
Seismic Response of a RC Framed Building with SSI

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Abstract

Earthquake is the seismic activity that can cause catastrophe and take millions of lives in one go. From the beginning of time and beginning of recorded history it is noticed that Earthquake is one of the many wraths of god which causes so much damage to the livelihood of the people. Conventional buildings are designed with no consideration for what seismic zones they are divided in, this causes a huge amount of risk for the residents of that particular structure. The zones are divided according to the risk of earthquakes in that particular area. This ignorance of zones can cause irreplaceable damage to the future of the building. Along with this there is mysterious interaction of the soil beneath on the capacity of the foundation which is yet to be fully studied and concluded, as the variety of soil is vastly dependent on the different geographical locations and cannot be easily compared. In this paper 3, buildings with different storey heights were analyzed (i.e G+4, G+6, and G+ 8) for different zones of India in SAP with different soil condition using equivalent spring constants.

Keywords

Earthquake, Foundation, Soil Structure Interaction, SAP, Storey Shear, Storey Drift, Zones

Introduction

Loads from structural systems are transferred to the ground through foundation. When these structural systems are subjected to seismic forces, relative motion of superstructure, substructure and the ground takes place. This process of the response of the soil influencing the motion of the structure and the motion of the structure influencing the response of the soil is termed as soil-structure interaction (SSI).[3] Effect of SSI is generally neglected while doing structural design. SSI can be neglected for light structures viz. low rise buildings & retaining walls in comparatively stiff soil. But it must be considered for heavy structures (High rise buildings, nuclear power plants, elevated highways etc.) resting on relatively soft soils. Many researchers have highlighted the response of foundation and ground during past earthquakes. Therefore design and analysis must include combined response of superstructure, substructure and ground during lateral loadings causing base shear and moment at the base, ignoring SSI [5] in the analysis may lead to unsafe design for both the building and construction. Many numerical analyses have shown that if there is increase in the natural period of a structure due to SSI it is not always helpful as thought earlier in simplified design codes. Softer soils increases the period of seismic waves and increase its natural period, possibly leading to resonance with the longer vibrations. It is noteworthy that, due to SSI ductility demand can very much increase with the increase in the natural period of the construction. The primary concept lies in the concept of Kinetic energy and Inertia.[1] Since the soil's inertia gives kinetic energy to the building and its foundation and the inertia again gives momentum to the structure. This transfer of oscillation is called soil structure Interaction. There can be various models to incorporate fixity of foundation some of which are described below:

1. A Mechanical Model
2. A Mathematical Model
3. A Numerical Model

Objective of this paper is to study the effect of SSI in response of buildings due to seismic loading for different zones. Three different building storey heights are considered for analysis i.e 4 storey, 6 storey and 8 storey. To consider the effect of soil, spring is modelled at the base of foundation and stiffness is considered by incorporating stiffness factor to the spring.

Methodology

Mathematical Model and Analytical Parameter:

In present study three models i.e. G+3, G+6 and G + 8 (Shown in fig.1) buildings [9] are considered and analyzed in SAP for different soil conditions with different zones of India.

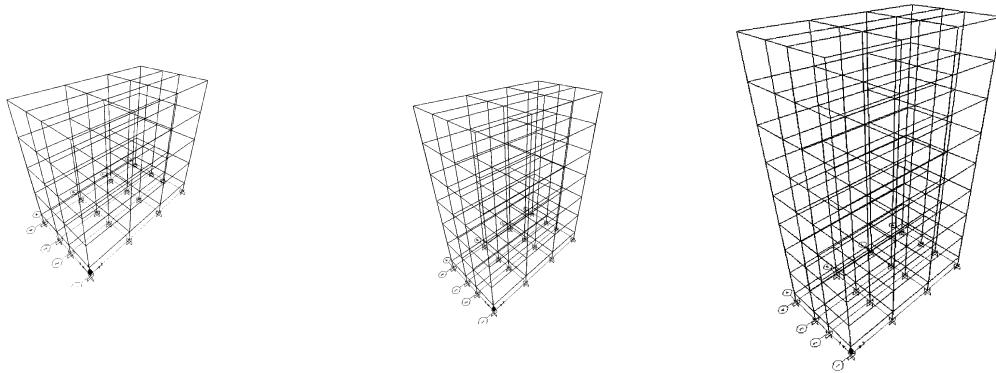


Figure 1: Models of the 4, 6, and 8 Storey Building

Results and Discussions

1. Base Shear Comparison with Respect to Soil Strata

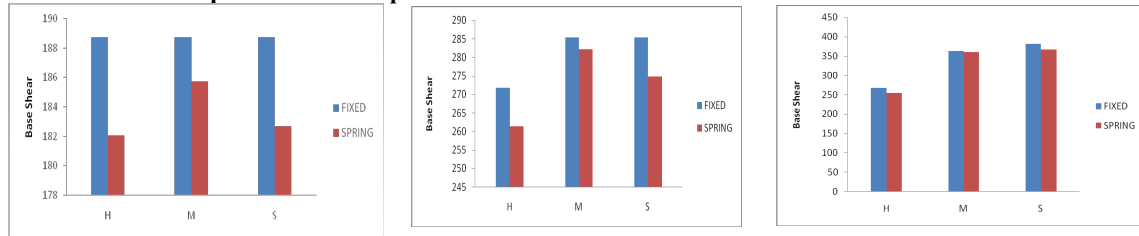


Figure 2: Comparison of Base Shear due to EQx for 4, 6 and 8 Storey Building with Fixed Base and Stiffness Spring for Zone 2

