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Seismic Performance of R.C. Mid-Rise Building Resting on Soft Strata

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ABSTRACT

This abstract provides a concise overview of the seismic performance considerations for reinforced concrete (RC) mid-rise buildings situated on soft soil. This study highlights the key factors and strategies essential for ensuring the safety and resilience of these buildings in earthquake-prone regions.

During severe seismic events, the dynamic response of the structure is affected not only by the behaviour of the superstructure but also by the nature and behaviour of the soil present in and around the substructure. The conventional structural design process usually assumes the base of the foundation to be completely restrained, i.e., in a fixed condition. However, this assumption is inaccurate as it neglects the effect of flexibility offered by the interaction of the soil with the structure. There is no clear consensus on either the beneficial or detrimental effects of soil-structure interaction (SSI) on the seismic response of structures. A case study is done to understand the non-linear dynamic response of building with different soil conditions (hard and soft). The results are represented in terms of fundamental period, base shear, and story drift.

Earthquakes have the potential to cause the greatest damage, among the other natural hazards. Earthquakes may be the most fight flighty and high destructive of all the natural disasters. Structures are subjected to different earthquakes leading behaves differently with diversification in dense, medium, and soft and hard soil. Soil properties get affected drastically as seismic waves pass through a soil layer. Soil liquefaction is a phenomenon in which saturated, or partially saturated soil temporarily loses its strength and stiffness, often due to the sudden application of stress, such as during an earthquake. This causes the soil to behave like a liquid, leading to potential ground instability and damage to structures built on or within the affected soil.

When a reinforced concrete (RC) mid-rise building is constructed on soft soil, it can have a significant impact on its seismic performance. Soft soil tends to amplify ground motion during an earthquake, which can lead to increased building vibrations and potential structural damage. To mitigate these effects, engineers use techniques like deep foundations, soil improvement methods, and base isolation systems. These measures help reduce the building's vulnerability to seismic forces.

The project employs advanced computational analysis and experimental investigations to assess the structural behaviour and dynamic response of these buildings The study aims to provide Insights into how soft and hard Strata Influence the seismic vulnerability and resilience of RC Structures. Factors such as ground motion characteristics Soil Structures interaction, and structural design will be examined to better understand the performance disparities between these two strata types.

When a building is constructed on soft soil, it can experience more intense shaking during an earthquake. This can lead to increased stresses and deformations in the structure, potentially compromising its stability. To address this, engineers use various techniques like deep foundations, soil improvement methods, and flexible structural systems to enhance the building's seismic performance on soft soil. It's all about making sure the building can withstand and safely absorb the seismic forces.

Chapter 1

INTRODUCTION

Structures are often mounted on layers of soil unless bedrock is very close to the ground surface. Based on the fact that seismic waves pass through kilometres of bedrock and usually less than 100 meters of soil, soil layers play a significant role in assigning the characteristics of the ground surface movement. When the ground is stiff enough, the dynamic response of the structure will not be influenced significantly by the soil properties during the earthquake, and the structure can be analysed under the fixed base condition. When the structure is resting on a flexible medium, the dynamic response of the structure will be different from the fixed base condition owing to the interaction between the soil and the structure. This difference in behaviour is because of the phenomenon, commonly referred to as soil-structure interaction (SSI), which if not taken into account in analysis and design properly; the accuracy in assessing the structural safety, facing earthquakes, could not be reliable. Performance-based engineering (PBE) is a technique for seismic evaluation and design using performance level prediction for safety and risk assessment. Soil structure interaction particularly for unbraced structures resting on relatively soft soils may significantly amplify the lateral displacements and inter-storey drifts. This amplification of lateral deformations may change the performance level of the building frames. Thus, a comprehensive dynamic analysis to evaluate the realistic performance level of a structure should consider effects of SSI in the model. The seismic performance of RC mid-rise buildings on soft soil necessitates a comprehensive understanding of geotechnical conditions and their impact on structural integrity. Site-specific geotechnical investigations are crucial to assess soil properties, including shear strength, settlement characteristics, and liquefaction potential. The data obtained from these investigations inform foundation design and construction methods.

The seismic performance of RC mid-rise buildings on soft soil requires a multi- faceted approach, encompassing geotechnical investigations, structural design, foundation engineering, compliance with codes, and dynamic analysis. Through a holistic understanding of these factors, engineers can ensure the safety and resilience of these structures in seismic-prone regions. The seismic performance of a midrise building resting on hard strata is influenced by various theoretical principles related to soil-structure interaction and seismic engineering. Here are some key theoretical considerations:

• Site Response Analysis: Site response analysis is crucial for understanding how the ground motion induced by seismic waves affects the building at a specific location. When a midrise building is situated on hard strata, the amplification of seismic waves is typically lower compared to softer soils. This is because hard strata tend to have higher shear wave velocities, which reduce the amplitude of ground motion. Foundation Design: The foundation design of a building on hard strata is typically more straightforward compared to buildings on softer soils. Since hard strata provide a stable and uniform support, the foundation system can be designed to efficiently transfer seismic forces to the ground without excessive settlement or differential movement.

• Dynamic Analysis: Dynamic analysis techniques, such as modal analysis and time-history analysis, are used to assess the response of the building to seismic excitation. Buildings on hard strata generally exhibit shorter natural periods of vibration compared to those on softer soils, which can influence the dynamic behaviour and response to seismic loads.

• Soil-Structure Interaction: Soil-structure interaction refers to the mutual influence between the building and the supporting soil during seismic events. In the case of a midrise building on hard strata, the interaction is typically characterized by a stiffer foundation response, which can reduce the lateral displacements and accelerations experienced by the structure.
• Seismic Code Compliance: Designing a midrise building on hard strata still requires adherence to seismic design codes and standards. Even though the seismic risk may be lower compared to buildings on softer soils, it's essential to ensure that the structure is designed to withstand potential seismic forces as per the applicable building codes and regulations.
Overall, the theoretical understanding of soil-structure interaction, foundation design principles, dynamic analysis techniques, and seismic code compliance informs the assessment and design of midrise buildings resting on hard strata to ensure adequate seismic performance and resilience.
1. In India, there have been instances of earthquakes where soil liquefaction has played a role. One notable example is the 2001 Bhuj earthquake in Gujarat. The seismic activity caused liquefaction in several areas, leading to widespread damage and loss of life. It serves as a reminder of the potential impact of soil liquefaction during earthquakes and the importance of considering soil conditions in building design and construction.
2. The 1993 Latur earthquake, also known as the Killari earthquake, occurred in Maharashtra, India. It had a magnitude of 6.3 and struck the Latur and Osmanabad districts. The earthquake caused significant damage, resulting in the collapse of buildings and infrastructure. Many lives were lost, and the region faced extensive recovery efforts. It serves as a reminder of the importance of earthquake preparedness and safety measures.
3. During the Alaska earthquake of 1964, the liquefaction of a sandy layer of soft clay beneath Turn again Heights, a suburb of Anchorage, caused a landslide in the mass of ground above that destroyed approximately 75 homes and disrupted utilities.
4. The 1964 Niigata earthquake caused widespread liquefaction in Niigata, Japan which destroyed many buildings. Also, during the 1989 Loma Prieta, California earthquake, liquefaction of the soils and debris used to fill in a lagoon caused major subsidence, fracturing, and horizontal sliding of the ground surface in the Marina district in San Francisco.
5. The 1985 Mexico City earthquake: This magnitude 8.1 earthquake struck Mexico City, causing severe damage. The soft soil in the area amplified the shaking, leading to the collapse of many buildings.
6. The 1995 Kobe earthquake: This magnitude 6.9 earthquake hit the city of Kobe, Japan. The soft soil in the region played a role in amplifying the ground shaking, resulting in widespread destruction and loss of life.
7. The 2011 Christchurch earthquake: This series of earthquakes, including a magnitude 6.3 event, struck the city of Christchurch in New Zealand. The soft soil in the area caused significant liquefaction, where the ground behaves like a liquid, leading to building damage and infrastructure issues.

Fig 1.1: (a)- (g) Past Earthquake

(a) Bhuj Earthquake

(b) Killari Earthquake

(c) Alaska Earthquake

(d) Niigata Earthquake

(e) Kobe Earthquake

(f) Mexico Earthquake

❖ Objectives of proposed work

1. To compare dynamic properties of the structure resting on hard/soft strata.
2. To compare element forces in the structure resting on hard/soft strata.
3. To investigate globe response of the structure on hard/ soft strata.

(g) Christchurch Earthquake

Chapter 2

LITERATURE REVIEW

1. **B. Fatahi and S. Tabatabaiefar (2014): -**The frame sections are modelled and analysed, employing finite difference method adopting FLAC 2D software under two different boundary conditions: (i) fixed base (no Soil-Structure Interaction), and (ii) flexible base considering soil structure interaction. It is concluded that reduction of the Plasticity Index could noticeably amplify the effects of soil-structure interaction on the seismic response of mid-rise building frames.

2. **H. Tabatabaiefar and T. Clifton (2016): -**The current study carries out a comprehensive critical review on available and well-known research studies in the area of seismic behaviour of braced and unbraced building structures affected by soil-structure interaction (SSI). Based on the current review outcomes, it has become apparent that considering effects of SSI in seismic design of braced building structures is not necessary and assuming fixed-base structure is deemed to be conservative. However, SSI effects can amplify the lateral deflections and corresponding inter-storey drifts of unbraced building structures founding on soft grounds, forcing the structure to behave in the inelastic range, resulting in severe damage of the building structures. Consequently, seismic design procedure of unbraced building structures founding on soft soils without taking into account detrimental influences of SSI cannot adequately assure structural sufficiency and safety for the benefit of the community.

