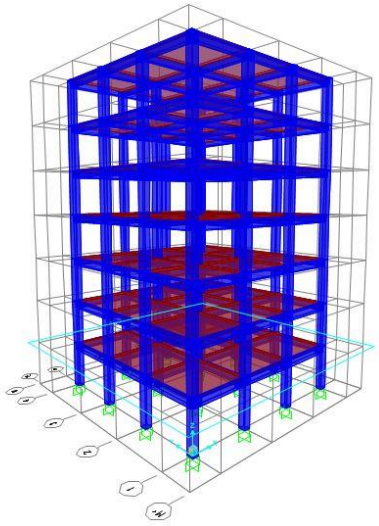

Figure 3-7:FEM model of Seven Storey Building with Fixed Based Condition

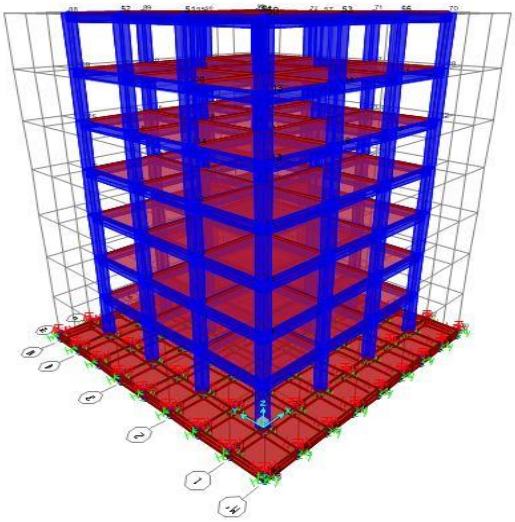

Figure 3-8: FEM model of Seven Storey Building with Spring Support Condition

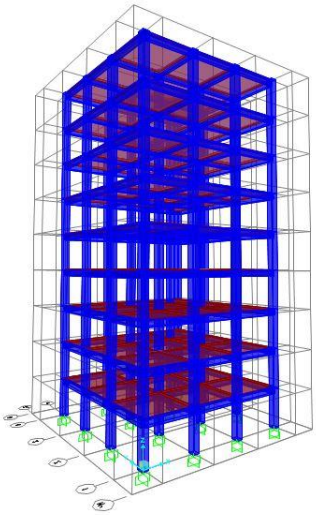

Fig 3-9 FEM model of Nine Storey Building with Fixed Based Condition

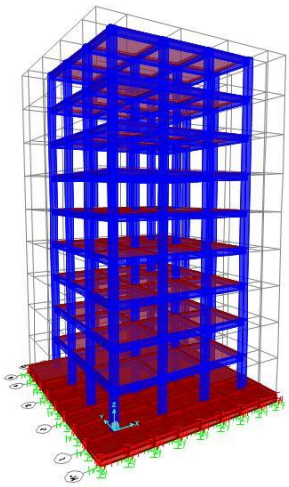

Fig 3-10 FEM model of Nine Storey Building with Fixed Based Condition

5. CONCLUSION

In order to understand the behavior of the RC framed structure incorporating the soil flexibility, a response spectrum analysis is performed. In this study, an analysis is performed to determine the influence of soil flexibility for five storey, seven storey and Nine storey buildings for fixed and flexible support condition in different soil condition.it is observed that the effect of SSI is more significant on soft soil than medium and hard soil. The performance of the building is compared in case of roof displacement, base shear and fundamental time period. Roof displacement is taken as the primary indicator for evaluating the performance of the structure. The conclusions derived from the study are as follows

- The natural time period of structure in our work increases due to consideration of SSI effect. Natural time period is primary parameter that relates to lateral response of framed structures. Evaluation of this parameter without considering SSI may result in misinterpretation in calculation of seismic design.
- Increase in soil flexibility causes increase in the base shear. For soft soil base shear increases with higher rate. Base shear shows a remarkable increment with increase in soil softness and storey height.
- Roof Displacement is also observed to be increasing in our work due to combination of SSI. For soft soil the roof displacement is higher and variations are less for five storey building and goes on increasing for nine storey building.

In this analysis shows that, SSI effect during earthquake shows significant changes in response of building. To incorporate SSI in structural analysis it has been easier with development in FEM and computer technology. This evolution in field of engineering should be exploited in fullest to better our knowledge about structural behavior so that safe construction practices are adopted.

6 RECOMMENDATION

1.The study is based upon on spring support which idealizes soil as springs. More realistic approach will be elastic continuum method. Hence further study by integration of this method can be carried out to find the more precise outcome.

2.Expanded studies may be carried out to find quantitative comparison of different types of foundation on structural member and sizes as well as contribution on construction cost and economy.

3.Further studies incorporating the nonlinear properties of soil can be carried out as well as kinematic interaction can incorporated for these conditions.

4.Studies can be carried out for other types of structures such as steel building and masonry building incorporating SSI.

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