SEISMIC ANALYSIS OF IRREGULAR REINFORCED CONCRETE BUILDING CONSIDERING SOIL STRUCTURE INTERACTION

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ABSTRACT

According to several studies on past earthquakes, Dynamic loading influences the seismic reaction of buildings. Sudden distress and failures in structures have been seen as a result of soil-structure interaction. Soil-structure interaction increases shear stresses in the structure's bottom storeys, making it less rigid and increasing lateral displacements such as storey drift, inter-storey drift, and roof displacements. Increased lateral displacements in high-rise buildings cause occupant discomfort. The interaction between soil and structure lengthens the building's natural time period. Three modelling approaches, fix foundation building, medium stiff base building, and low stiff base building, have been investigated and analysed using SAP2000 V14, taking into account soil-structure interaction (SSI). The results can be used to build a detailed performance-based seismic design approach that considers the influence of soil structure interaction.

Keywords – Seismic Analysis, Soil Structure Interaction, Seismic Response, SAP2000

1. Introduction

Multi-story structures are increasing rapidly in metropolitan areas in developing countries like India to provide accommodation and workplace for the population. A highrise building's structural plan has an impact on its behaviour during a large earthquake. An irregular plan or vertical configuration is one of the most common reasons of failure during earthquakes. As a result, irregular constructions, particularly those in seismic zones, are a source of concern. In most cases, structures include a number of irregularities, and predicting seismic reaction based on only one irregularity may not be enough. The kind, degree, and location of irregularities in structural design are critical since they help to improve the structure's use and aesthetics. The impact of soil structure interaction on seismic efficiency has been studied in the past, and buildings with and without soil structure interaction have been built (SSI). These structures are studied, built, and evaluated using SAP2000 software under two different boundary conditions: fixed-base and considering nonlinear dynamic analysis soil-structure interaction [1]. To idealise the soil, an elastic continuum technique is best suited method [2]. interaction of soil and structure cannot be ignored while designing structures like buildings, bridges, nuclear power plants, liquid retaining structures, dams, etc., against the expected earthquake forces [3].

The objective of the study is to propose simplified and practical design approach which enables designers to consider effects of interaction of soil and structure in earthquake analysis and design of multi storey irregular building to assure the design safety and reliability. In recent years, most standard codes have treated low stiff soil in irregular buildings with recommendations to design a fixed base regular structure. It has been discovered by previous research that the seismic response of irregular buildings is a complex phenomenon. The response of a ten-story irregular building under soil structure interaction with various soil conditions was compared for seismic loads in this study.

2. Modelling Parameters

2.1 Building Modeling

A G+9 reinforced concrete building has been modelled in SAP2000 V14 with regular fixed base building and flexible base. For conventional building fix base is considered at lowermost storey. For soil structure interaction two medium stiff and low stiff soil has been considered as per IS code. Building is situated in Zone V as per IS 1893(Part I):2002. Building height is considered as 35 m with 3.5 m floor to floor height. Raft foundation is selected for the analysis with 700 mm thickness. The length of beam in transverse direction X and longitudinal direction Y is 5 m respectively. Dead load is calculated as per the density of material and dimension of element used in modelling. Load of brick masonry on external beam is 15.40 kN/m and 7.70 kN/m on internal beams. Parapet beams has the load intensity of 6.60 kN/m. M25 grade of concrete is used RCC members.

2.2 Soil Modeling

Linear elastic continuum is the most suitable method to idealized soil response and behaviour of supporting soil medium. In Elastic Continuum or finite element model, the finite soil mass is considered based on convergence study, with boundary far beyond a region where structural loading has no effect. Indrajit Chowdhary et. al (2009), suggests expressions to calculate the mesh size of soil. Clay of low Compressibility (CL) and Silt of high Compressibility (MH) is selected for this analysis as per IS 1893. Soil is modelled by using solid element with a depth of which is about 2.5 times more than the width of the building. In this case soil depth is considered as 50 m. Interface element is provided between structure and soil. These elements are provided to avoid no tensile forces will be transmitted between soil and structure. Interface element is provided between soil-raft. For modelling of interface element spring is used and the stiffness is calculated. Stiffness of building is calculated using empirical formula developed by M.H Rayhani et. al.(2008). For Clay of low Compressibility (CL) and Silt of high Compressibility (MH) values of spring stiffness is 168611 kN/m and 35787 kN/m respectively.

