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Investigating Three-Dimensional RCC Frames under Seismic Loading with Various Soil Conditions

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Abstract. Equivalent lateral forces are used in earthquake engineering to build structures that can survive seismic shocks. Considering seismic waves affect how the Earth moves, buildings in India's seismically active areas must be built to withstand earthquakes. This study examines how multistorey reinforced concrete building frames function seismically while taking into account different soil types, loading scenarios, and seismic Zones IV. For a twelve-storey skyscraper, the analysis includes earthquake reaction storey displacement. This study looks into how soil changes in seismic zone IV affect buildings' responses, as well as how seismic zones themselves affect them. The building's natural time periods were evaluated using both response spectrum analysis and time history analysis methods. These results provide insightful information about the complex interaction between soil type and seismic zone, Member stresses and maximum displacement are calculated using static and dynamic analysis. In India's seismically active region, the necessity for earthquake-resistant structures is highlighted by seismic waves that alter the motion of the earth. Response spectrum analysis combines modal responses via techniques including SRSS, CQC, and ABS, taking into account a variety of response modes. This study compares earthquake loads using various soil types in Zone IV to evaluate building performance during earthquakes. This project's primary goal is to analyse a multistorey building's seismic response. Staad Pro Software does load calculations in order to analyse the entire structure. Staad-Pro analysis employs the Limit State create approach, which complies with the Indian Standard Code of Practice.

Keyword-: SRSS, CQC, ABS, soil types, Zone IV, building performance, multistorey building, seismic response,

1 Introduction

The core idea behind earthquake engineering is the application of equal lateral pressure. Determining the maximum displacement or member stresses in structural systems requires a dynamic analysis that moves from partially dynamic to partially static. Seismic waves travelling through soil strata have a dramatic effect and drastically change how the earth moves. The term storey displacement describes the lateral movement or repositioning of whole floor or storey inside a building. This displacement, which is commonly measured horizontally and perpendicular to the vertical axis of the building, is an important factor to consider when evaluating how a structure will react to different external stresses, such seismic activity. Comprehending the overall integrity as well as stability of a building during dynamic events is highly dependent on the storey displacement. Engineers utilise exact measuring techniques for the purpose of evaluating storey displacement and ensuring that a structure can withstand potential forces. It provides them substantial information about the functioning of building in different scenarios In India, which is located in a seismically active subcontinent, earthquake-resistant buildings span more than 60% of the country's land (in Fig. 1) underscoring the importance of human life and safety. With the availability of low-cost computers and specialised software, the evaluation and design of structures for static forces have become commonplace; however, the dynamic assessment is laborious and requires additional information about the mass of the structure as well as an understanding of structural dynamics in order to interpret the results [1-2]. Throughout their lives, reinforced concrete (RC) frame buildings—which are common in India's cities—withstand a number of forces, including both dynamic forces brought on by earthquakes and static forces from dead and live loads. In particular, this study explores how earthquake loads—a crucial dynamic force—affect structural analysis [3]. The evaluation and design of structures for static forces have become commonplace with the advent of affordable computers and specialised software; however, the dynamic assessment is time-consuming and requires knowledge of structural dynamics and additional information about the mass of the structure in order to be interpreted. These forces include both static forces resulting from dead and live loads and dynamic forces caused by earthquakes [4-5]. This work specifically investigates the impact of earthquake loads, an important dynamic factor, on structural analysis. Understanding how computers may cut down on the number of man-hours needed to complete a project, proficiency with Staad.pro guarantees accurate execution and quick, effective planning. Staad.Pro commercial edition is used extensively in structural analysis and design since it can handle several design codes for structures made of steel, concrete, and wood. Its adaptability encompasses a variety of dynamic analyses, such as response spectrum analysis, time records, a modal extraction [6-10]. Furthermore, under earthquake excitation, the study investigates the interdependent impacts of supporting soil flexibility and the phenomena of pounding, which occurs between adjacent buildings of identical height. Modelled as inelastic lumped mass systems with different structural elements, the seismic reactions of two nearby three-storey buildings are recorded on different types of soil and explored throughout a range of peak ground accelerations. An effective way to capture impact forces during collisions is with a nonlinear viscoelastic pounding force model. The study uses spring-dashpot components for simulating the rotational and horizontal movements of the supporting soil. The structural nonlinear responses and the time histories of energy dissipation during vibrations brought on by hammering are shown by numerical simulation results. The study investigates the dynamics of the building-soil interaction by modelling the building structure as an n-degree-of-freedom oscillator and the soil as a linear elastic 1/2-area [11-13]. In spite of the absence of classical normal modes, the system's response can be understood as the superposition of responses from damped linear oscillators that are exposed to one-of-a-kind excitations. The work sheds light on how interaction affects damping ratios and all resonant frequencies, but tends to reduce resonant frequencies. It explores in further detail the initial modes of n-storey systems, modified natural frequency and damping ratio, and altered excitation for single-storey systems [14-17]. The study comes to the conclusion that interaction tends to reduce all resonant frequencies using example computations for interaction systems with one, two, and ten stories. But in many n-storey systems, the effects are greatest for the fundamental mode, with the effects being more noticeable for rocking than for translation. Additionally, the study expands its analysis to include idealised building clusters during seismic events, concentrating on their reactions, how they affect ground motion, and how they interact with surrounding structures and the earth [18]. The research, which simulates the ground motion during the Northridge earthquake of 1994, finds that the impacts of soil-structure interaction (SSI) vary depending on the quantity and dynamic characteristics of the buildings, their distance from one another, and the impedance of the soil. The final conclusions drawn from the studies are concluded as variations in roof displacement, changes in the higher natural frequencies of building foundation systems, a major decrease in soil stability along with high ground spatial changes [19]. There has been study that focusses on the detailed dynamics of multi-story buildings under seismic and wind loads, along with providing some insights into the complex interactions that may occur in between structural components, soil conditions, along with the surrounding buildings when there is an event of natural shocks due to earthquakes in the environment.

