

# ANALYSIS OF SOIL STRUCTURE INTERACTION EFFECTS ON MULTI-STOREY R.C. STRUCTURE

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**Abstract** - Rapid urbanization and global expulsion of the population with high land value and lack of available free space lead to construction of clusters of high-rise buildings in the Metropolitans like Bangalore, Delhi and Mumbai, where very often buildings are built close to each other without considering the safety of structure. Under such circumstances there is high chance of a Dynamic interaction among closely built structure due to Strong external forces such as earthquake, hence it becomes vital to study and understand the Dynamic response of these structures in depth by considering all the possible scenarios which might adversely affect the response of structure by giving higher priority to Safety and serviceability of the Structure. Soil structure Interaction is one of such concepts which is grossly underestimated while designing the structure for earthquake resistance. The study was done to understand effect of Soil Structure Interaction on Reinforced concrete Multi-storey buildings, where the three basic Models with different number of storey were considered viz, G+8, G+10 and G+12, which are assumed to located in all the seismic zones as per IS 1893:2016 and the models were assumed be supported on three major soil types ( Hard soil, Medium soil and Soft soil). To imitate effect of the Underground soil Winkler's Soil spring model is used. SAP 2000, v22 software is used to analyze the models by using Response spectrum analysis method. The results obtained from modelling the buildings on a fixed base and on flexible base are compared.

**Key Words:** Soil structure interaction, Winkler's spring model, Flexible Base, Seismic zone, Response spectrum analysis...

## 1. INTRODUCTION

It is well known fact that Earthquakes are natural phenomenon, when two tectonic plates push or collide with each other it results into build-up of large amount of energy in them, when this energy exceeds the ultimate energy it causes failure in fault plane, then build-up energy is released as seismic waves in all direction, that Energy in the form of Seismic wave is experience as Tremors or Shakings on the surface of the earth which have a devastating effect on Human life

## 1.1 SOIL STRUCTURE INTERACTION

All the Civil engineering structures consist of structural elements which are directly supported on ground. When an external force such as Earthquake act on the structure neither the structure nor the ground responds independent of each other, the process in which the response of the soil due to earthquake influences the motion of the structure and the motion of the structure due to earthquake influences the response of soil is called Soil Structure Interaction (SSI).

## 2. OBJECTIVES OF THE STUDY

(i) To study the Behaviour Fixed base structure (without considering SSI) under seismic loads.

(ii) To study the Behaviour of structure with Flexible base (Considering SSI) under seismic loads.

(iii) To understand the importance and influence of height of building, type of foundation soil and presence of seismic zone on the Response of a building With Fixed and Flexible base.

(iv) To comprehensively study the Soil structure interaction effect on RC buildings by comparing Seismic analysis results of structure with Fixed and flexible base by considering variation in height, supporting Soil type and presence Seismic zone.

## 3. METHODOLOGY

In this project we are trying to study and understand the Effect of Soil structure interaction on high rise Reinforced concrete building by considering all important parameters like Height of structure, type of soil and Different seismic zones according to Indian standard codes, we are analyzing response and behavior of the structure using Response spectrum analysis in SAP 2000 V22 software package.

(i) Modelling three different height (G+8, G+10, G+12) multi-storey building with different foundation soil condition in different seismic zones using SAP 2000 Software.

(ii) Analyzing all the building models using Response spectrum seismic analysis method with fixed base support without considering Soil structure interaction in SAP 2000 software.

(iii) Modelling all buildings with flexible base (considering SSI) using Winkler’s soil spring Model by computing Spring stiffness values from Richart and Lysmer’s Equations.