3. **M. Hoseny,et al. (2016): -**The seismic design of RC buildings requires determining the expected base shear, lateral drift at each story level and internal forces of the structural elements. In the analysis, it is common for the structural engineers to consider a fixed base structure which means that the foundations and the underlying soil are assumed to be infinitely rigid. This assumption is not proper since the underlying soil in the near field often consists of soft soil layers that possess different properties and may behave nonlinearly leading to drastic variation of the seismic motion before hitting the structure foundation. In addition, the mutual interaction between the structure, its foundation and the underlying soil during the vibrations can substantially alter the structure response. This response variation depends on the structure characteristics, the soil properties and the nature of the seismic excitation. Consequently, an accurate assessment of inertial forces and displacements in structures requires a rational treatment of soil structure interaction (SSI) effects.

4. **B. Santhosh Kumar(2017): -**In this study, different soil strata, with rigid and flexible base foundation types are illustrated and corresponding base shear and lateral displacement are determined with variation in floors as G+7, G+8 and G+9 for Earthquake Zones 3, 4 and 5. IS 1893: 2002 “Criteria for Earthquake Resistant Design of Structures” gives response spectrum for different types of soil such as hard, medium, and soft. The building is modelled using ETABS - 2015 having different Winkler’s springs as its foundation corresponding to different soil properties. To find out seismic performance of rigid and flexible to RCC building, parameters as Lateral displacement, Storey shear and Storey drift should be studied. It was found that by comparing the flexible base results with fixed base results, flexible base structure shows better seismic performance in all soil conditions.

5. **M. Bagheri, S. ASCE, et al. (2018): -**A series of numerical simulations were carried out on two types of superstructures and six types of piled raft foundations to investigate the effects of seismic soil–pile–structure interaction (SSPSI) on the seismic responses of the superstructures. In this research, the effectiveness of a piled raft application was assessed; the pile optimum numbers, locations, and configurations were estimated; and finally, a comparison was made between the nonlinear structural responses of the obtained two-dimensional (2D) and three-dimensional (3D) models. Parametric studies were conducted to achieve strategies for optimized designs of piled raft foundations subjected to the low- to-high intensities of real earthquake records as the input motions.

6. **A. Suryawanshi and V.Bogar (2019): -**RCC structures been used along with and without soil structure interaction on sloping ground to compare the displacement, story shear, story drift and base shear of buildings. RCC structures are commonly used on plain ground without SSI (soil structure interaction). The above parameters are evaluated for buildings with and without soil structure interaction in buildings on sloping ground. The performances of structures have been evaluated using response spectrum analysis. To achieve this objective; G+19 structures with and without soil

structure interaction are carried out in ETABS 2016, and from the obtained results, the values of parameters such as displacement, story drift, story shear, base shear are compared.

7. **Ibrahim Oz, S. Senel, et al. (2020): -**Different soil conditions classified according to shear wave velocities were reflected by using substructure method. Inelastic deformation demands were obtained by using nonlinear time history analysis and 20 real acceleration records selected from major earthquakes were used. The results have shown that soil-structure interaction, especially in soft soil cases, significantly affects the seismic response of old buildings. The most significant increase in drift demands occurred in first stories and the results corresponding to fixed base, stiff and moderate cases are closer to each other with respect to soft soil cases. Distribution of results has indicated that effect of soil-structure interaction on the seismic performance of new buildings is limited with respect to old buildings.

8. **F. Wani, et al. (2022): -**During severe seismic events, the dynamic response of the structure is affected not only by the behavior of the superstructure but also by the nature and behavior of the soil present in and around the substructure. The conventional structural design process usually assumes the base of the foundation to be completely restrained, i.e., in a fixed condition. However, this assumption is inaccurate as it neglects the effect of flexibility offered by the interaction of the soil with the structure. There is no clear consensus on either the beneficial or detrimental effects of soil-structure interaction (SSI) on the seismic response of structures. The main objective of this paper is to study the effect of SSI on a multi-story (G þ 10) building resting on a mat foundation. The building is modeled using Finite Element Method (FEM) software and SSI is incorporated using Winkler's (un-coupled) and pseudo-coupled approaches. A case study is done to understand the non-linear dynamic response of building with different soil bearing capacities. The results are represented in terms of fundamental period, base shear, and story drift.

Chapter 3

METHODOLOGY

The principle on which our project is based is described below:

• Literature review begin by conducting thorough review of existing literature review on seismic performance of building on soft soil. This will help you understand the current state of knowledge, identify gap, and determine the appropriate methodologies.

• Study of past earthquake: - study of past earthquakes will help to know about the earthquake patterns and reasons of earthquake. And by studying past earthquake we can suggest better solution for that.

• Modelling of Midrise RC building: - Develop a numerical model of the midrise building using Etabs software. Make two models one is resting on hard strata and another on soft strata.

• Dynamic analysis: - perform dynamic analysis of RC midrise building resting on soft strata. In which perform modal analysis of building, story drift, story displacement and Earthquake analysis.

• Similarly perform analysis for RC midrise building resting on hard strata. And do modal analysis, story drift, story displacement and Earthquake analysis.

• Comparing the results of building resting on hard strata and soft strata • After getting all the results of building resting on hard strata and soft strata discuss the result and get appropriate conclusion.

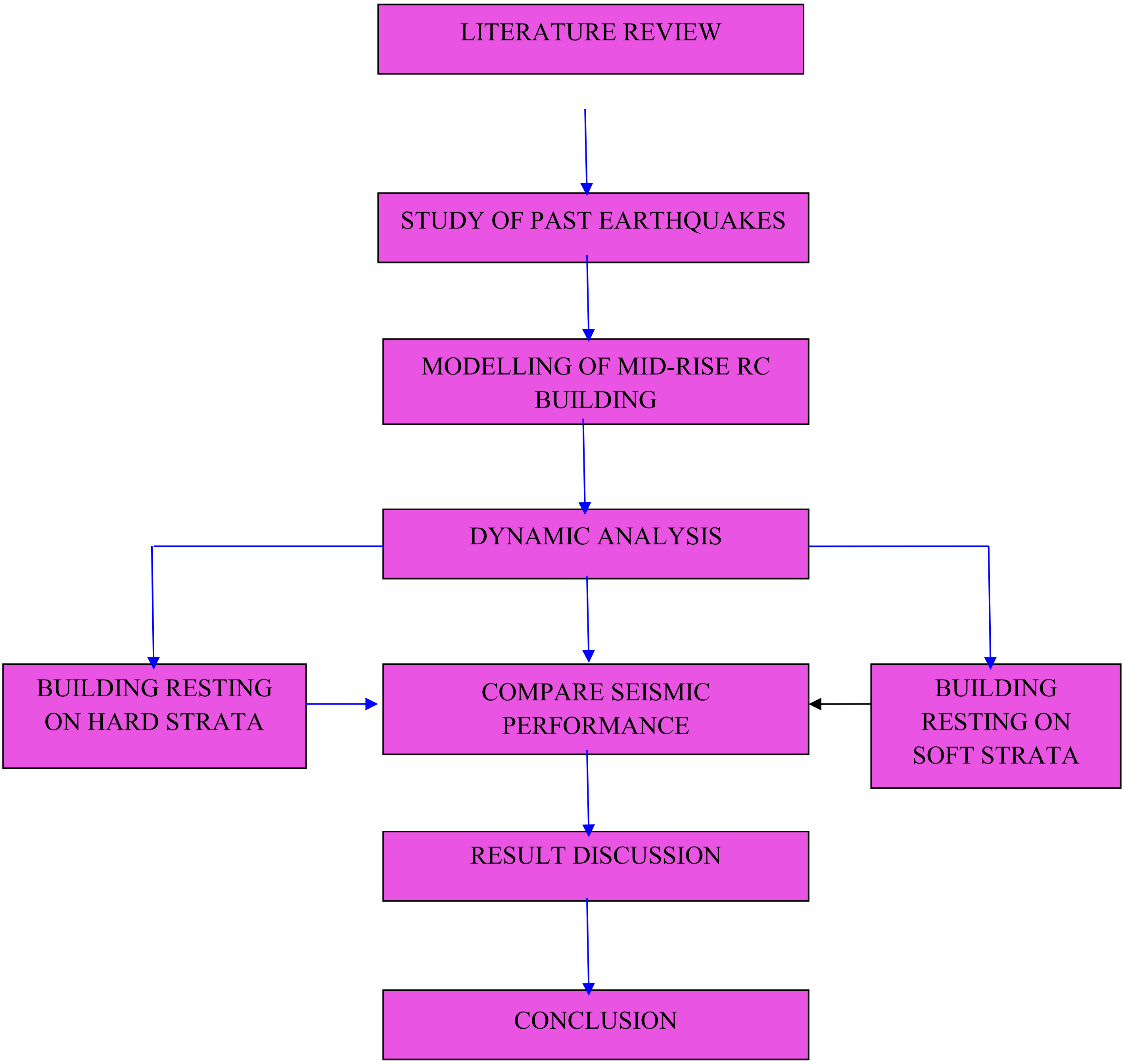

Fig 3.1: Methodology

Chapter 4

SEISMIC PERFORMANCE OF RC MID RISE BUILDING ON SOFT STRATA

The seismic performance of a midrise building resting on soft strata differs significantly from that of a building on hard strata due to the contrasting soil conditions. Here are some key theoretical considerations for a midrise building on soft strata:

• Site Amplification: Soft strata, such as loose sands or clayey soils, tend to amplify seismic waves due to their lower shear wave velocities and higher compressibility compared to hard strata. This amplification can result in higher ground accelerations and longer duration shaking, which can potentially increase the seismic forces experienced by the building.

