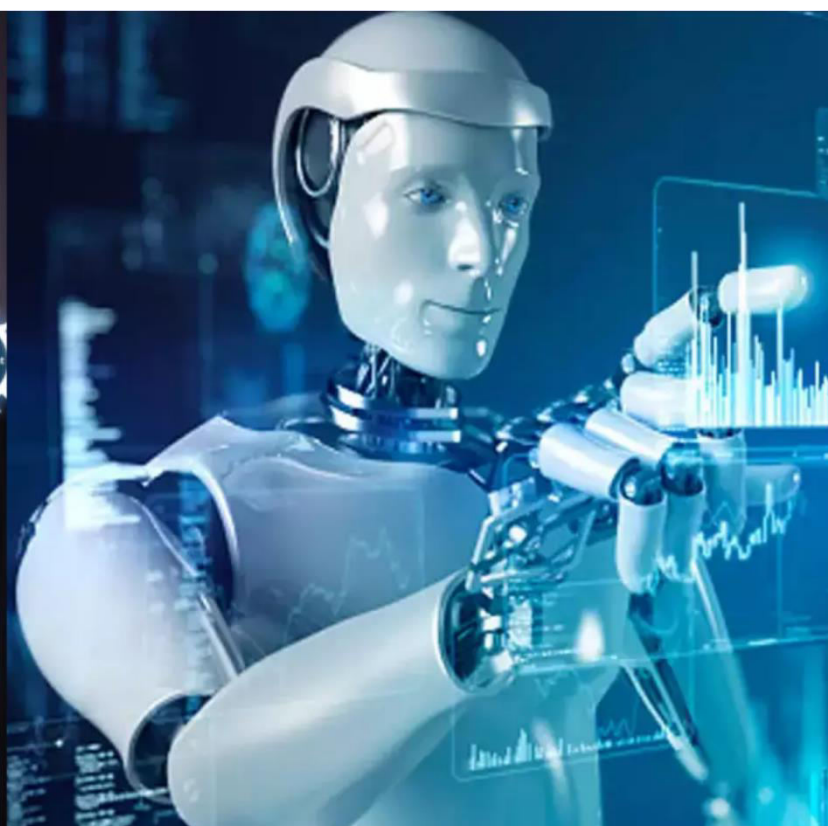




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Seismic Performance of Buildings Considering Soil-Structure Interaction with Medium Soil

Shashank S. Surve¹, Dr.V.A. Patil²

PG Student, B. R. Harne College of Engineering & Technology, Karav, Thane, India¹

Guide & Principal, B. R. Harne College of Engineering & Technology, Karav, Thane, India²

ABSTRACT: The investigation on the mechanism of energy transfer from soil to structures during seismic events is essential for the design of earthquake-resistant buildings. Additionally, the growing demand for high-rise, cost-effective buildings has intensified the need for research into soil-structure interaction (SSI), highlighting its importance now more than ever. Generally, in the analysis of structures which is subjected to seismic forces also, is usually assumed that the structure is fixed at the base to simplify the mathematical problem. This assumption leads to an error in assessment of overall response under seismic loads. The interaction phenomenon is principally affected by the mechanism of energy transfer between the structure and soil during the earthquake. The influence of soil- structure interaction on the seismic response of such high-rise building is a major concern to incorporate the necessary change in the designing such structures. Hence in this study, three- dimensional FEM model is constructed to analyze the effect of soil conditions and number of stories on the vibration characteristics and seismic response demands of building structures. Numerically results obtained using soil structure interaction model conditions are compared to those corresponding to fixed-base support conditions. The peak responses of story shear, story moment, story displacement, story drift, moment at beam ends, as well as force of inner column are analyzed. The analysis result of different approaches is used to evaluate the advantages, limitations, and ease of application of each approach for seismic analysis.

KEYWORDS: Soil Structure Interaction (SSI); RCC; Soil Spring constant; Earthquake analysis; Shear wave velocity; Story shear, Story moment, Story displacement, Story drift.