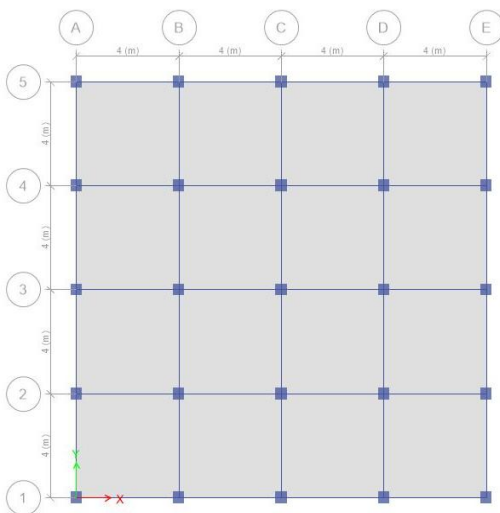
(iv) MAT foundation is selected as common foundation for all the flexible base models, which will be designed and checked for all structural checks as per IS 456: 2000 in SAFE 2016 software.

(iv) Analyzing all the flexible base models using SAP 2000 software.

(v) Comparing results obtained from all the above fixed base models with their respective flexible base models

### 3. Modeling of R.C. Building

The buildings selected for the earthquake analysis is a Reinforced concrete frame building with 4 bays in both X and Y direction of 4-meter width and typical storey height of 3 meter for three models of G+8, G+10 and G+12 storey, Dimension of building is 16mX 16m and height of building is 27m, 33m and 39m respectively, buildings are modelled as fixed (without SSI) and Flexible base(with SSI), which is modelled using Indirect method where equivalent soil spring stiffness values are computed using the Richter and Lysmer’s equations and applied to the Mat or Raft foundation of dimension 18mX18m to emulate the soil behavior at the time of seismic activity.



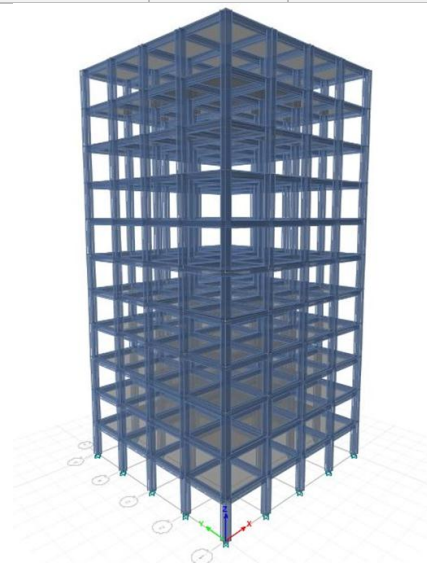
**Fig -1:** Name of the figure

#### 3.1 Member Dimensions and Materials used

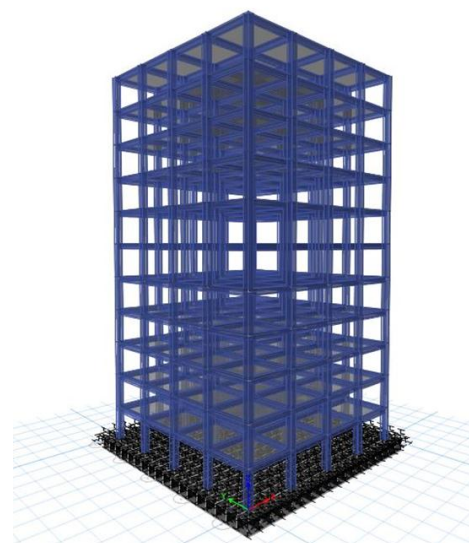
All structural member dimensions are selected as per IS 456: 2000 and IS 13829: for considering ductile detailing of the members and structure as whole. (Table I), (Figure II),

**Table -1:** Member Dimensions and Properties

Structure	G+8	G+10	G+12
No of Storey	9	11	13
All Storey Height (m)	3	3	3
Column dimension (mm)	400X400	450X450	500X500
Beam dimension (mm)	300X400	300X450	300X500
Slab thickness (mm)	200	200	200
Grade of Concrete	M25, M40	M25, M40	M25, M40
Rebar used	HYSD 500	HYSD 500	HYSD 500



**Fig -2:** Fixed base Model



**Fig -3:** Flexible base model

### 3.2 Soil springs

Soil springs are modelled using the Winkler model (Figure 04) which uses an independent series of discrete, narrowly spaced linear springs to simulate the underlying soil medium. For computing the spring stiffness values of translational and rotational springs of the structure we are using Richart and Lysmer's chart.