• Soil Liquefaction: In areas with loose or saturated soils, seismic shaking can induce liquefaction, where the soil loses its strength and behaves like a liquid. Liquefaction can lead to significant ground settlement and lateral spreading, posing a severe threat to the stability of buildings resting on soft strata.

• Foundation Design Challenges: Building foundations on soft strata require special attention to mitigate settlement and differential movement. Techniques such as deep foundations (e.g., piles or caissons) or ground improvement (e.g., compaction or soil stabilization) may be necessary to provide adequate support and mitigate the effects of soil settlement during seismic events.

• Dynamic Response: Buildings on soft strata typically exhibit longer natural periods of vibration and higher damping compared to those on hard strata. This longer period of vibration can result in larger displacements and accelerations during seismic events, potentially leading to greater structural damage if not properly accounted for in the design.

• Seismic Retrofitting: Existing midrise buildings resting on soft strata may require retrofitting to enhance their seismic performance. Retrofitting measures may

Overall, the seismic performance of a midrise building resting on soft strata is influenced by factors such as site amplification, soil liquefaction potential, foundation design challenges, dynamic response characteristics, and the need for seismic retrofitting. Understanding these theoretical considerations is essential for assessing and mitigating the seismic risks associated with buildings on soft strata

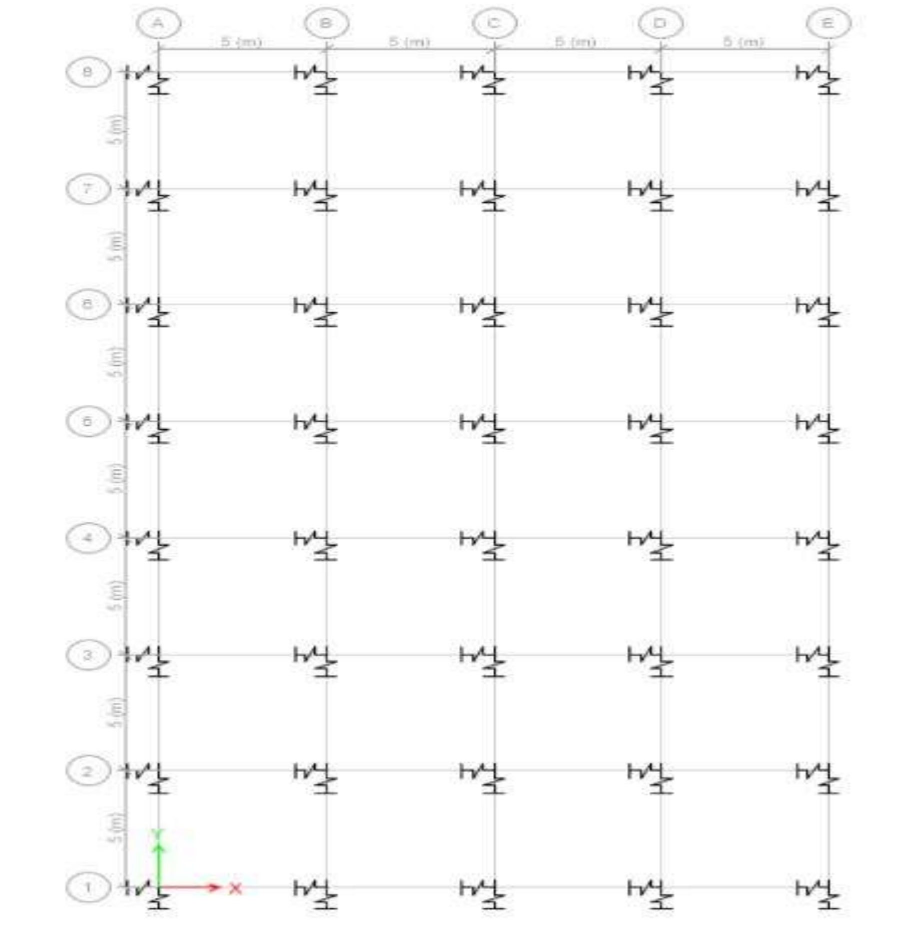

Fig 4.1: Plan of building resting on soft strata (with springs)

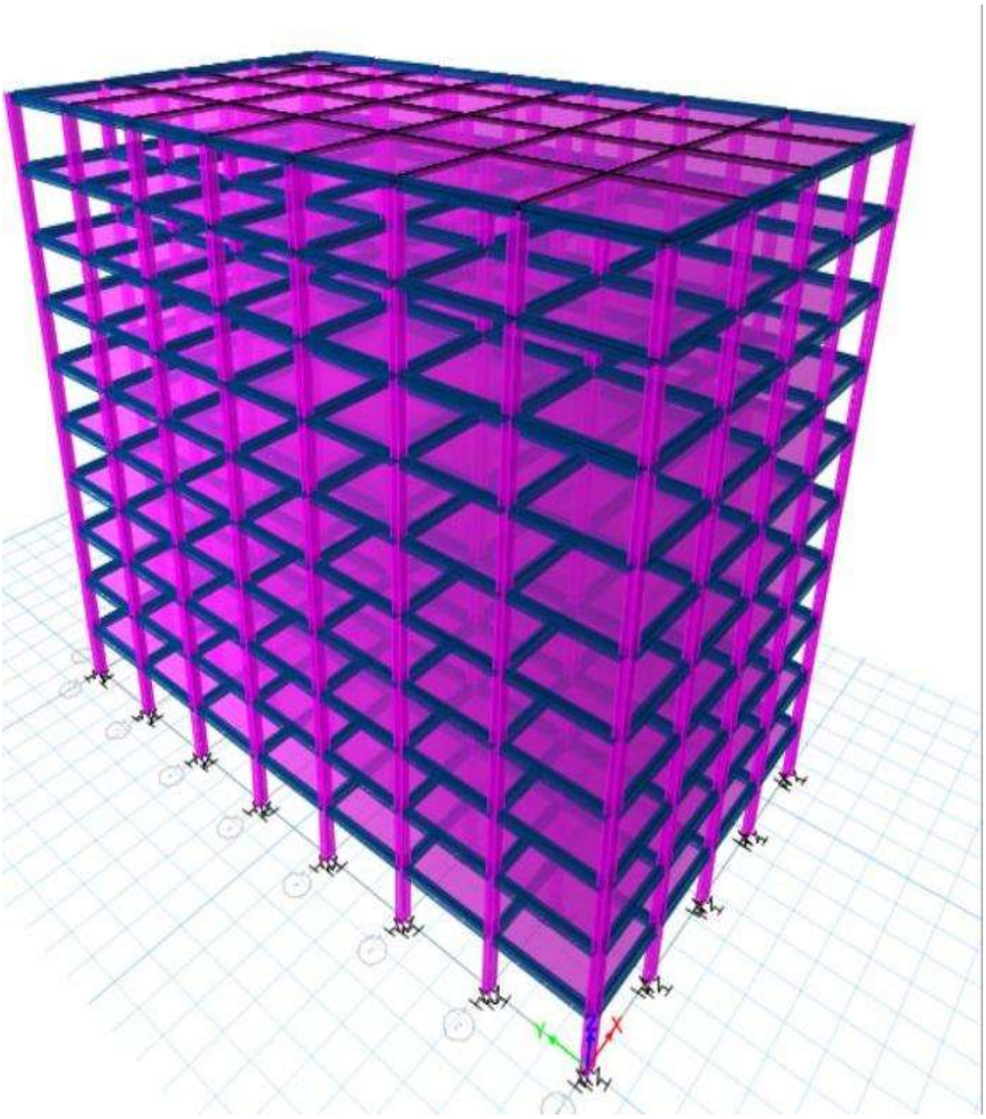

Fig 4.2: Etabs 3D model of soft strata (with springs)

❖ **MODAL ANALYSIS**

In structural engineering, modal analysis uses the overall mass and stiffness of a structure to find the various periods at which it will naturally resonate. These periods of vibration are very important to note in earthquake engineering, as it is imperative that a building's natural frequency does not match the frequency of expected earthquakes in the region in which the building is to be constructed. Modal analysis is a technique used to study the dynamic behaviour of structures. It helps engineers understand how a structure will respond to vibrations and determine its natural frequencies and mode shapes. By analysing the modes of vibration, engineers can identify potential resonance issues and design structures to avoid them. It's a fascinating field that plays a crucial role in structural engineering.