A study indicated that geopolymer concrete exhibits superior properties as compared to traditional concrete [20-21].

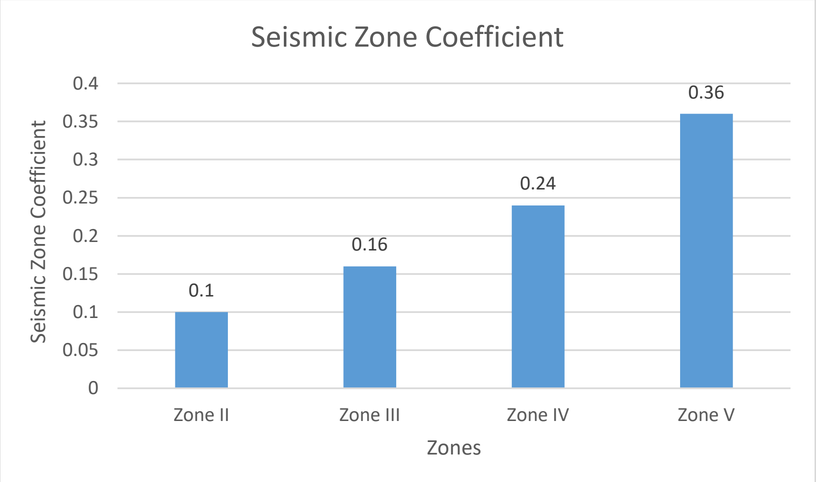

Fig. 1: Seismic zone coefficient

The IS code assigns a zone factor covers the areas with the highest risk of suffering earthquakes of intensity or more significantly. The IS code assigns a zone factor of 0.10, 0.16, 0.24 and 0.36 for Zone II, III, IV and V, also provided the representation in Fig. 1. Structural designers use this factor for the earthquake-resistant design of structures. The zone factor of 0.10, 1.16, 0.24 and 0.36 (the maximum horizontal acceleration that a structure can experience) [22].

