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SEISMIC ANALYSIS OF RC BUILDING CONSIDERING SOIL-STRUCTURE INTERACTION

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ABSRACT
During seismic activity, the response of structures is influenced by Soil Structure Interaction (SSI) which is the process where the response of soil particles to earthquake ground motion affects the motion of structure, and the response of structure affects the motion of soil mass. In design offices the base of multi-storey buildings is taken as fixed and analysed for earthquake response using provisions of IS 1893-2016 with the aid of response spectrum given for medium soil in foundation. But the type of soil present in and around the foundation structure also participates in the seismic response and the assumption of fixed base becomes conservative. Soil structure interaction usually carried out for medium soil. The RC building considered to analyse SSI is G+10 Storey with an elevation of 30 m and with the plan shape of 40m X 30m. The study has used the finite element tools STAAD for modelling and analysis. The effect of SSI on seismic response including storey drift, storey displacement, base shear, natural time period, bending moment, Shear Force variations in structural elements are evaluated. Results obtained using SSI are compared to those corresponding to fixed base support.

INTRODUCTION

SSI is a phenomenon is the response of soil caused by the presence of structures. During earthquake soil conditions have a deal to with damages to structures. During an earthquake, a motion at the foundation of a structure is the most important state of seismic design. Generally, SSI problem is subdivided into two parts: kinematics SSI and inertial SSI. SSI mainly depends on the relative stiffness of the soil and structure; dynamic behaviour of structure can have a high impact on SSI. Since last 40 years, various techniques have been suggested for the solution of wave equations in unbounded domains. This paper briefly explains the literature present with particular focus on the dynamic soil-structure interaction. In general, there are two approaches in which it can categorize i.e.: global and local procedures. Characteristics of the strong ground motion can define the scale of socio-economic damages. Earthquake ground motions results mainly from the three factors that are, source characteristics, the propagation path of waves, and local site conditions. The problem of SSI has become a vital feature in Earthquake Engineering, with the advancement of huge constructions on various soils such as nuclear power plants, embankment, waste landfill and earth dams. Some structures such as underground tunnel, bridges and Gravity dams may require specific attention to be given to the problems of SSI. The basic SSI model is that in which structure has a rigid foundation. These models have an additional six degree of freedom in which there are three translations and three rotations. These models in practical found to be too simple. It’s hard to find models with flexible foundations. Strong motions are recorded in structure denotes the damaged shaking is often accompanied by non-linear response of the foundation’s soil. Several times subject of SSI have been reviewed and various aspects have been studied. Due to the response of structure the soil properties, the structure of soil and its nature of excitation get affected. Implementing SSI effect will help the designer to assess the displacement and inertial forces of the soil foundation under the influence of free field motion.

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LITERATURE REVIEW

Dhiraj Raj and Bharathi M (2013) Modeled four stroyed reinforced concrete (RC) building (without bracing and with bracing at different locations and orientation), located in seismic zones IV and V, founded on three different types of soils as per IS 1893: 2002 (Part I), has been analyzed with the foundation as fixed and as flexible incorporating soil-structure interaction (SSI) effects as per FEMA 356 and FEMA 440. Fifty different combinations of the above said RC building were analyzed as per various codes. It was found that for a relatively stiff structure (with bracing), the increase in the fundamental time period for the building considering SSI effect (TSSI) is around 2 times as that of the fundamental time period with fixed base (T) for Type-III soil. For a relatively stiff structure (with bracing), the increase in the fundamental time period for the building considering SSI effect (TSSI) is around 1.5 times as that of the fundamental time period with fixed base (T) for Type-II soil. Considering SSI effect for a relatively flexible structure (regular building without bracing) founded on Type-II shows least variation in storey drift. considering SSI effect for a relatively stiff structure (with bracing) founded on Type-III soil shows maximum variation in storey drift. For both cases i.e., fixed and considering SSI effect, among all position and orientation of bracings, the building with inverted mid bracing has the least storey drift in Zones IV and V.

Taha Amil Ansari, Sagar Jamle (2014) Studied the effect on seismic response of regular ten storey building due to interaction of structure and soil using linear static analysis. In this study performance-based analysis also performed using non-linear static analysis. A 10-storey reinforced concrete building was modeled in SAP 2000 V14 with regular fixed base building and flexible base. For soil structure interaction two medium stiff and low stiff soil were considered as per IS code. Building was 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 1.2 m thickness. It was concluded from the study that as the flexibility of the base of the building increases hinge formation near to ultimate also increases. SSI effect building showed increase in time period, roof displacement and storey drift

OBJECTIVES

Our objective is to study the influence of soil flexibility in soil structure interaction (SSI) on building frames.