Table 4.1: Result of modal analysis of building on soft strata

TABLE: Modal Participating Mass Ratios								
Case	Mode	Period Sec	**UX**	**UY**	**UZ**	**SumUX**	**SumUY**	**SumUZ**
Modal	1	11.154	0.8357	0	0	0.8357	0	0

Modal	2	8.436	0	0.8858	0	0.8357	0.8858	0
Modal	3	5.601	0	0	0	0.8357	0.8858	0
Modal	4	2.137	0.1586	0	0	0.9943	0.8858	0
Modal	5	2.126	0	0.1082	0	0.9943	0.9939	0
Modal	6	1.588	0	0	0	0.9943	0.9939	0

RX	RY	RZ	SumRX	SumRY	SumRZ
0	0.1642	0	0	0.1642	0
0.1138	0	0	0.1138	0.1642	0
0	0	0.9491	0.1138	0.1642	0.9491
0	0.8138	0	0.1138	0.978	0.9491
0.8599	0	0	0.9737	0.978	0.9491
0	0	0.0447	0.9737	0.978	0.9939

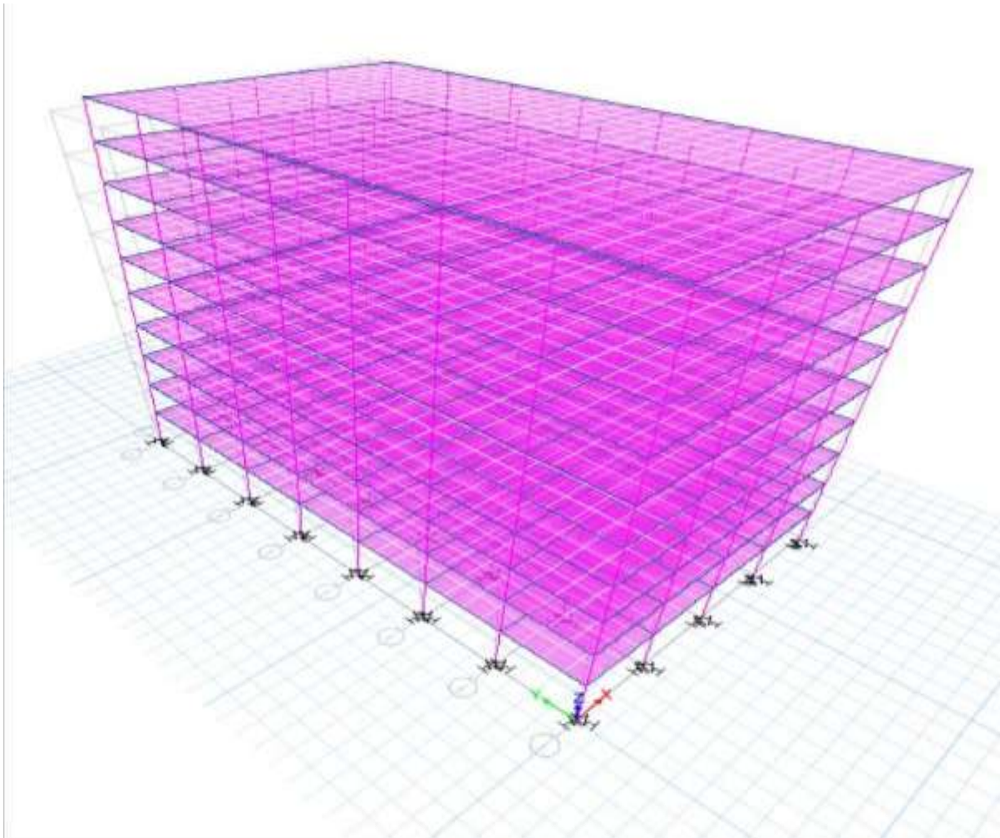

Fig 4.3: Etabs 3D model of modal analysis on soft strata (with springs)

❖ STORY DRIFT: -

Story drift refers to the relative displacement or movement between different levels or stories of a building during an earthquake or other dynamic events. It is an important parameter to consider in structural engineering, as excessive story drift can indicate potential damage or structural instability.

During an earthquake, the ground shakes and imparts forces on the building. These forces cause the building to vibrate and deform. The different levels or stories of the building may respond differently to these forces, resulting in differential displacements or drifts between them.

Excessive story drift can lead to several issues, such as:

1. Structural Damage: Excessive story drift can cause damage to structural elements, such as columns, beams, or connections, compromising the overall stability of the building.

2. Non-structural Damage: It can also result in damage to non-structural elements like partitions, ceilings, or utilities, affecting the functionality and safety of the building.

3. Occupant Comfort: Excessive story drift can cause discomfort for occupants, especially if the drift is noticeable or affects the functionality of the building. To mitigate story drift, engineers employ various design strategies, such as:

1. Stiffness and Strength: Designing the structure to have sufficient stiffness and strength to resist lateral forces and minimize drift.

2. Lateral Load-Resisting Systems: Implementing appropriate lateral load- resisting systems, such as shear walls, moment frames, or braced frames, to help distribute and resist the forces during an earthquake.

3. Damping Devices: Incorporating damping devices, like viscous dampers or tuned mass dampers, to dissipate energy and reduce the building's response to vibrations.

By considering story drift and implementing appropriate design measures, engineers aim to ensure the structural integrity, functionality, and safety of buildings during dynamic events like earthquakes.

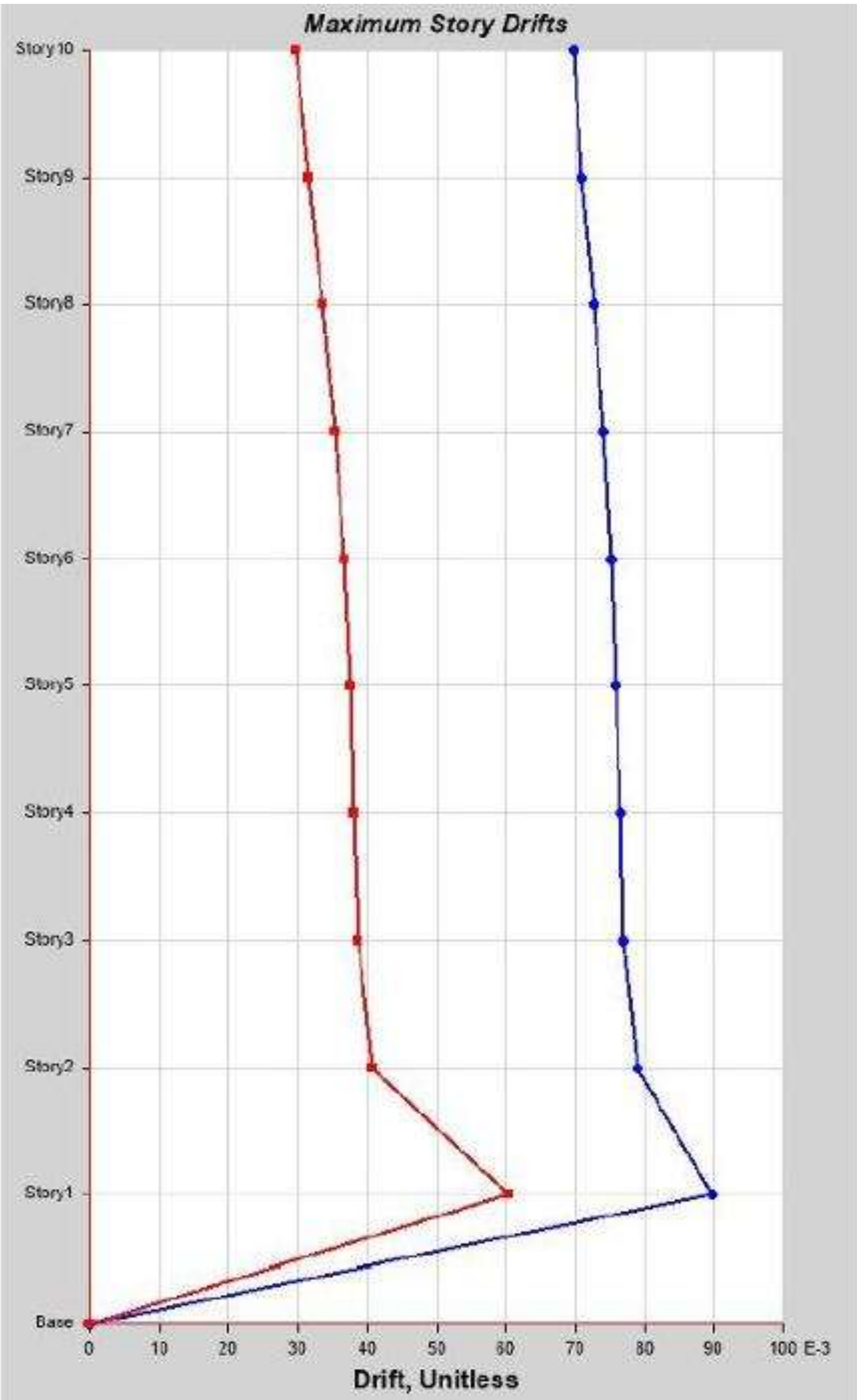

Fig 4.4: Result of Story Drift on soft strata for EQX and EQY

❖ **STORY DISPLACEMENT: -**

During an earthquake, story displacement refers to the relative movement or displacement between different levels or stories of a building. When the ground shakes, the forces transmitted to the building can cause each floor or story to move differently. This movement can result in the displacement of one story in relation to another.

Story displacement during an earthquake is a critical consideration in structural engineering. Excessive displacement can lead to structural damage, compromising the integrity and safety of the building. Engineers use various techniques to design structures that can withstand and minimize story displacement, such as incorporating strong lateral load-resisting systems, optimizing the stiffness of the structure, and implementing damping devices to absorb energy.

By carefully analysing and designing structures to mitigate story displacement, engineers aim to ensure the safety and resilience of buildings during seismic events.