Table -1: Geometric Properties of Building Frame and Foundation

S.No.	Structural Element	Dimension
1	Beam	500 x 200 mm
2	Column	500 x 300 mm
3	Slab	150 mm (Thickness)
4	Raft	700 (Thickness)

Table -2: Soil Properties

S.No.	Parameters	CL (Medium)	MH (Soft)
1	Unit Weight γ	20 kN/m^3	17 kN/m^3
2	Modulus of Elasticity Ec	80 kN/m^2	8 kN/m^2
3	Soil Friction Angle ϕ	350	300
4	Interface Friction Angle δ	220	220
5	Shear Modulus G	30769.23 kN/m2	3076.92 kN/m2
6	Bulk Modulus K	66666 kN/m2	6666 kN/m2

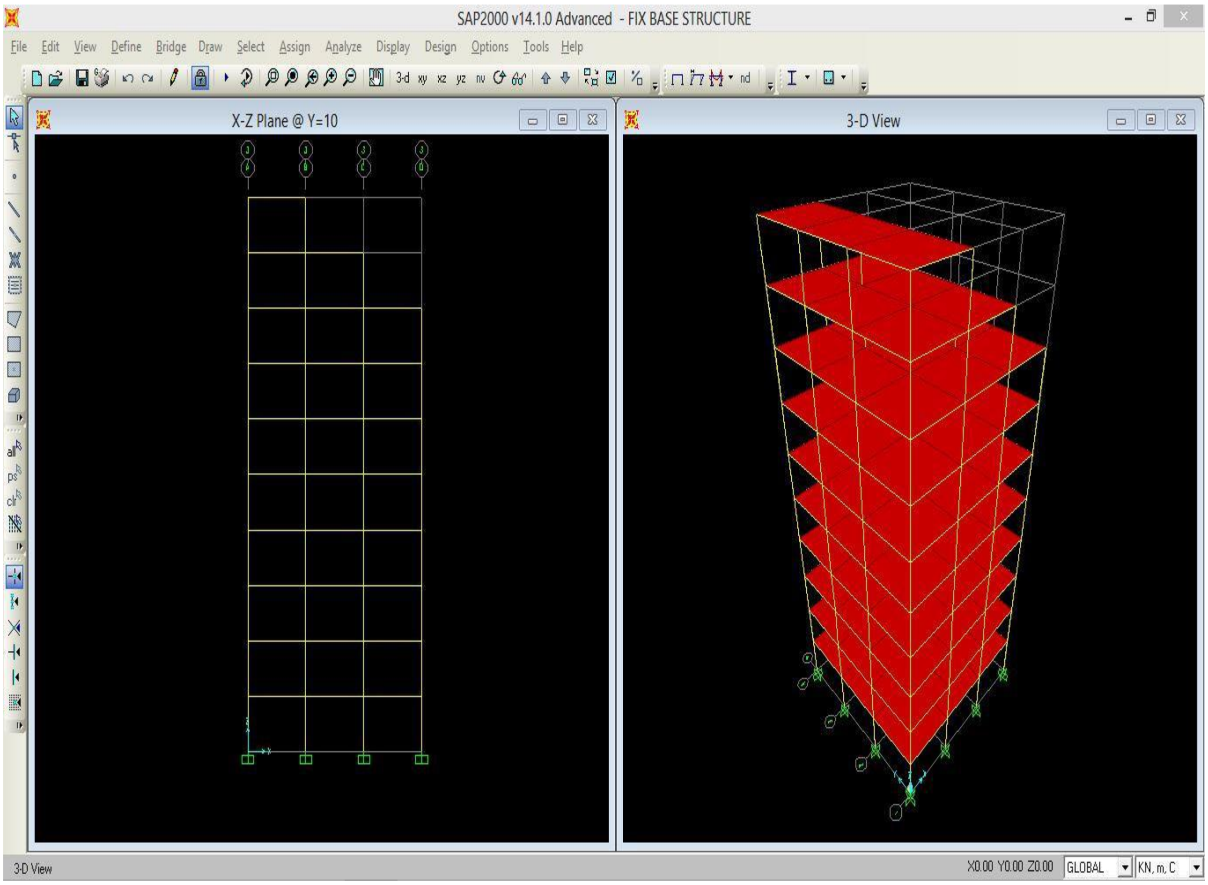

Fig -1: Conventional Fixed Base Building