2 Methodology

The dynamics of multi-storey buildings under seismic and wind loads are essentially revealed by this extensive study, which also sheds insight on the complex interactions between structural components, soil properties, and surrounding structures during these dynamic occurrences [23-25]. This study compares earthquake loads using various soil types in Zone IV to evaluate building performance during earthquakes. This project's primary goal is to analyse a multistorey building's seismic response. Staad Pro Software does load calculations in order to analyse the entire structure. Staad-Pro analysis employs the Limit State create approach, which complies with the Indian Standard Code of Practice. This study aims to provide a comparative assessment of a G+12 storey structure, taking into account seismic zones IV and different soil types, to comprehend the structural behaviour under the application of live load, dead load, as well as seismic load. The modelling and analysis processes are conducted utilizing Staad.pro software.

2.1 Characteristics of seismic

A Zone Coefficient (z) of 0.24, an Importance Index (I) of 1.5, and a Factor of Response Reduction of 5 are used to analyse a structure's seismic properties, which are presented in Table 1. These metrics show a region's seismic intensity, the significance of the structure, and how well seismic design strategies lessen the way buildings react to earthquakes. The hardness or softness of the soil has an impact on the ground motion amplification and seismic response of the structure [26]. Based on certain soil properties, seismic reactions can be adjusted with a specific soil type coefficient of 0.05. The way that structures are constructed to withstand earthquakes is determined by these factors, which are essential for seismic design.

Table 1: Seismic properties

Characteristics of seismic properties	
Zone Coefficient (z)	0.24
Importance Index (I)	1.5
Factor of Response Reduction	5
Type of soil	Hard and Soft
particular type of soil	0.05

2.2 Condition of Loading

Based on the standards IS 875 Part-1 and IS 875 Part-2, Table 2 provides an overview of the computations required to determine the dead and live loads on structure, together with particulars on slab weight and live load requirements.

Table 2: Dead and live load calculations

Calculation Aspect	**Details**	**Value**
Dead Load Calculation		
Reference Standard	IS 875 (PART-1)	-
Slab Weight Calculation		
Thickness of Slab		0.150 m
Density of Concrete		25 kN/m³
Self-Weight of Slab	Concrete Density × Thickness of Slab	-
Finishing Floor Level Weight		1.5 kN/m²
Total Weight of Slab	At storey level	5.25 kN/m²
Live Load Calculation		
Reference Standard	IS 875 (PART-2)	-
Floor Live Load	For public building	4 kN/m²
Roof Live Load	At roof level	1.5 kN/m²

3 Building Configuration

To further understand their realistic behaviour under seismic conditions, structures of varied heights—more specifically, G+12 RC multi-storey framed buildings—have been used for this investigation. The overall plan and elevation of the models are created in accordance with the requirements of reinforced concrete construction. Within seismic zone IV, all construction models are taken into consideration [27]. Using Staad Pro software, the Response Spectrum seismic analysis method with fixed support is used to do the structural study. The base is three metres high, as is the regular height of each storey in the buildings. The soil type is divided into Hard and Soft categories for a thorough analysis. Table 3 presents the structural configuration that is being examined, which is a G+12 building with particular geometric qualities.

Table 3: The structure's geometrical specifications

Items	Properties
The no. of stories.	G+12
Total height of the structure	39m
Average Height of Storeys	3m
Minimum Storey Elevation	4m
Diaphragm for the Floor	Rigid
The number of bays along the length	4
The quantity of bays along width	5
Size of Beams	450x600mm
Shape of Beams	Rectangular
Column Length	600x600mm
Shape of a Column	Rectangular
Depth of Slab	150mm
Distribution Bar's Yield Strength	Fe415
Main Bar's Yield Strength (fymain)	Fe415
Concrete Grade	M25 for the structure

Define the property using the General-Property command in accordance with the size specifications for the relevant building on Staad-Pro. Following the assignment of selected beams and columns, beams and columns have been generated. defining the attributes of the Beam and Column sections. The study takes into account three different sizes: 450 x 600 mm for beams, 600 x 600 mm for columns, and 150 mm for slab.