I. INTRODUCTION

The rapid growth of urban populations and the increasing pressure on limited space have had a significant impact on residential development in cities. High land costs, the need to prevent disorganized urban sprawl, and the desire to preserve land for essential agricultural purposes have all driven the shift toward vertical housing solutions. In urban areas with topographical limitations, multi-storey buildings are often the only viable option to accommodate the rising demand for housing.

The concept of multi-storey buildings emerged in response to the growing need for concentrated business activity in city centers, where space is scarce. These buildings are commonly seen as symbols of prestige for commercial enterprises. The demand for such buildings is further fueled by the influx of tourists and the business community. The soil structure interaction is a special field of analysis in earthquake engineering. This soil structure interaction is defined as "The dynamic interrelationship between the response of the structure is influenced by the motion of the soil and the soil response is influenced by the motion of the structure is called a soil structure interaction."

II. METHODOLOGY

The present work attempts to study the behavior of framed structures with rigid and flexible foundations. Framed structures with symmetrical and irregular plans have been considered with fixed and flexible foundations resting on medium soil. A framed structure of rectangular regular and irregular plans with 10 stories is analyzed for earthquake load considered in zone-IV, an importance factor of 1.5, with medium soil type and fixed and flexible base conditions. Static analysis for the 10-storied structure is done, and the parameters like time period, base shear, bending moment in columns, and top story displacement are measured and presented below. In the flexible base condition, the

soil and foundation are modeled as soil springs. The stiffness of the spring is calculated based on soil properties and foundation details using empirical formulae..

All the building models are analyses in ETABS. The properties of the building configurations are considered in the present work are summarized below.

2.1 SPECIFICATION OF THE BUILDING

- Height of each floor: 3m and Plan dimension: 18x18m
- Floor thickness: 0.125m and Wall thickness: 230mm
- Compressive strength of concrete $f_{ck}=30 \text{ N/mm}^2$ and steel used $F_e = 500 \text{ N/mm}^2$
- Density of concrete: 25 kN/m^3 and Brick: 20 kN/m^3
- Size of column: 3000mmx300mm to 650mmx650mm as per the structural requirement
- Size of beam: 230mmx600mm
- Seismic zone factor 'z' = (IV) and Damping ratio= 0.05
- Response reduction factor 'R'= 3 and Importance factor 'I'= 1.5
- Live load on top story: 4 kN/m^2 and on remaining story: 4 kN/m^2
- The floor finish load is: 1.5 kN/m^2
- Wall load at floor is: 11.00 kN/m and for parapet is: 4.6 kN/m

2.2 Details of soil parameters considered.

Sr. no.	Soil type	Soil Parameters				
		Poissons ratio 'v'	Modulus Of elasticity 'E' Kn/Sq.m	Mass density 'ρ' Kn/Cu.m	Soil S.B.C. Kn/Sq. m	Modulus of subgrade reaction 'Ks' Kn/Cu.m
1	Medium soil (sandy clay)	0.3	25000	19	200	32000

Table no.- 01

2.3 Equivalent Spring Constant

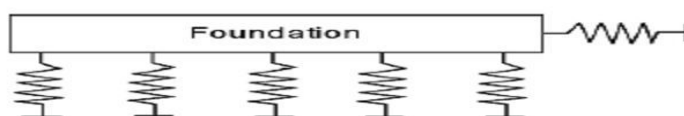


Fig. no 01

As per Winkler's model, the soil medium is represented by number of identical but mutually independent, closely spaced, discrete linearly elastic springs. The movement of foundation is generally considered in two perpendicular horizontal directions and in vertical direction. The rotation of the same about these three directions should also be considered as shown in fig..... For building with isolated footing, below each column, three translation springs along three directions and three rotational springs about those mutually perpendicular axis should be put together to simulate the effect of soil flexibility,