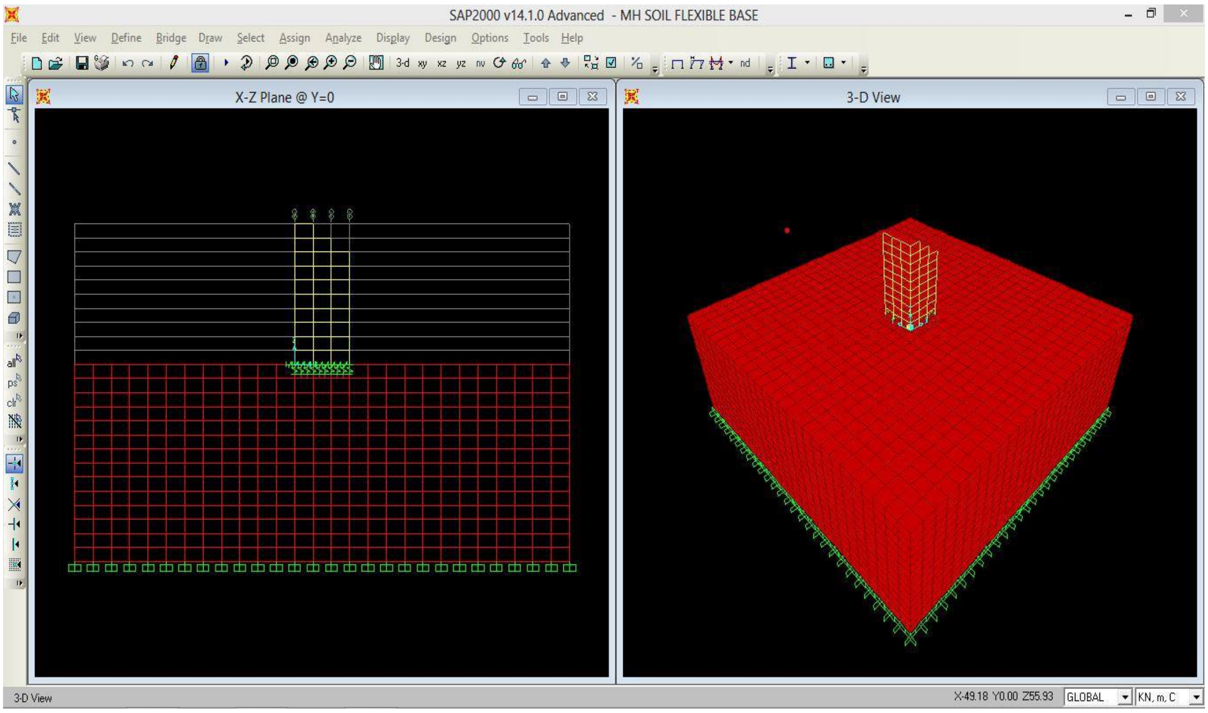

Fig -2: Building with Soil Structure Interaction

3. Results and Discussions

3.1 Time Period

Time-period is compared for irregular fixed base building and building with medium and stiff base. Result is shown figure 3. From the analysis it has been observed that time-period increases in building having SSI.MH soil has largest time-period and 15% more than regular building. For CL soil, time-period increases to narrow extent. Due to the flexibility of the base time-period increases which leads to larger roof displacements in buildings.