The present study involves all three major categories of soil, i.e., Category I (Hard soil), Category II (Medium soil) and Category III (Soft soil), all the soil parameters are considered as per the standard practices to calculate soil spring stiffness values for each category of soil and those values are used in the respective models by defining Point springs for all the Flexible base models which are then assigned to the Mat foundation.

Using above soil parameter values and the Dimension of the Mat foundation (Length = Breadth = 18m) the soil spring stiffness values are calculated for Vertical, Horizontal direction and Rocking and for Rocking and Twisting movements, Then the calculated Soil spring stiffness values are applied to the Mat foundation if respective models accordingly by Defining soil spring in SAP 2000 software.

### 3.3 Different Loads and load combinations

Different loads on structure is taken as per IS 875 (part I) for dead load and IS 875 (part II) for live load and load combination is taken as per IS 1893:2002. (Table III)

**Table -2:** Soil spring stiffness values

No	Parameters	Values
1	Imposed Loads	2kN/m <sup>2</sup>
2	Floor finish load	1.5kN/m <sup>2</sup>
3	Wall load	For Floors 0.3m, For Terrace 0.1m
4	Earthquake load	As per IS 1893 (part-1):2002
5	Seismic zones	II, III, IV, V
6	Zone factor	0.1, 0.16, 0.24, 0.36
7	Response Reduction factor	5
8	Importance factor	1
9	Damping	5%

### 4. Analysis of R.C. building

All the three models with and without SSI, considering varying height of the building, foundation Soil type and seismic zone were analyzed using Response spectrum analysis in SAP 2000, V22. software to comprehensively

understand the Effect of soil structure interaction on Buildings. Each flexible base model (with SSI) is compared with its respective fixed base (without SSI) model using analysis results such as.

All the models while comparing data for different height were considered to be situated in seismic ZONE- V as per Indian standard and supported on Soil category III (Soft soil).

**Fixed Base Models:** Conventional Models where Structure is assumed to be Restrained In all directions (No movement is allowed, Zero degrees of freedom)

**Flexible Base Models:** Structure with Soil Spring mimicking the Real condition at site. (Some degree of Freedom is provided which will be based on the Type of foundation Soil)

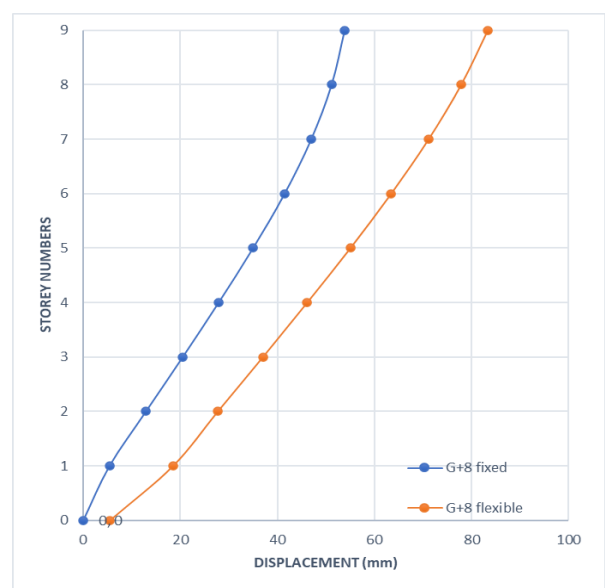
### 4.1 Max Storey Displacement

It is the total displacement of  $i^{th}$  storey with respect to ground and for maximum storey displacement there is a maximum permissible limit prescribed in IS 1893:2016 code.

For buildings with different Height with fixed and flexible base.