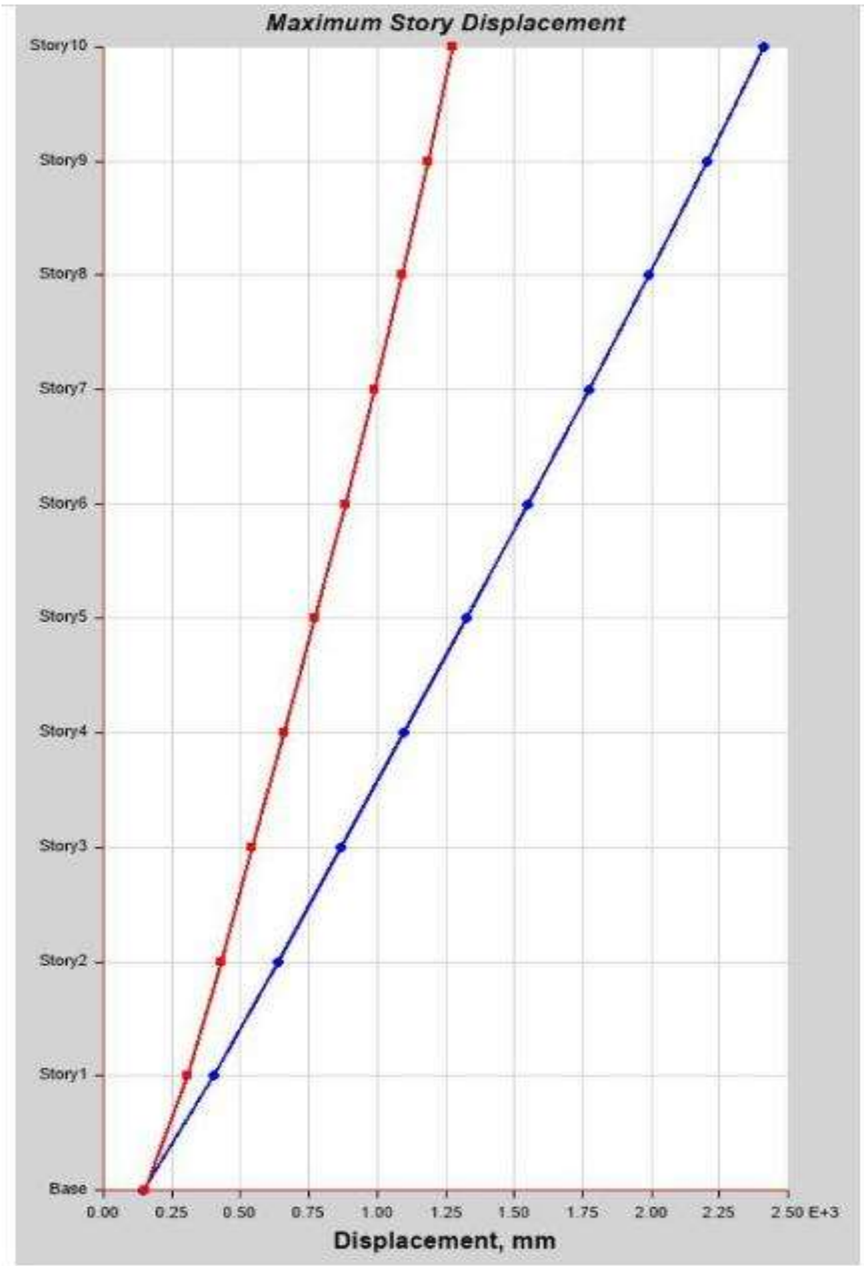

Fig 4.5: Result of Story Displacement on soft strata for EQX and EQY

❖ EARTHQUAKE ANALYSIS

When an earthquake strikes, it creates horizontal forces that shake building from side to side. Because buildings are made of concrete, which is strong but has little

flexibility, these forces can stretch the concrete and cause it to crack.

Table 4.2: Result of earthquake analysis of building on soft strata

Table Base Reaction							
Output Case	Case Type	FX	FY	FZ	MX	MY	MZ
		kN	kN	kN	kN-m	kN-m	kN-m
EQ-X	LinStatic	-11300.3408	-0.000001222	0	0.00002537	-261673.4664	197755.9639
EQ-X	LinStatic	-11300.3408	-0.000001222	0	0.00002537	-261673.4664	197755.9639
EQ-X	LinStatic	-11300.3408	-0.000001222	0	0.00002537	-261673.4664	197755.9639
EQ-Y	LinStatic	-6.945E-07	-11300.3408	0	261673.4664	-0.00001387	-113003.4079
EQ-Y	LinStatic	-6.945E-07	-11300.3408	0	261673.4664	-0.00001387	-113003.4079
EQ-Y	LinStatic	-6.945E-07	-11300.3408	0	261673.4664	-0.00001387	-113003.4079

Chapter 5

SEISMIC PERFORMANCE OF RC MID RISE BUILDING ON HARD STRATA

The seismic performance of a midrise building resting on hard strata is influenced by various theoretical principles related to soil-structure interaction and seismic engineering. Here are some key theoretical considerations:

Site Response Analysis: Site response analysis is crucial for understanding how the ground motion induced by seismic waves affects the building at a specific location. When a midrise building is situated on hard strata, the amplification of seismic waves is typically lower compared to softer soils. This is because hard strata tends to have higher shear wave velocities, which reduce the amplitude of ground motion.

Foundation Design: The foundation design of a building on hard strata is typically more straightforward compared to buildings on softer soils. Since hard strata provides a stable and uniform support, the foundation system can be designed to efficiently transfer seismic forces to the ground without excessive settlement or differential movement.

Dynamic Analysis: Dynamic analysis techniques, such as modal analysis and time-history analysis, are used to assess the response of the building to seismic excitation. Buildings on hard strata generally exhibit shorter natural periods of vibration compared to those on softer soils, which can influence the dynamic behavior and response to seismic loads.

Soil-Structure Interaction: Soil-structure interaction refers to the mutual influence a midrise building on hard strata, the interaction is typically characterized by a stiffer foundation response, which can reduce the lateral displacements and accelerations experienced by the structure.

Seismic Code Compliance: Designing a midrise building on hard strata still requires adherence to seismic design code sand standards. Even though the seismic risk may be lower compared to buildings on softer soils, it's essential to ensure that the structure is designed to with stand potential seismic forces as per the applicable building code sand regulations.

Overall, the theoretical understanding of soil-structure in teraction, foundation design principles, dynamic analysis techniques, and seismic code compliance in forms the assessment and design of midrise buildings resting on hard strata to ensure adequate seismic performance and resilience.

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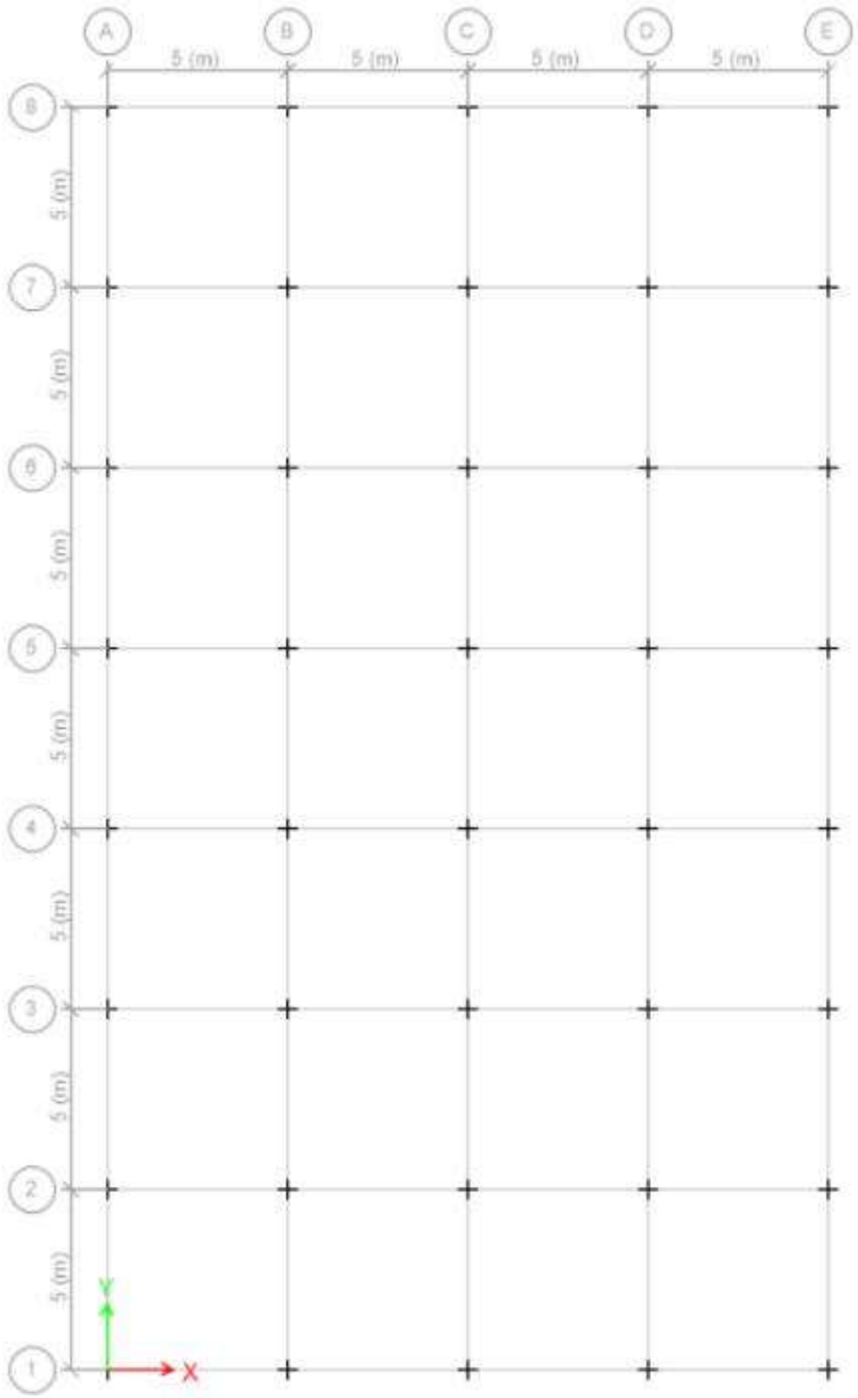