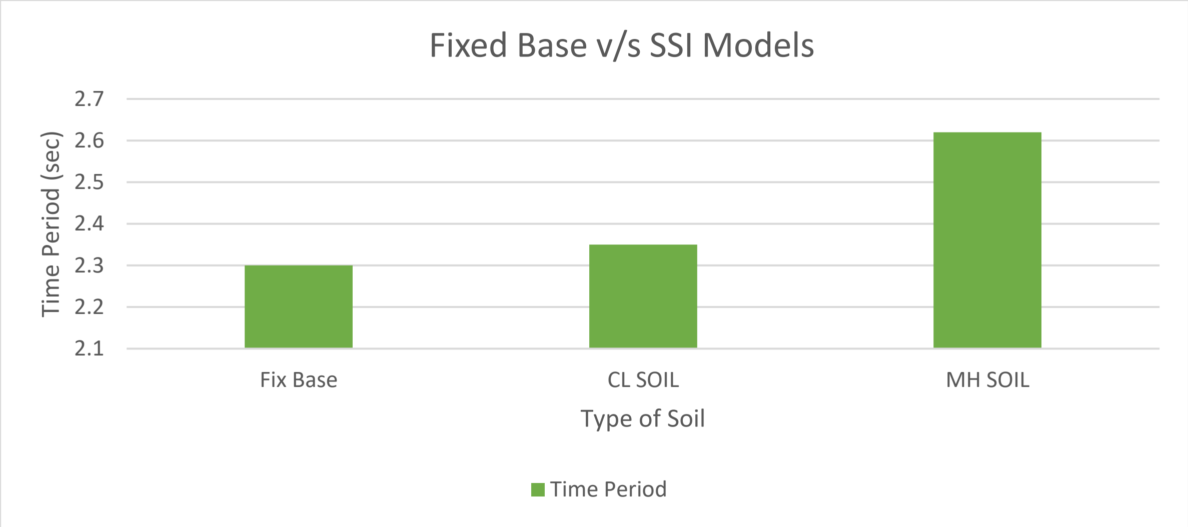

Fig -3: Time Period Comparison

3.2 Storey Shear

Comparison of storey shear forces is shown in figure 4. It has been found that on considering flexible base, storey shear increases at lower storeys and decreases in upper storeys. From the above result it can be concluded that as storey shear decreases in upper storey leads to economical design of structural elements. From the design prospect ground storey building should be designed for higher seismic loads.

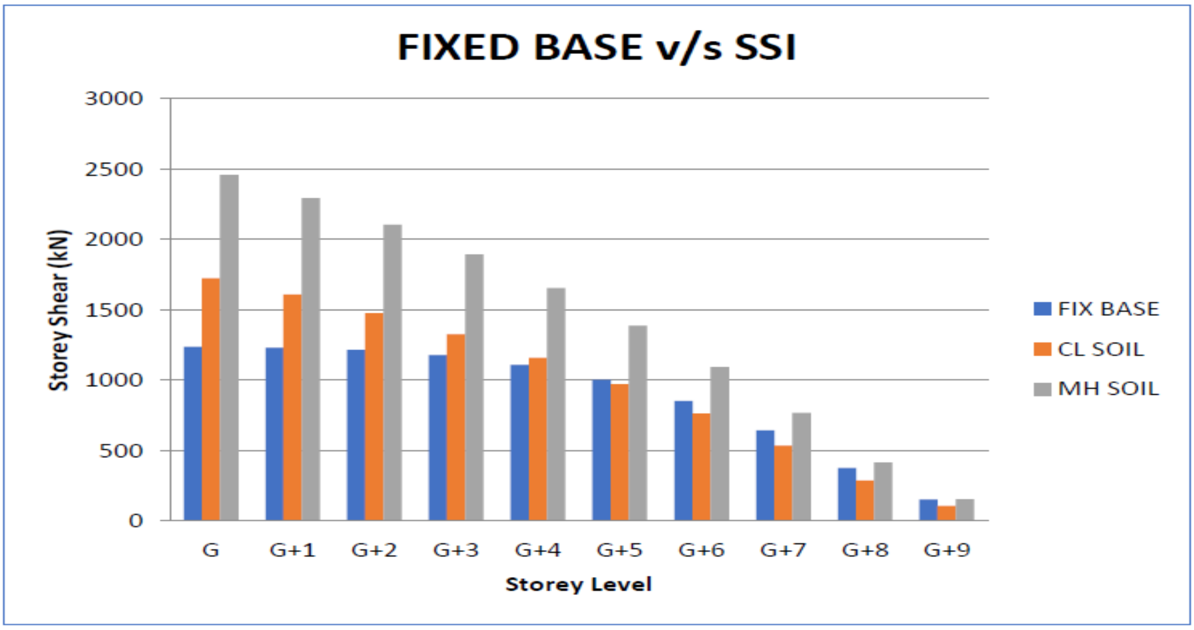

Fig -4: Storey Shear Comparison

3.3 Roof Displacement

Results for displacement in roof is shown in figure 5. Due to the flexibility incorporated in term of physical modelling of medium and soft soil, roof displacement increases by 15% due to interaction of soil and structure.