3. Results and Discussion

Determining the maximum displacement or member stresses in structural systems requires a dynamic analysis that moves from partially dynamic to partially static. Seismic waves travelling through soil strata have a dramatic effect and drastically change how the earth moves. The term storey displacement describes the lateral movement or repositioning of whole floor or storey inside a building. Equivalent lateral forces are used in earthquake engineering to build structures that can survive seismic shocks Considering seismic waves affect how the Earth moves, buildings in India's seismically active areas must be built to withstand earthquakes. This study examines how multistorey reinforced concrete building frames function seismically while taking into account different soil types, loading scenarios, and seismic zones IV. For a twelve-storey skyscraper, the analysis includes earthquake reaction storey displacement Response Spectrum analysis has been used in a comparaison study to look at a building's storey displacement, base shear, maximum shear force, and bending moment. The findings from the study are highlighted in the section below, and a detailed comparison analysis is given in the explanation that follows.

Table 4: Base shear results for a hard soil type zone IV G+12 RCC building

Storey of Floor	**Storey Level**	**Base Shear**	**Displacement in mm**
13	39.00	210	19.5
12	36.00	456	17.8
11	33.00	613	17.2
10	30.00	724	16.1
9	27.00	889	15.5
8	24.00	956	14.2
7	21.00	1004	13.4
6	18.00	1090	11.3
5	15.00	1136	8.1
4	12.00	1298	6.4
3	9.00	1345	3.9
2	6.00	1394	2.3

1	3.00	1458	1.1
BASE	0.00	1458	0.00

A structural analysis of a multi-storey structure made on hard soil is shown in Table 4, which looks at the relationship between base shear forces, displacements, and storey levels. The "Base Shear" column shows the lateral force applied at the base by outside forces like as seismic activity or wind, while the "Storey of Floor" column specifies the floor number. Under the imposed base shear, the lateral displacement of each storey is measured in the "Displacement in mm" column. According to the data, the storey level grows as the building rises, signifying the height above the ground. The base shear value reaches its greatest at the base after initially increasing from the top storey. The displacement shows a decreasing trend from top to bottom, indicating that the upper floors move more than the lower floors due to lateral loads.

Table 5: Base shear results for a soft soil type G+12 RCC structure in zone IV

Storey of Floor	**Storey level**	**Base Shear in KN**	**Displacement in mm**
13	39.00	290	31.3
12	36.00	548	29.9
11	33.00	897	29.1
10	30.00	1143	28.2
9	27.00	1389	26.8
8	24.00	1498	23.6
7	21.00	1686	21.5
6	18.00	1820	18.7
5	15.00	1976	15.8
4	12.00	2143	12.5
3	9.00	2188	9.2
2	6.00	2205	4.8
1	3.00	2238	1.9
BASE	0.00	2238	0.00

The outcomes for the G+12 RCC shape on soft soil in zone IV, a sector of high seismic interest, as proven in Table 5. Storey levels, base shear values, and lateral offsets are involve in the data for every floor, starting from the ground and going up to the 13th. The "storey of floor" shows the wide variety of every stage above ground, rising to 39 meters on the thirteenth level, or which displays the shear force carried out at the base because of seismic activity. The "displacement in mm" column measures the displacement experienced by each floor under seismic forces, showing a decreasing trend from the top floor down to the base. The largest displacement occurs at the top (31.3 mm), gradually decreasing to zero at the base, highlighting the increased flexibility and movement potential of higher floors compared to the more rigid lower floors.