Fig 5.1: Plan of building resting on hard strata (with fixed support)

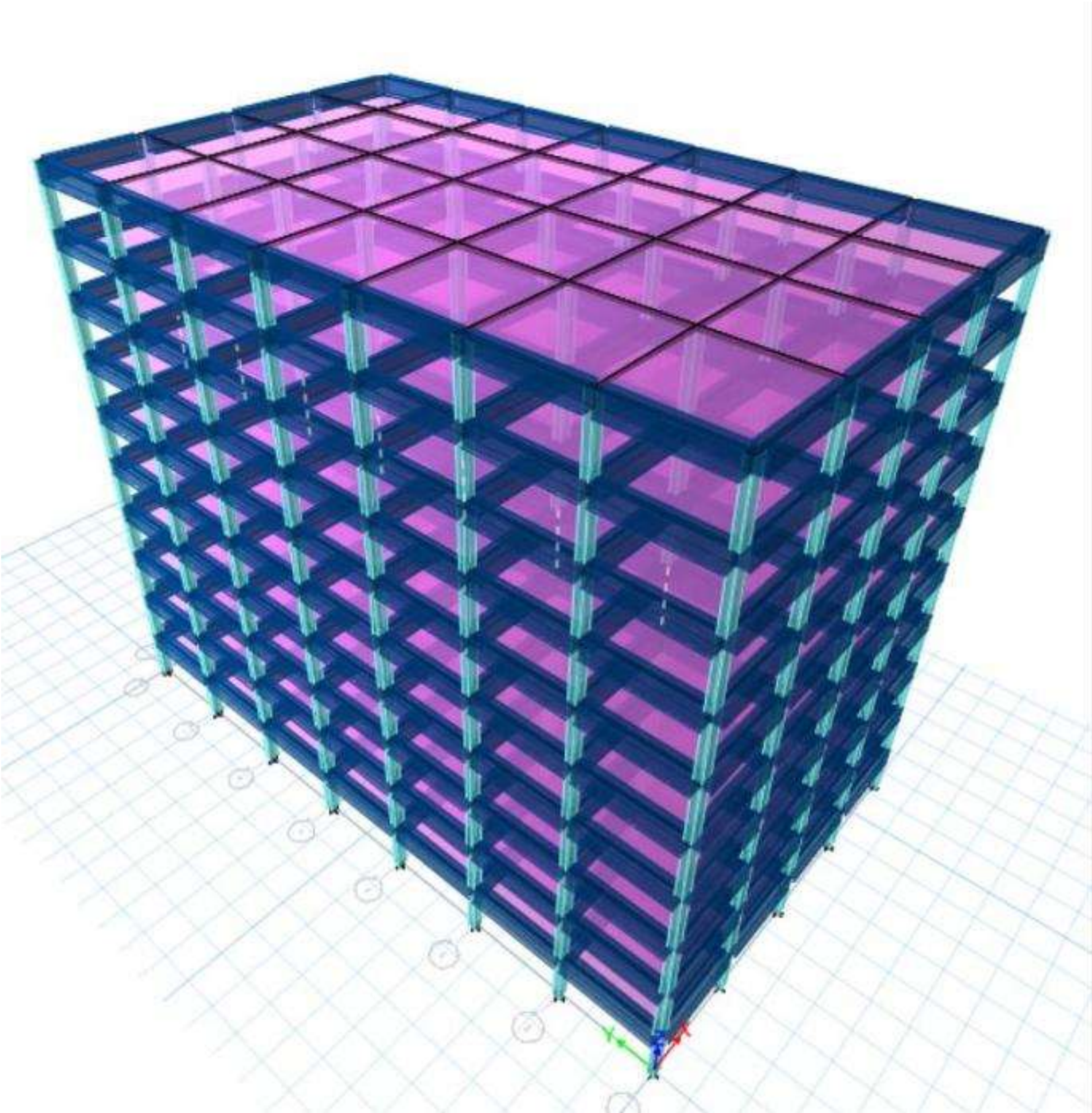

Fig 5.2: Etabs 3D model of hard strata (with fixed support)

❖ MODAL ANALYSIS

Table 5.1: Result of modal analysis of building on hard strata

TABLE: Modal Participating Mass Ratios							
Case	**Mode**	**Period**	**UX**	**UY**	**UZ**	**SumUX**	**SumUY**
sec							
Modal	1	3.595	0	0.8426	0	0	0.8426
Modal	2	2.343	0	0	0	0	0.8426
Modal	3	2.333	0.8268	0	0	0.8268	0.8426

Modal	4	1.208	0	0.0952	0	0.8268	0.9378
Modal	5	0.783	0	0	0	0.8268	0.9378
Modal	6	0.779	0.1052	0	0	0.932	0.9378

SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
0	0.1554	0	0	0.1554	0	0
0	0	0	0.8331	0.1554	0	0.8331
0	0	0.1731	0	0.1554	0.1731	0.8331
0	0.6549	0	0	0.8103	0.1731	0.8331
0	0	0	0.1004	0.8103	0.1731	0.9335
0	0	0.6228	0	0.8103	0.7958	0.9335

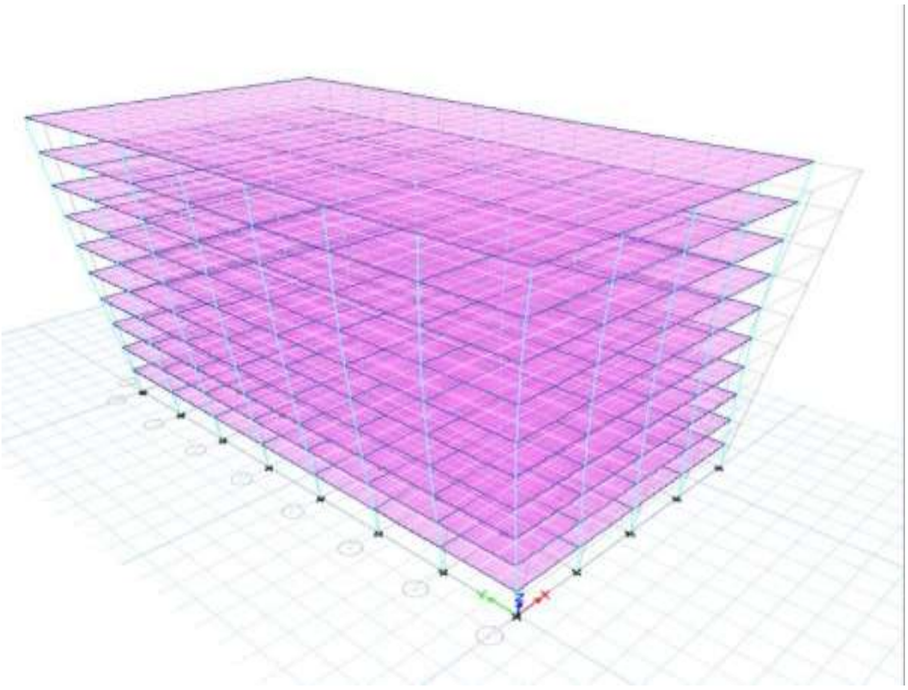

Fig 5.3: Etabs 3D model of modal analysis on hard strata (with fixed support)