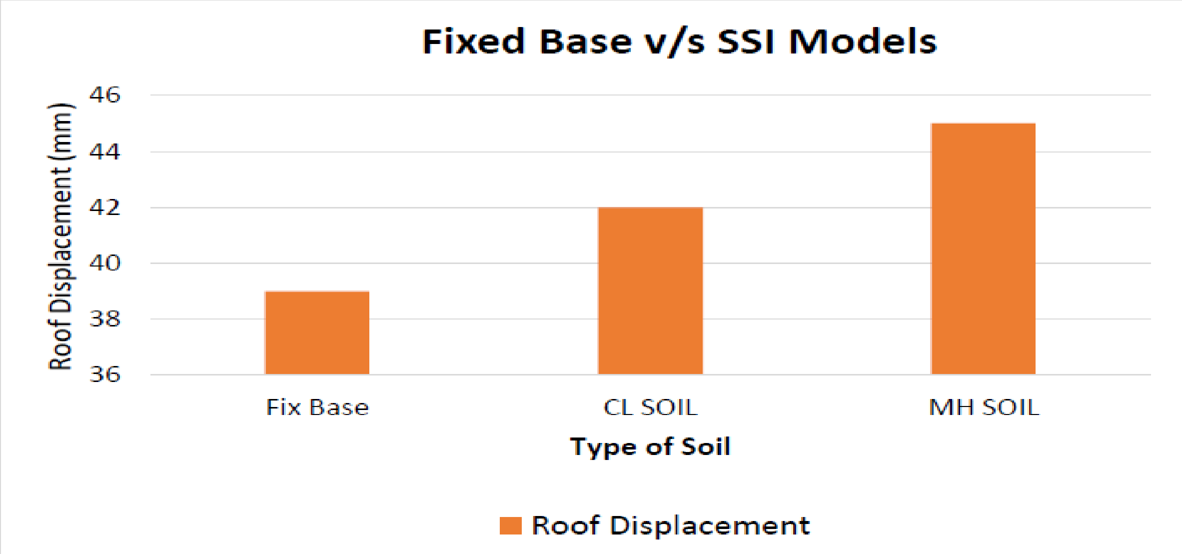

Fig -5: Roof Displacement Comparison

3.4 Storey Drift

Storey drift limitation in buildings is 0.004 times the storey height. CL and MH soil with building having fix base is represented in 6. It is found that storey drift increases on incorporating flexibility. Effect is more notable at bottom stories, while at upper storey drift low stiff soil shows more storey drift.