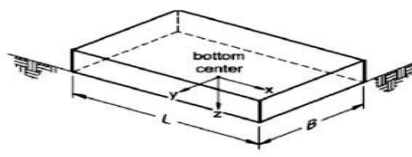
Degree of Freedom	Stiffness of Foundation at Surface	Note
Translation along x-axis	$K_{x, sur} = \frac{GB}{2-v} \left[3.4 \left(\frac{L}{B} \right)^{0.65} + 1.2 \right]$	 <p>Orient axes such that $L \geq B$</p>
Translation along y-axis	$K_{y, sur} = \frac{GB}{2-v} \left[3.4 \left(\frac{L}{B} \right)^{0.65} + 0.4 \frac{L}{B} + 0.8 \right]$	
Translation along z-axis	$K_{z, sur} = \frac{GB}{1-v} \left[1.55 \left(\frac{L}{B} \right)^{0.75} + 0.8 \right]$	
Rocking about x-axis	$K_{xx, sur} = \frac{GB^3}{1-v} \left[0.4 \left(\frac{L}{B} \right) + 0.1 \right]$	
Rocking about y-axis	$K_{yy, sur} = \frac{GB^3}{1-v} \left[0.47 \left(\frac{L}{B} \right)^{2.4} + 0.034 \right]$	
Torsion about z-axis	$K_{zz, sur} = GB^3 \left[0.53 \left(\frac{L}{B} \right)^{2.45} + 0.51 \right]$	

Table no.- 02

Also correction factor for depth of footing is applied to each spring constant values, calculated from above formulas.

2.3.1 CASE A- Regular 10 story model

Table no.- 03 Soil Spring constant

1) Condition 1 -Medium soil (Sandy clay sand SBC = 20 T)

Column no.	Column Sizes	Column forces 'KN'	Footin g sizes	Depth of Footin g 'D'	Thickne ss of footing 'd'	SPRING VALLUE					
						Kx	Ky	Kz	Kxx	Kyy	Kzz
C1,4,5,8	450X450	1723	3x3	2 M	400 mm	161728	161728	125631	269996	320610	498988
C2,3,6,7,13,14,15,16	600X600	3103	4x4	2 M	400 mm	192519	192519	158857	579774	695861	1058970
C9,10,11,12	700X700	5004	5x5	2 M	400 mm	222651	222651	191998	1068124	1285982	1919413

Table 03

2.3.2 CASE B- Irregular 10 story model

1) Condition 2 -Medium soil (Sandy clay sand SBC = 20 T)

Column no.	Column Sizes	Column forces 'KN'	Footin g sizes	Depth of Footin g 'D'	Thickne ss of footing 'd'	SPRING VALLUE					
						Kx	Ky	Kz	Kxx	Kyy	Kzz
C8,17,18,20,22	450X450	2726	3x3	2 M	400 mm	161728	161728	125631	269996	320610	498988
C1,3,5,6,7,13,14,15,19,21	600X600	4792	4x4	2 M	400 mm	192519	192519	158857	579774	695861	1058970
C2,9,10,11,12,16	700X700	7620	5x5	2 M	400 mm	222651	222651	191998	1068124	1285982	1919413

Table 04

According to above structural and loading specification, structural models are prepared as shown below,