❖ STORY DRIFT

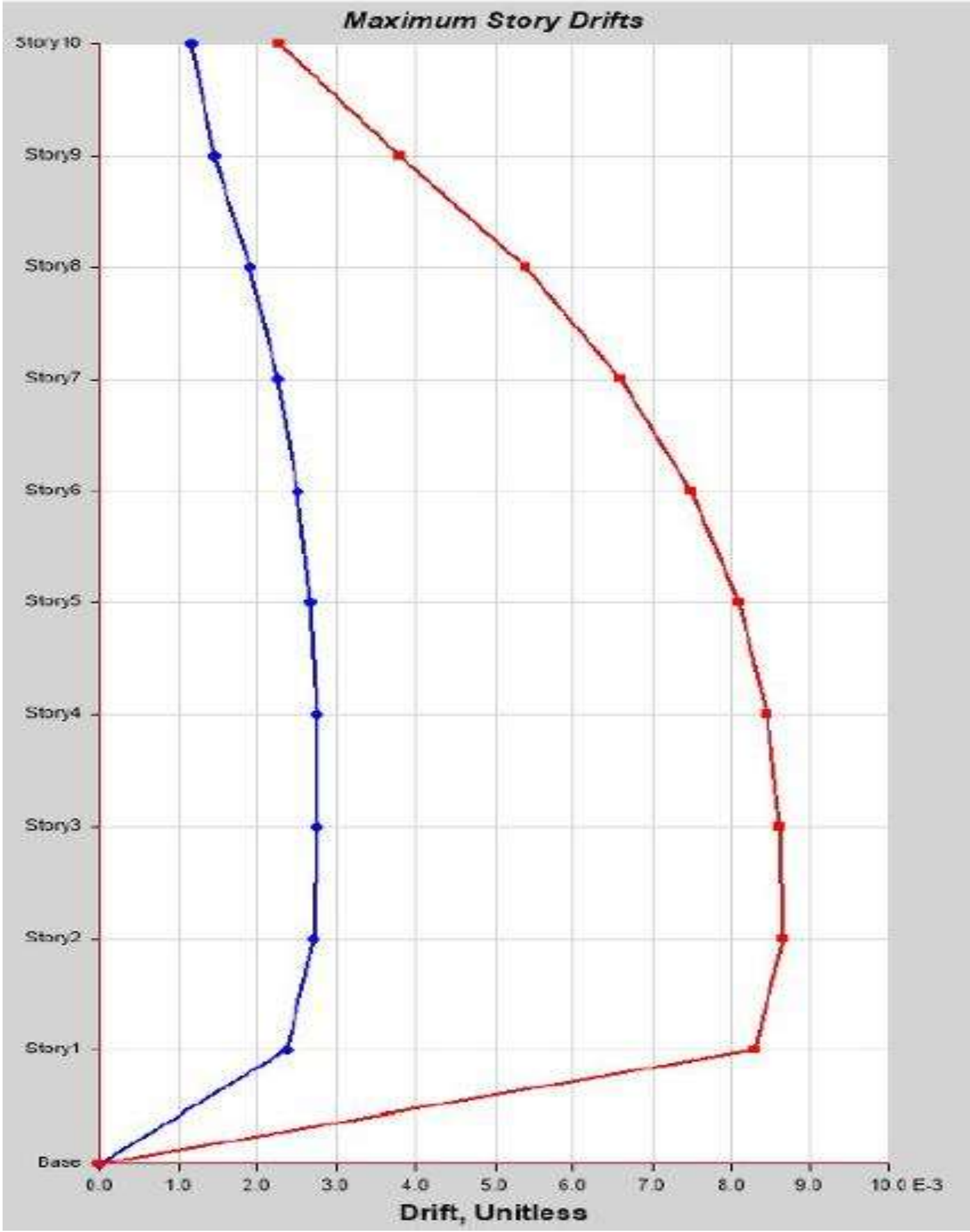

Fig 5.4: Result of Story Drift on hard strata for EQX and EQY

❖ **STORY DISPLACEMENT**

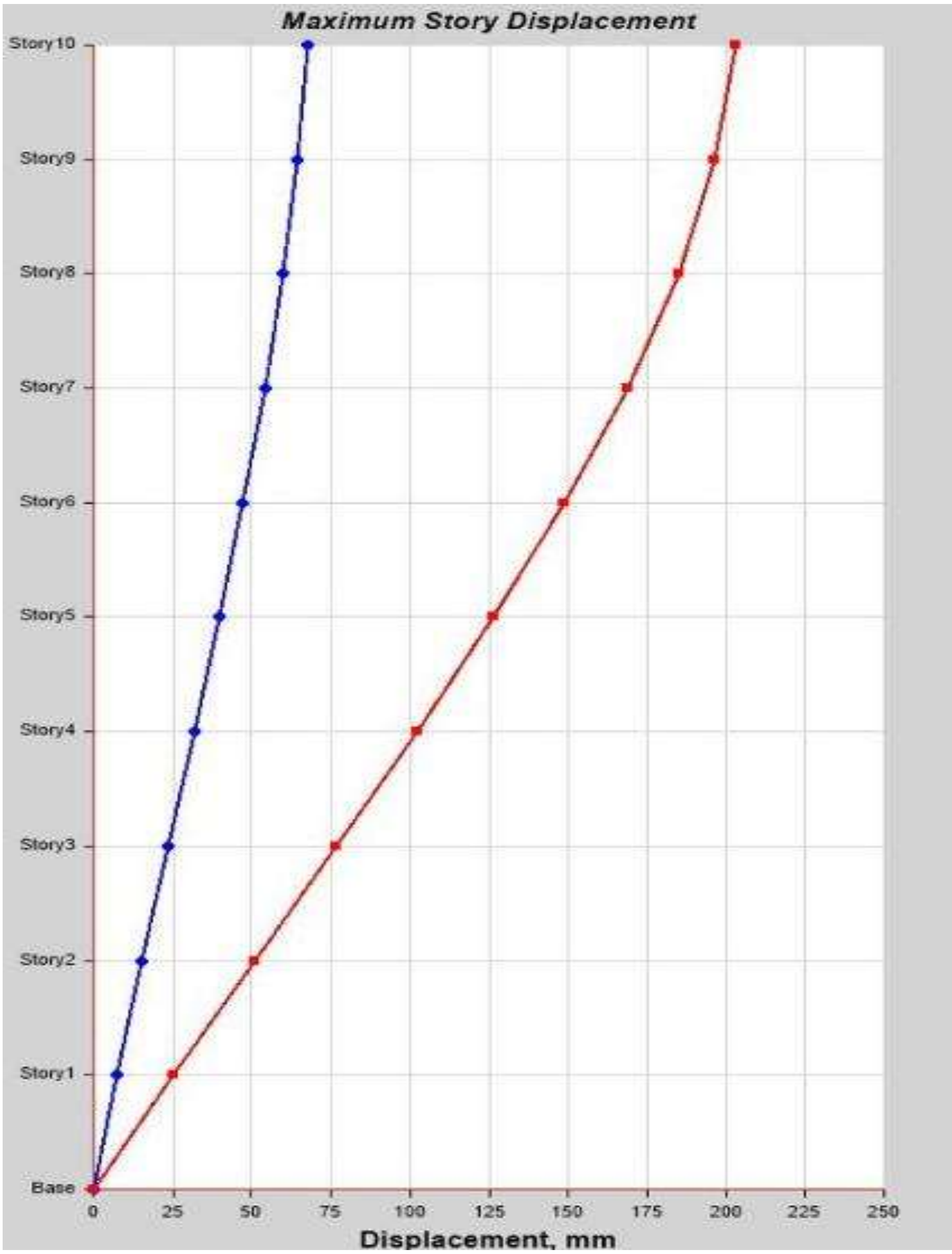

Fig 5.5: Result of Story Displacement on hard strata for EQX and EQY

❖ EARTHQUAKE ANALYSIS

Table 5.2: Result of earthquake analysis of building on hard strata

TABLE: Base Reactions					
Output Case	**Case Type**	**StepType**	**Step Number**	**FX**	**FY**
				kN	kN
EQ-X	LinStatic	StepBy Step	1	-10106.3321	0
EQ-X	LinStatic	StepBy Step	2	-10106.3321	0
EQ-X	LinStatic	StepBy Step	3	-10106.3321	0
EQ-Y	LinStatic	StepBy Step	1	0	-13364.2944
EQ-Y	LinStatic	StepBy Step	2	0	-13364.2944
EQ-Y	LinStatic	StepBy Step	3	0	-13364.2944

MX	**MY**	**MZ**
kN-m	kN-m	kN-m
7.452E-07	-230125.9278	176860.812
7.452E-07	-230125.9278	176860.812
7.452E-07	-230125.9278	176860.812
304311.2598	-0.000002307	-133642.9444
304311.2598	-0.000002307	-133642.9444
304311.2598	-0.000002307	-133642.9444

Chapter 6

RESULT DISCUSSION

❖ **Comparison between soft and hard strata**

	SOFTSTRATA			HARDSTRATA		
Time Period	11.1536509947387 SEC			3.59499458001202 SEC		
Modal Analysis (MODES)	1	0.8357	0	1	0	0.8426
	2	0	0.8858	2	0	0
	3	0	0	3	0.8268	0
	4	0.1586	0	4	0	0.0952
	5	0	0.1082	5	0	0
	6	0	0	6	0.1052	0
Earthquake Analysis		FX	FY		FX	FY
	EQX	-11300.3408	-0.000001222	EQX	-10106.3321	0
	EQX	-11300.3408	-0.000001222	EQX	-10106.3321	0
	EQX	-11300.3408	-0.000001222	EQX	-10106.3321	0
	EQX	-6.945E-07	-11300.3408	EQX	0	-13364.2944
	EQX	-6.945E-07	-11300.3408	EQX	0	-13364.2944
	EQX	-6.945E-07	-11300.3408	EQX	0	-13364.2944
Story drift	0.089			0.0086		
Story displacement	2412.67			203.09		

Chapter 7

CONCLUSION

In the present project report seismic design analysis of a symmetrical plan of RC midrise building is carried out. Multi storied building frames with fixed (Hard Strata) and spring (Soft Strata) base subjected to seismic forces were analysed and designed for different soil conditions. 10 storeys building model was analysed in the software ETABS with the configuration as shown above.

1. Base shear values increases when the type of soil changes from hard to soft for fixed and spring base buildings.

2. Earthquake analysis on soft strata having moment both direction for EQX and EQY (FX AND FY).

3. Earthquake analysis on hard strata having moment in one direction for EQX (FX) and for EQY (FY).

4. Storey drift values increases by 9.6% when the type of soil changes from hard to soft for fixed and spring base buildings.

5. Storey drift values of fixed base building were found to be lower as compared to spring base building.

6. Storey displacement values increases by 8.41% when the type of soil changes from hard to soft for fixed and spring base buildings.

7. Storey displacement values of fixed base building were found to be lower as compared to spring base building.

8. Hence suitable soil condition must be adopted along with the type of foundation while designing building for earthquake resistant.

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DEPARTMENT OF CIVIL ENGINEERING

SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE.

A SYNOPSIS

ON

SEISMIC PERFORMANCE OF R.C. MID-RISE BUILDING RESTING ON SOFT SOIL.

Submitted to

DEPARTMENT OF CIVIL ENGINEERING, SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE.

For Partial Fulfilment of

FINAL YEAR B. TECH CIVIL ENGINEERING

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2024-25

• **RELEVENCE**

This abstract provides a concise overview of the seismic performance considerations for reinforced concrete (RC) mid-rise buildings situated on soft soil. This study highlights the key factors and strategies essential for ensuring the safety and resilience of these buildings in earthquake-prone regions.