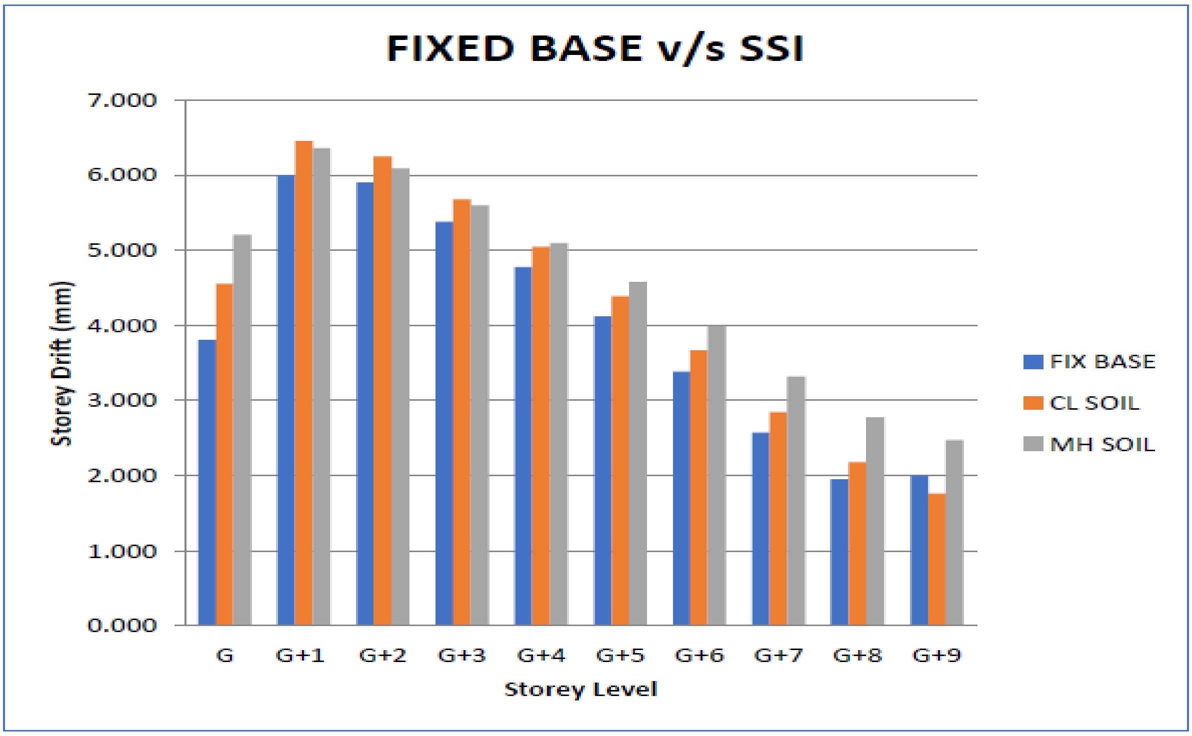

Fig -6: Storey Drift Comparison

4. Conclusions

Traditionally, seismic analysis of building is carried out by considering structures as fixed in ground. Since, seismic response of structure is arduous because soil shows nonlinear behaviour. In this study three design approaches for an irregular building with different base condition have been studied. Comparison of seismic analysis parameters for linear static have been studied in this study considering SSI effect for medium stiff CL Soil and low stiff MH Soil.

1. For G+9 irregular building, it is observed that on incorporating soil structure interaction, bottom stories attract more storey shear as compared to fix base structure.
2. On considering SSI effect bottom stories should redesign with higher seismic forces.
3. For upper stories on considering SSI effect, storey shear decreases as compared to fix base structure which leads to economical design of upper storey.
4. SSI effect building shows increase in time period, roof displacement and storey drift and among the three cases, building with soft soil is more susceptible to earthquake effects.

References

1. N. Dongol, P. Pradhan, S. Manandhar (2020), Study of Pushover Analysis on RC Framed Structure with Underground Structure Considering the Effects of Soil Structure Interaction, JsCE, Vol. 8, pp 22-29.
2. Vaibhav Singh, Kanchan Mala (2017), Effect on Seismic Analysis of Reinforced Cement Concrete Building with Underground Storey Considering Soil Structure Interaction, IAETSD Journal for Advanced Research in Applied Sciences, Vol. 4, pp 96-102.
3. Prajakta Barsinge, L. R. Wankhade (2017), Pushover Analysis over a Structure with Vertical Irregularities Using Soil Structure Interaction, ICLTESHM, ISBN 9789386171313, pp 327-333.
4. Indrajit Chowdhury, shambhu P. Dasgupta, (2009), Dynamics of structure & foundation 1. fundamentals, pp. 477-83.
5. Steven L. Kramer, (1996), Geotechnical Earthquake Engineering, pp. 300-304.
6. Ch. Subba Rao, 2013, Estimation of Shear Wave Velocity from Soil Indices, Indian Geotechnical Journal , pp. 267-27
7. Ohta Y, Goto N 1978, Empirical shear wave velocity equations in terms characteristic soil indexes, Earthquake Engineering-Structure Dynamics, vol 6, pp.167- 187.
8. IS 456, Plain and Reinforced Concrete Code of Practice (fourth revision), New Delhi Bureau of Indian Standards, 2000