#### i. G+8 Model

From the analysis results of G+8 models, it is observed that, there is an increase of 54.54% Max storey Displacement of G+8 flexible base model from G+8 fixed base model. (**Chart -1**)



**Chart -1:** G+8 Max storey Displacement

ii. G+10 Model

From the analysis results of G+10 models, an increase of 74.66% is observed in Max storey displacement of Flexible base model compared to Fixed base model. (Chart -2)

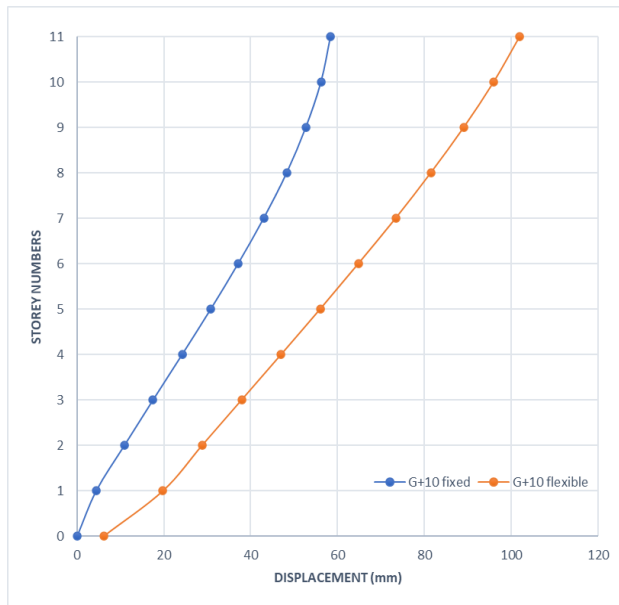


Chart -2: G+10 Max storey Displacement

iii. G+12 Model

From the analysis results of G+12 models, it is observed that, there is an increase of 94.55% Max storey Displacement of G+12 flexible base model from G+12 fixed base model. (Chart -3)

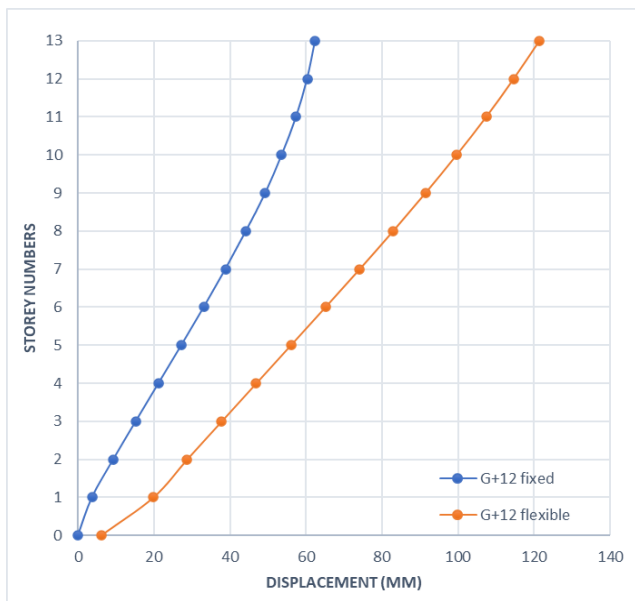


Chart -3: G+12 Max storey Displacement

iv. G+10 Model in Different soil condition

to understand Response of structure and influence of Soil structure interaction effects in different soil conditions, a Fixed and Flexible base G+10 Model is taken, which is assumed to be in Seismic ZONE V and the different soil conditions considered are Soil Category I (Hard or stiff soil), Category II (Medium soil) and Soil category III (Soft soil).