From fig. 2 it can be seen that, for 4 Storey building, base shear value for fixed base condition in all soils has no notable change, the value remains constant. While in soil structure model the variation in base shear is seen, first the base shear value is increased in medium soil and later it falls for soft soil. The base shear value is decreased by 1.64 % in soft soil with respect to medium soil. For 6 Storey building, the base shear value for fixed base condition for soft soil is increased by 5.01 % with respect to hard soil and remains constant in medium and soft soil condition. While in soil structure model, the variation in base shear is seen, initially base shear value is increased in medium soil and later it falls in soft soil. The base shear value is increased by 5.01 % in medium soil with respect to hard soil and decreased by 2.62 % in soft soil with respect to medium soil. For 8 Storey building, the base shear value for fixed base condition for soft soil is increased by 42.84 % with respect to hard soil and 5.03 % increment with respect to medium soil. While in soil structure model, the base shear value for soft soil is increased by 44.01 % with respect to hard soil and increased by 1.833 % with respect to the medium soil.

2. Base Shear Comparison for with Respect to Storey Height in different Earthquake Zone

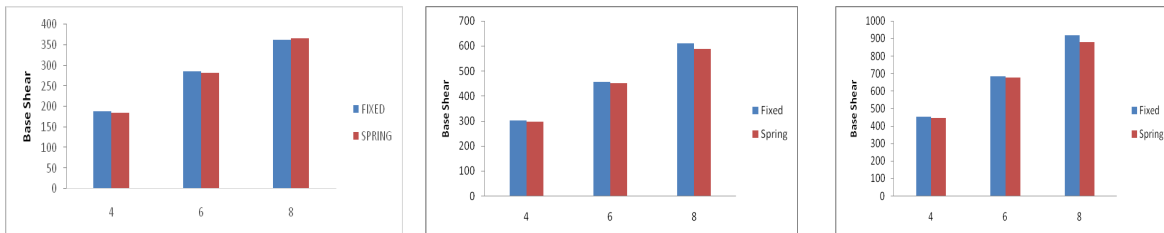


Figure 3: Comparison of Maximum Base Shear due to EQx with Varying Building Height for Fixed Base and Stiffness Spring for Zone 2, 3 & 4

From figure 3 It can be seen that, The base shear value for fixed base support condition increases with increase in height, there is increase in 92.5 % value of base shear for 8 storey building with respect to 4 storey and 27.41 % increase in base shear with respect to 6 storey building. While base shear value in soil structure model, is increased by 97.38 % in 8 storey building with respect to 4 storey building and 30 % increment with respect to 6 storey building.

3. Base Shear Comparison with Respect to Different Earthquake Zones

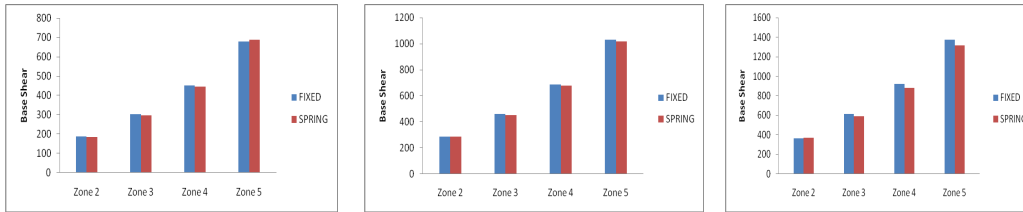


Figure 4: Comparison of Maximum Base Shear due to EQx in Earthquake Zones for Fixed Base and Stiffness Spring for 4,6,8 Storey.

From figure 4, it can be observed that, the base shear value for fixed base condition for 4 storey building in zone 3 is increased by 59.9 % with respect to zone 2 base shear value, for zone 4 it is increased by 49.9 % with respect to zone 3 and for zone 5 it is increased by 50 % with respect to zone 4. The base shear value for soil structure model, in zone 3 is increased by 59.9 % with respect to zone 2, for zone 4 it is increased by 49.71 % with respect to zone 3 and for zone 5 it is increased by 54.49 % with respect to zone 4.