1. To study the effect of SSI on various structural parameters like.
2. Base Shear - Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity.
3. Natural Time period - Natural Period Tn of a building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by its mass m and stiffness k.
4. Storey Displacement- Story displacement is the deflection of a single story relative to the base or ground level of the structure. Intuitively, we can expect higher total displacement values as we move up the structure.
5. Bending Moment & Shear Force variations at column base. - Bending moment is the tendency of a beam or column to bend or rotate due to the applied loads, while shear force is the tendency of a beam or column to slide or shear along its cross-section

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STRUCTURAL MODELLING

G + 10 Storey building is to be modelled and analysed. A building with plan dimension 40 m X 30 m is modelled with the help of STAAD with regular fixed base building and flexible base. For conventional building fix base is considered at lowermost storey. For soil structure interaction medium soil has been considered as per IS code. Building is situated in Zone III as per IS 1893(Part I). Building height is considered as 30 m with 3.0 m floor to floor height. Raft foundation is selected for the analysis with 1.0 m 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 modeling. Load of brick masonry on outer beam is taken as 12 KN/m.

The modulus of subgrade reaction is a conceptual relationship between applied pressure and deflection for a plate resting on an elastic support system. The defining equation is k=q/δ where q=pressure, δ=deflection and k is known as the modulus of subgrade reaction.The vertical spring stiffness values (K-value) is calculated as per IS:9214 section 2.3 alternate formula. The whole area is meshed, and soil springs are applied as per below formula.

$$\left[K = \frac{0{\cdot}70}{d} \text{ kgf/cm}^2\text{/cm} \right]$$

Where d is the settlement in mm.

Assuming the settlement for our soil is 60mm this will provide the value of subgrade modulus of approximately 10,000 Kn/m2/m.

RESULTS AND DISCUSSIONS

Base Shear

Following table shows the variation in Base Shear for building with fixed base and building with flexible base.

S.NO	BASE TYPE	SOIL TYPE	BASE SHEAR (KN)
1	FIXED BASE	SOIL TYPE II	1251.45
2	FLEXIBLE BASE (SSI)	SOIL TYPE II	1216.66

The base shear for flexible base condition is compared to fixed base condition. There is a variation of 2.88%.

Top Storey Displacement

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S.NO	BASE TYPE	Load Type	Displacement (mm)
1	FIXED BASE	EX	35.6
2	FIXED BASE	EZ	32.04
1	FLEXIBLE BASE	EX	38.4
2	FLEXIBLE BASE	EZ	35.4

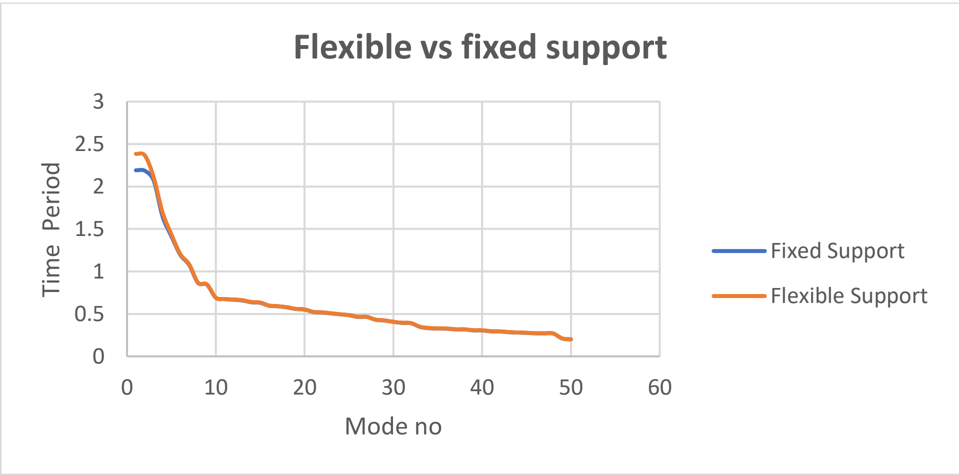
The Storey displacement for flexible base condition is compared to fixed base condition. There is a variation of 8-10%.

Natural Time Period

Following table shows Natural time period comparison with respect to mode numbers for fixed and flexible base conditions.

Table 15 Natural Period comparison

MODE	Fixed Base	Flexible Base
1	2.19196	2.38495
2	2.18643	2.36755
3	2.07335	2.11092



The natural time period in case of building with fixed base in first mode is 2.19 sec and increases to 2.38 sec in case of flexible base.

CONCLUSION

- RC building of 10 storeys has been analysed with and without considering Soil Structure Interaction. SSI has been incorporated by Mat foundation.

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- Response Spectrum method is used to analyse the structure response as per IS 1893 (PART 1) 2016.
- Seismic response results of flexible base in terms of storey displacement, bending moment, base shear and natural time period are compared with fixed base conditions.
- The following conclusions are drawn after comparing the responses of both support conditions.
- Storey displacement is high for building with fixed base as compared to flexible base.
- The natural time period in case of building with fixed base in first mode is 2.19 sec and increases to 2.38 sec in case of flexible base condition. Similarly, an amount of increase in the natural time period is found in all modes.
- Base shear in flexible base condition is less compared to fixed base condition.
- Bending moment at column base in flexible base condition is more than to fixed base condition.
- Shear force at column base in flexible base condition is more than to fixed base condition.
- Mass participation in first mode for fixed base support condition to be observed in z direction as compared to flexible base support in which mass participation for first mode observed in x direction.

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