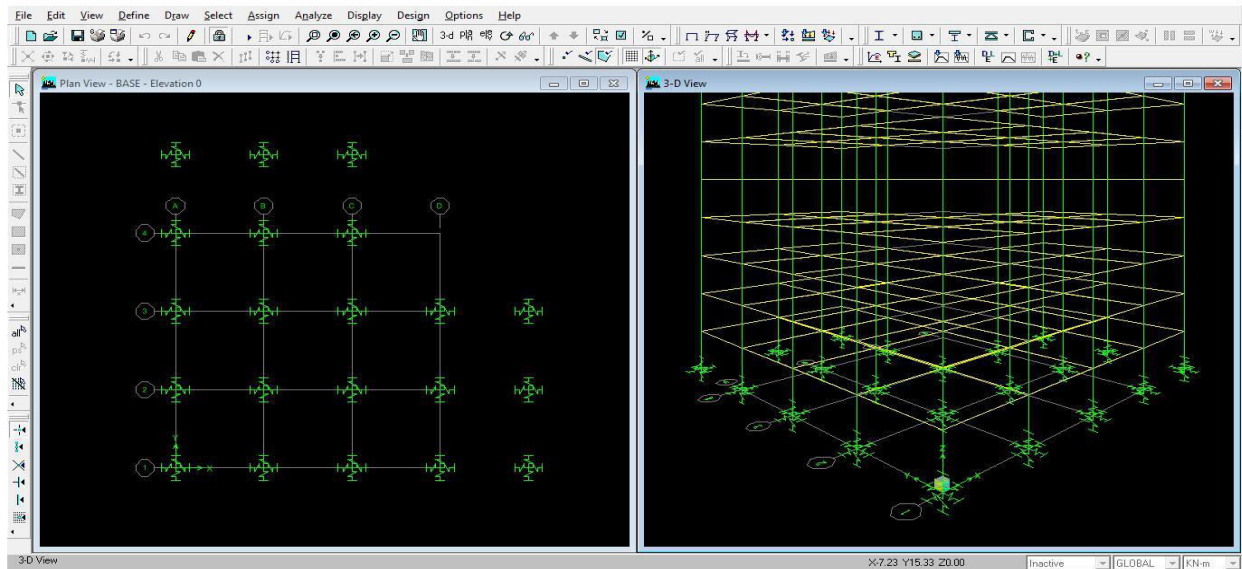


Fig. no 02 Etabs Analysis model

III. RESULT AND DISCUSSION.

A sample representation of base shear and displacement for the 10-story fixed footing model, as per the software representation, is shown below in the figure.

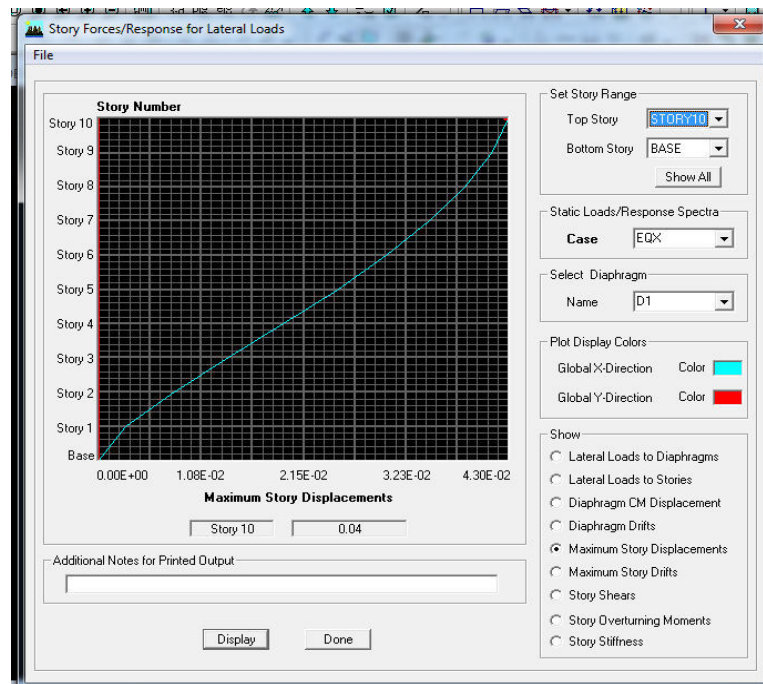


Fig. no. 03- Story Displacement Diagram (10 st. regular shaped with fixed footing).