4. Maximum Displacement Comparison with Respect to Soil Strata

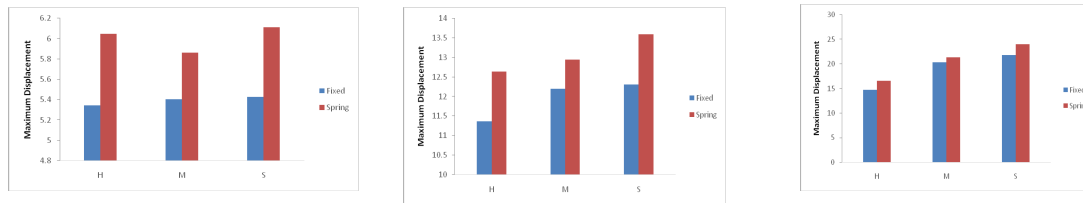


Figure 5: Comparison of Maximum Displacement due to EQx for 4, 6 and 8 Storey Building with Fixed Base and Stiffness Spring for Zone 2

From figure 5, it can be observed that, the maximum displacement values for 4 storey building and for fixed base condition in zone 2 is increased for hard soil by 1.54 % in comparison with soft soil and increased by 0.43 % with respect to medium soil. Whereas for soil structure model, maximum displacement value is increased by 1.09 % with respect to hard soil and increased by 4.6131 % with respect to the medium soil.

5. Comparison of Different Zones with respect to maximum displacement

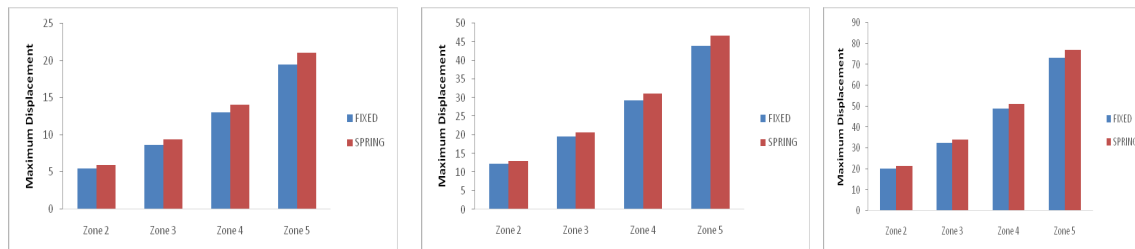


Figure 6: Comparison of Maximum Displacement due to EQx for 4, 6 and 8 Storey Building with Fixed Base and Stiffness Spring for all Zones

6. Storey Drifts with respect to Storey

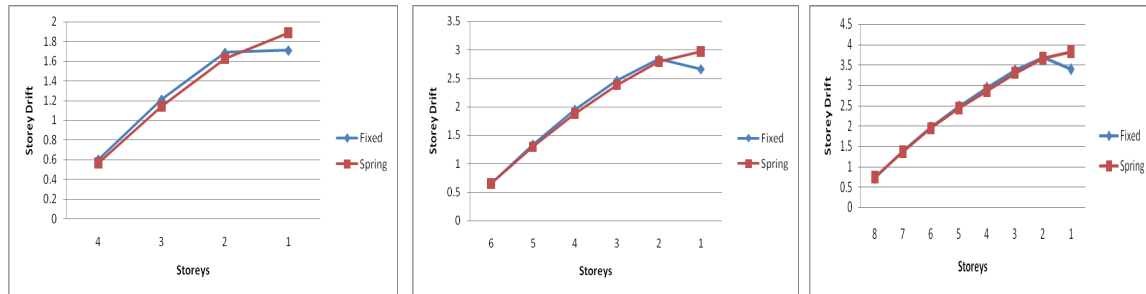


Figure 7: Comparison of Storey Drift due to EQx for 4, 6 and 8 Storey Building with Fixed Base and Stiffness Spring for Zone 2

It can be seen that, the storey drift for 4 storey building in zone 2 for EQx and fixed base condition decreases with increase in storey with 1.38 %, 39.98 % 101.95 % with respect to its lower storey. While in soil structure modeling the decrease in the storey drift is 16.07 %, 42.47 %, 101.40 % with respect to its lower storey.

Conclusion

1. Base shear value for 4 storey building in fixed base condition remains constant irrespective of soil condition.
2. Base shear value for 6 storey and 8 storey building increases as soil condition becomes loose.
3. Base shear value has unpredictable nature for soil structure interaction with varying soil condition.
4. Base shear value for both fixed base condition as well as for soil structure interaction increases with increase in storey height.
5. Base shear value, keeping storey height constant increases with increase in zone number for both soil structure interaction and fixed base condition.
6. The percentage of storey drift value decreases with respect to lower storey as storey height increases.
7. The maximum displacement value of building increases with zone no. for both soil structure interaction as well as fixed base condition.
8. The results shown are with respect to Winkler's Model , if we use any other improved model the result would be different since Winkler's model only takes into account only the effect of soil directly below it ignoring the effect of surrounding soil.
9. The base shear values for a fixed foundation are always greater than the values of base shear for a spring foundation.

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