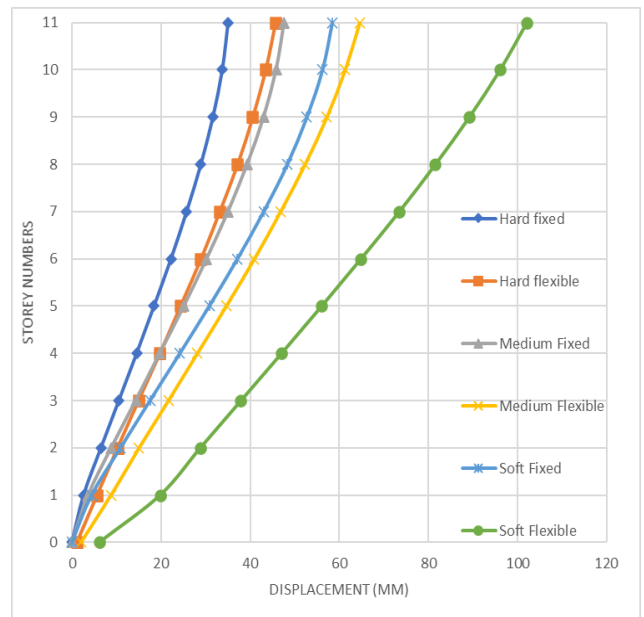
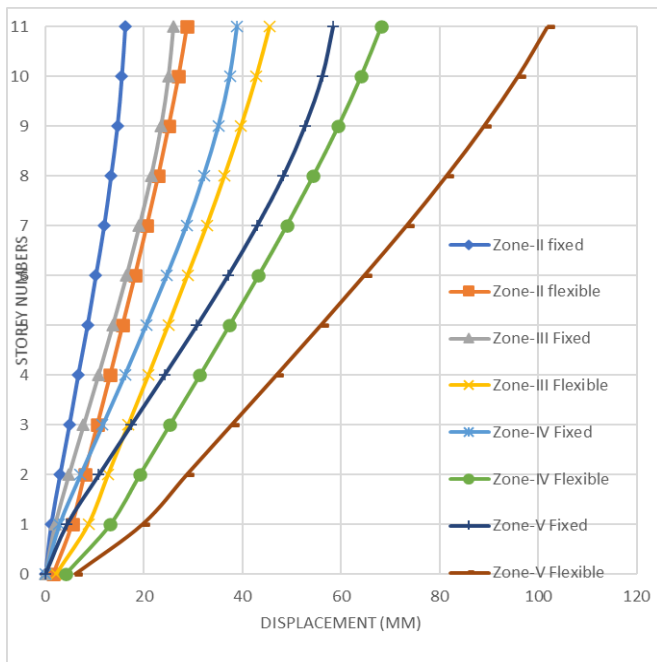


Chart -4: Max storey Displacement at different Soil condition

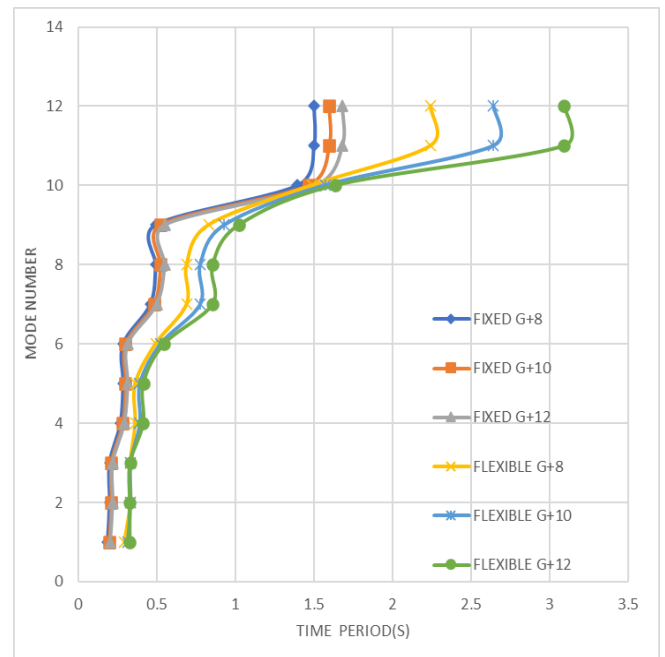
v. G+10 Model in Different seismic zone condition

to understand Response of structure and influence of Soil structure interaction effects in different Seismic Zones a Fixed and Flexible base G+10 Model is taken, which is assumed to be supported on Soil category III (soft soil), and all the different seismic zones are considered according to the IS 1893: 2016. (viz Zone II, III, IV, V)

Effect of SSI on different zone was as follows: Zone-V > Zone-IV > Zone-III > Zone-II, hence SSI effect will be more on higher seismic zones. (Chart -5)



**Chart -5:** G+10 Max storey Displacement at different zones



**Chart -6:** Natural time period at different height

#### 4.2 Natural Time period

it is the time taken by the building to undergo one complete cycle of oscillation, it depends on mass and stiffness of the building.