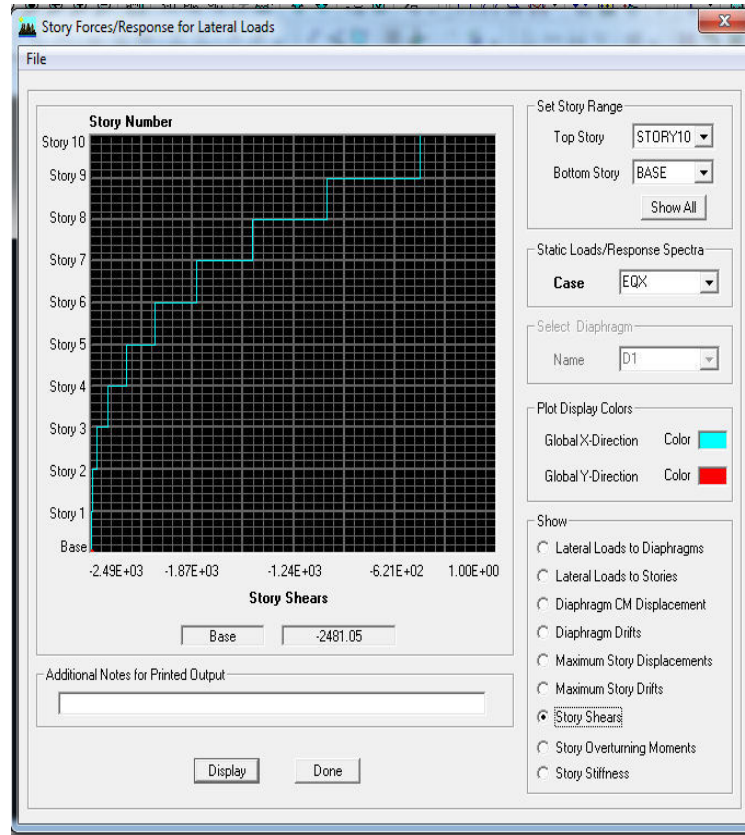


Fig. no. 04- Story Shear Diagram (10 st. regular shaped with fixed footing).

Similarly, story shear and story Displacement results for regular shaped but flexible footing also shown below,

3.1 10 story Regular shaped structure standing on different type of footings.

STRUCTURE CASE	SOIL CONDITION	FOUNDATION CONDITION	STRUCTURAL PARAMETERS		
			Base shear (KN)	Time Period(Sec)	Deflection(mm)
	MEDIUM	FIXED	2283.64	1.4718	56.42
REGULAR SHAPE		FLEXIBLE	2052.976	1.6461	63.85

Table no.- 05 Results for 10 stories regular shape structure.

Graphical representation of above results.

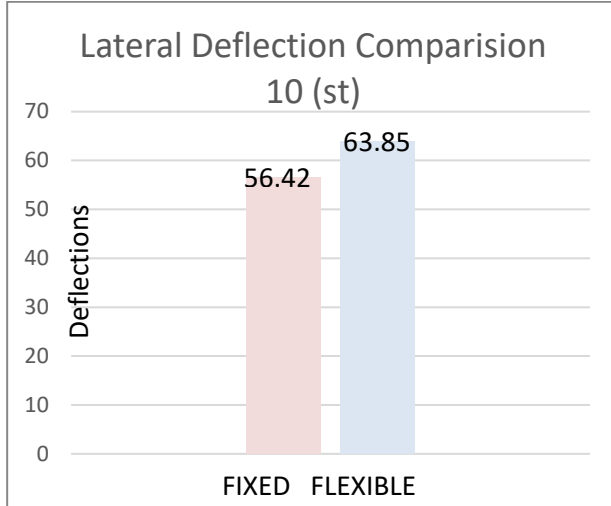


Fig. no. 05- Lateral Deflection Comparison

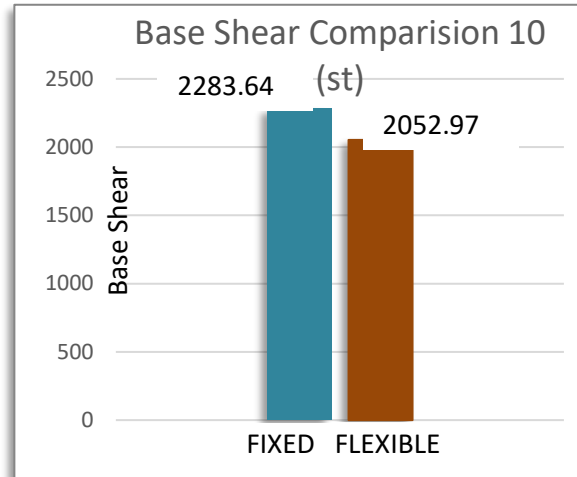


Fig. no. 05- Base shear Comparison.