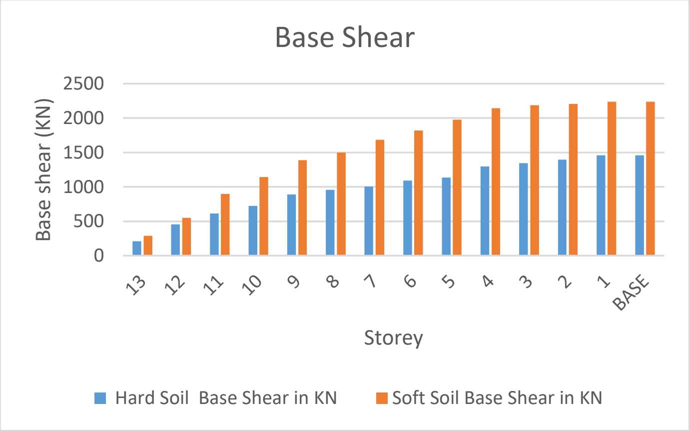

Fig. 2: Base Shear variation for hard and soft soil

The base shear values, expressed in kilonewtons (kN), provide insights into the lateral force resistance provided by the structure at each floor level. The base shear value on varies across different storeys, reflecting the building's design to withstand lateral forces like seismic activity According to our research, the inertial and kinematic interaction results of the soil-shape systems have a discernible impact at the buildings' structural reaction. These interconnected results cause variations in the structural factors' base shear and displacement. In particular, it is miles discovered that shifting from hard to soft soil effects in elevated base shear in RCC frame structures in Fig. 2.

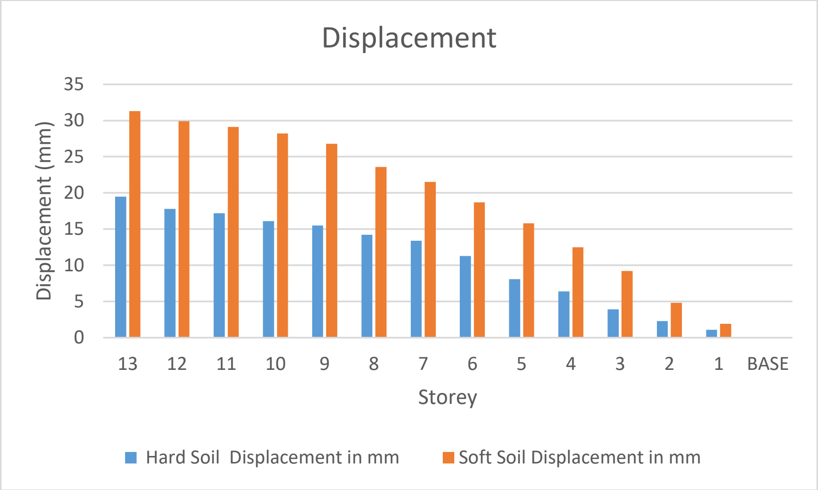

Fig. 3: Displacement variation for hard and soft soil

The description provides that various structural analysis metrics for a building across its different storeys, starting from the displacement to the 13th floor. The Fig. 3 is providing critical information on the storey level and displacement. Our findings demonstrate that the type of soil along with the storey number clearly influence the structural response of the buildings. These interactions have different impacts on the displacement and base shear of the structural elements. More specifically, Fig. 3 illustrates how moving from hard to soft soil causes a more rapid storey displacement in RCC frame systems.

4 Conclusion

This study examines how multistorey reinforced concrete building frames function seismically while taking into account different soil types, loading scenarios, and seismic zones IV. For a twelve-storey building, the analysis includes earthquake reaction storey displacement. Considering seismic waves affect how the Earth moves buildings in India's seismically active areas must be built to withstand earthquakes. Our findings indicate that the soil-structure systems' kinematic and inertial interaction effects clearly affect the structural response of the buildings.

a. Seismic waves significantly alter earth's movement through soil strata. Storey displacement refers to the lateral movement or displacement of a building's floor or storey.
b. Response spectrum is crucial in earthquake engineering to build structures that can withstand seismic shocks. Study examines multistorey reinforced concrete building frames' seismic function considering different soil types, loading scenarios, and seismic zones IV.
c. It is known that these interaction influences result in variations in the base shear and displacement of the structural parts. More precisely, it is discovered that in RCC frame constructions, foundation shear and storey displacement increase when one shifts from hard to soft soil. These changes that have been seen highlight how crucial it is for seismic assessments to take soil-structure interaction into consideration for understanding and addressing how dynamically buildings behave during earthquakes.
d. In particular, it is discovered that moving from hard to soft soil causes an increase in the displacement of storeys in RCC frame buildings.

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