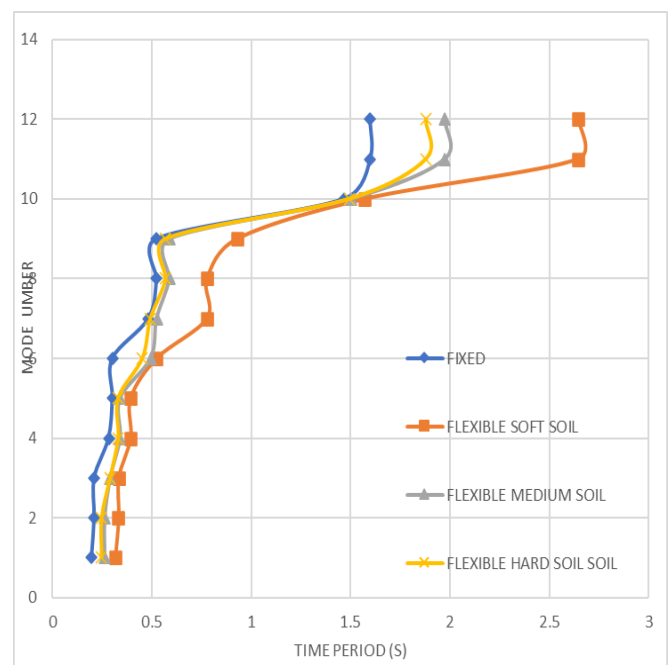
##### i. For buildings with different Height

From results of seismic analysis, increase in the time period of all the flexible base models is observed compared to their respective fixed base models, the increase in the Natural time period is due to decrease in the Stiffness of the structure as the Flexible base models with Soil springs decrease the Stiffness of overall structure.

Increase in the Percentage of Natural time period of Models from Fixed base to flexible base models from G+8, G+10 and G+12 was seen an increasing trend in the percentage increase in Time period values. (Graph VI)

##### ii. For buildings with Different foundation soil

From results of seismic analysis, increase in the values of Natural time period of all the flexible base models is observed compared to their respective fixed base models. (Graph VII)



**Chart -7:** Natural time period at different soil condition

## 5. CONCLUSIONS

The study was done to understand effect of Soil Structure Interaction on Reinforced concrete Multi-storey building, where the three basic Model with different number of storey were considered viz, G+8, G+10 and G+12, which are assumed to be located in all the seismic zones (Zone-II, Zone-III, Zone-IV and Zone-V) as per IS 1893:2016 and the models were assumed to be supported on three major soil types (Hard soil, Medium soil and Soft soil). SAP 2000, v22 software is used to analyze the models by using Response spectrum analysis method. Following conclusions are drawn after analyzing the results thoroughly

i. Increase in Top story displacement is observed in all flexible base building models with Soil structure interaction when compared to their respective fixed base models.

ii. From the Analysis it was found that SSI effect will be predominant as the height of the Structure increases.

iii. SSI effect will be more for Structure built on Soft soil than the medium and Hard soil as the stiffness of soil increases from Soft soil to Medium soil to Hard soil.

iv. SSI effect will be more for a Structure located in higher seismic zone, the earthquake induced forces in a structure increases as the Seismic zone type increases,

v. increase in time period is observed in all flexible base models, and the main reason for the increase is Lower stiffness of whole structure due to presence of soil springs.

Height of the structure, Foundation Soil type and Seismic zone of the structure are crucial for the seismic analysis of high-rise structures, which are grossly undermined by analyzing structure by providing fixed base, hence it is important to Analyze high-rise structures by considering Soil structure interaction for seismic analysis.

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