Results for 10 Story Regular Shaped Structure

3.2 Summary of results for 10 story Irregular shaped structure standing on different type of footings.

STRUCTUR E CASE	SOIL CONDITIO N	FOUNDATIO N CONDITION	STRUCTURAL PARAMETERS		
			Base shear (KN)	Time Period(Sec)	Deflection(mm)
IRREGULA R SHAPE	MEDIUM	FIXED	3022.74	1.4845	57.89
		FLEXIBLE	2763.561	1.6447	66.85

Table no.- 06 Results for 10 stories Irregular shape structure.

Graphical representation of above results.

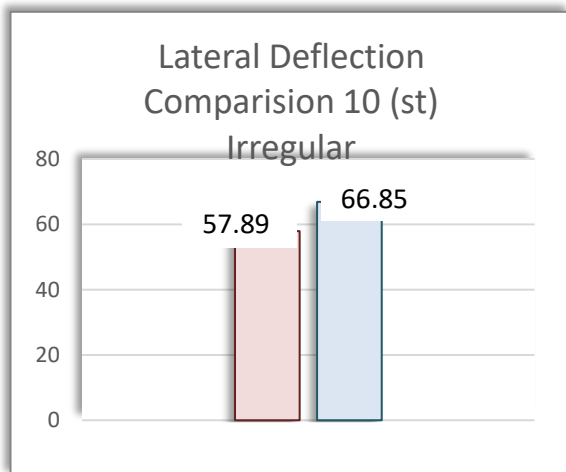


Fig. no. 06- Lateral Deflection Comparison

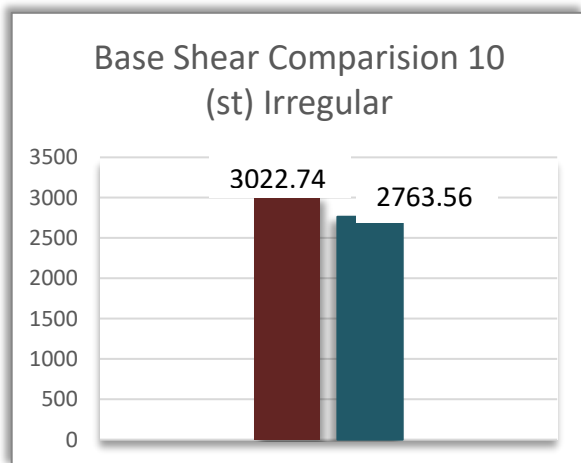


Fig. no. 06- Base shear Comparison.

Results for 10 Story Irregular Shaped Structure

IV. DISCUSSION

As per the above observations, comparative calculation for various factor has been worked out for further study of structural behavior due to soil structure interaction.

Some of the comparative factor has worked out and tabulated for simplifications of assessment

SR. NO.	STRUCTURE TYPE	% CHANGE IN BASE SHEAR	CHANGE IN DEFLECTION
		MEDIUM	MEDIUM
1	10 STORY REG.	10.1	7.43
2	10 STORY IRREG.	8.57	8.96

Table no.- 07 Overall Result comparison

As shown in the above table, Percentage changes of seismic base shear and Displacement for all the case are summaries, these variations are among Fixed rigid footing and Flexible footings representing structure type..

V. CONCLUSION

The study as a whole may prove useful in formulating design guidelines for seismic design of building frames incorporating the effect of soil flexibility.

- 1) Maximum lateral displacement
 - Lateral displacement of the structures increases as foundation condition changes from Fixed Rigid footing to Flexible footing.
 - Variation in deflection in irregular shaped building is higher than compared to regular shaped building.
- 2) Change in Superstructure Reaction,
 - Due to the application of SSI, column moments at the base is reduced.
 - Reaction of beams also changes by some minor extent.
- 3) Fundamental natural period and Base shear
 - The fundamental natural period of specific structures and their base shear increases as soil foundation moves on Rigid footing to Flexible footing.
 - Natural frequency of the structure reduces as foundation condition changes from fixed to flexible.
 - Variation in time period in irregular shaped building is quite more than compared to regular shaped building.
 - Variation in Base shear in irregular shaped building is quite lesser than compare to regular shaped building

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