The seismic performance of RC mid-rise buildings on soft soil necessitates a comprehensive understanding of geotechnical conditions and their impact on structural integrity. Site-specific geotechnical investigations are crucial to assess soil properties, including shear strength, settlement characteristics, and liquefaction potential. The data obtained from these investigations inform foundation design and construction methods. the seismic performance of RC mid-rise buildings on soft soil requires a multi-faceted approach, encompassing geotechnical investigations, structural design, foundation engineering, compliance with codes, and dynamic analysis. Through a holistic understanding of these factors, engineers can ensure the safety and resilience of these structures in seismic-prone regions.

Earthquakes have the potential to cause the greatest damage, among the other natural hazards. Earthquakes may be the most fight flighty and high destructive of all the natural disasters. Structures are subjected to different earthquakes leading behaves differently with diversification in dense, medium, and soft and hard soil. Soil properties get affected drastically as seismic waves pass through a soil layer.

Soil liquefaction is a phenomenon in which saturated, or partially saturated soil temporarily loses its strength and stiffness, often due to the sudden application of stress, such as during an earthquake. This causes the soil to behave like a liquid, leading to potential ground instability and damage to structures built on or within the affected soil.

When a reinforced concrete (RC) mid-rise building is constructed on soft soil, it can have a significant impact on its seismic performance. Soft soil tends to amplify ground motion during an earthquake, which can lead to increased building vibrations and potential structural damage. To mitigate these effects, engineers use techniques like deep foundations, soil improvement methods, and base isolation systems. These measures help reduce the building's vulnerability to seismic forces. The project employs advanced computational analysis and experimental investigations to assess the structural behaviour and dynamic response of these buildings The study aims to provide Insights into how soft and hard Strata Influence the seismic vulnerability and resilience of RC Structures. Factors such as ground motion characteristics Soil Structures interaction, and structural design will be examined to better understand the performance disparities between these two strata types.

When a building is constructed on soft soil, it can experience more intense shaking during an earthquake. This can lead to increased stresses and deformations in the structure, potentially compromising its stability. To address this, engineers use various techniques like deep foundations, soil improvement methods, and flexible structural systems to enhance the building's seismic performance on soft soil. It's all about making sure the building can withstand and safely absorb the seismic forces.

Soft soil can have a significant impact during an earthquake. The soft soil tends to amplify the ground shaking, causing more intense vibrations and potentially increasing the risk of structural damage. Buildings resting on soft soil may experience greater settlement, lateral spreading, and soil liquefaction, which can lead to instability and structural failure. It's crucial to consider the soil conditions when designing and constructing buildings to ensure their resilience to seismic events. During an earthquake, soil liquefaction can occur in saturated or loose soil layers. The shaking from the earthquake causes an increase in pore water pressure within the soil, reducing its effective stress and causing it to lose strength. As a result, the soil behaves like a liquid, leading to ground settlement, lateral spreading, and potential damage to structures. It's important to consider soil liquefaction potential when designing buildings in areas prone to earthquakes and implement measures like ground improvement techniques or deep foundations to mitigate its effects.

1. In India, there have been instances of earthquakes where soil liquefaction has played a role. One notable example is the 2001 Bhuj earthquake in Gujarat. The seismic activity caused liquefaction in several areas, leading to widespread damage and loss of life. It serves as a reminder of the potential impact of soil liquefaction during earthquakes and the importance of considering soil conditions in building design and construction. 2. The 1993 Latur earthquake, also

known as the Killari earthquake, occurred in Maharashtra, India. It had a magnitude of 6.3 and struck the Latur and Osmanabad districts. The earthquake caused significant damage, resulting in the collapse of buildings and infrastructure. Many lives were lost, and the region faced extensive recovery efforts. It serves as a reminder of the importance of earthquake preparedness and safety measures.

4. The 1964 Niigata earthquake caused widespread liquefaction in Niigata, Japan which destroyed many buildings. Also, during the 1989 Loma Prieta, California earthquake, liquefaction of the soils and debris used to fill in a lagoon caused major subsidence, fracturing, and horizontal sliding of the ground surface in the Marina district in San Francisco.

• LITERATURE REVIEW

1. **B. Fatahi and S. Tabatabaiefar (2014): -** The frame sections are modelled and analysed, employing finite difference method adopting FLAC 2D software under two different boundary conditions: (i) fixed base (no Soil-Structure Interaction), and (ii) flexible base considering soil structure interaction. It is concluded that reduction of the Plasticity Index could noticeably amplify the effects of soil-structure interaction on the seismic response of mid-rise building frames.

2. **H. Tabatabaiefar and T. Clifton (2016): -**The current study carries out a comprehensive critical review on available and well-known research studies in the area of seismic behaviour of braced and unbraced building structures affected by soil- structure interaction (SSI). Based on the current review outcomes, it has become apparent that considering effects of SSI in seismic design of braced building structures is not necessary and assuming fixed-base structure is deemed to be conservative. However, SSI effects can amplify the lateral deflections and corresponding inter-storey drifts of unbraced building structures founding on soft grounds, forcing the structure to behave in the inelastic range, resulting in severe damage of the building structures. Consequently, seismic design procedure of unbraced building structures founding on soft soils without taking into account detrimental influences of SSI cannot adequately assure structural sufficiency and safety for the benefit of the community.

3. **M. Hoseny,et al. (2016): -** The seismic design of RC buildings requires determining the expected base shear, lateral drift at each story level and internal forces of the structural elements. In the analysis, it is common for the structural engineers to consider a fixed base structure which means that the foundations and the underlying soil are assumed to be infinitely rigid. This assumption is not proper since the underlying soil in the near field often consists of soft soil layers

that possess different properties and may behave nonlinearly leading to drastic variation of the seismic motion before hitting the structure foundation. In addition, the mutual interaction between the structure, its foundation and the underlying soil during the vibrations can substantially alter the structure response. This response variation depends on the structure characteristics, the soil properties and the nature of the seismic excitation. Consequently, an accurate assessment of inertial forces and displacements in structures requires a rational treatment of soil structure interaction (SSI) effects.

4. **B. Santhosh Kumar(2017): -** In this study, different soil strata, with rigid and flexible base foundation types are illustrated and corresponding base shear and lateral displacement are determined with variation in floors as G+7, G+8 and G+9 for Earthquake Zones 3, 4 and 5. IS 1893: 2002 "Criteria for Earthquake Resistant Design of Structures" gives response spectrum for different types of soil such as hard, medium, and soft. The building is modelled using ETABS - 2015 having different Winkler's springs as its foundation corresponding to different soil properties. To find out seismic performance of rigid and flexible to RCC building, parameters as Lateral displacement, Storey shear and Storey drift should be studied. It was found that by comparing the flexible base results with fixed base results, flexible base structure shows better seismic performance in all soil conditions.

5. **M. Bagheri, S. ASCE, et al. (2018): -** A series of numerical simulations were carried out on two types of superstructures and six types of piled raft foundations to investigate the effects of seismic soil–pile–structure interaction (SSPSI) on the seismic responses of the superstructures. In this research, the effectiveness of a piled raft application was assessed; the pile optimum numbers, locations, and configurations were estimated; and finally, a comparison was made between the nonlinear structural responses of the obtained two-dimensional (2D) and three-dimensional (3D) models. Parametric studies were conducted to achieve strategies for optimized designs of piled raft foundations subjected to the low-to-high intensities of real earthquake records as the input motions.

6. **A. Suryawanshi and V.Bogar (2019): -**RCC structures had been used along with and without soil structure interaction on sloping ground to compare the displacement, story shear, story drift and base shear of buildings. RCC structures are commonly used on plain ground without SSI (soil structure interaction). The above parameters are evaluated for buildings with and without soil structure interaction in buildings on sloping ground. The performances of structures have been evaluated using response spectrum analysis. To achieve this objective; G+19 structures with and without soil structure interaction are carried out in ETABS 2016, and from the obtained results, the values of parameters such as displacement, story drift, story shear, base shear are compared. 7. **Ibrahim Oz, S. Senel, et al. (2020): -** Different soil conditions classified according to shear wave velocities were reflected by using substructure method. Inelastic deformation demands were obtained by using nonlinear time history analysis and 20 real acceleration records selected from major earthquakes were used. The results have shown that soil-structure interaction, especially in soft soil cases, significantly affects the seismic response of old buildings. The most significant increase in drift demands occurred in first stories and the results corresponding to fixed base, stiff and moderate cases are closer to each other with respect to soft soil cases. Distribution of results has indicated that effect of soil-structure interaction on the seismic performance of new buildings is limited with respect to old buildings.

8. **F. Wani, et al. (2022): -** During severe seismic events, the dynamic response of the structure is affected not only by the behavior of the superstructure but also by the nature and behavior of the soil present in and around the substructure. The conventional structural design process usually assumes the base of the foundation to be completely restrained, i.e., in a fixed condition. However, this assumption is inaccurate as it neglects the effect of flexibility offered by the interaction of the soil with the structure. There is no clear consensus on either the beneficial or detrimental effects of soil- structure interaction (SSI) on the seismic response of structures. The main objective of this paper is to study the effect of SSI on a multi-story (G þ 10) building resting on a mat foundation. The building is modeled using Finite Element Method (FEM) software and SSI is incorporated using Winkler's (un-coupled) and pseudo-coupled approaches. A case study is done to understand the non-linear dynamic response of building with different soil bearing capacities. The results are represented in terms of fundamental period, base shear, and story drift.

• OBJECTIVES OF PROPOSED WORK

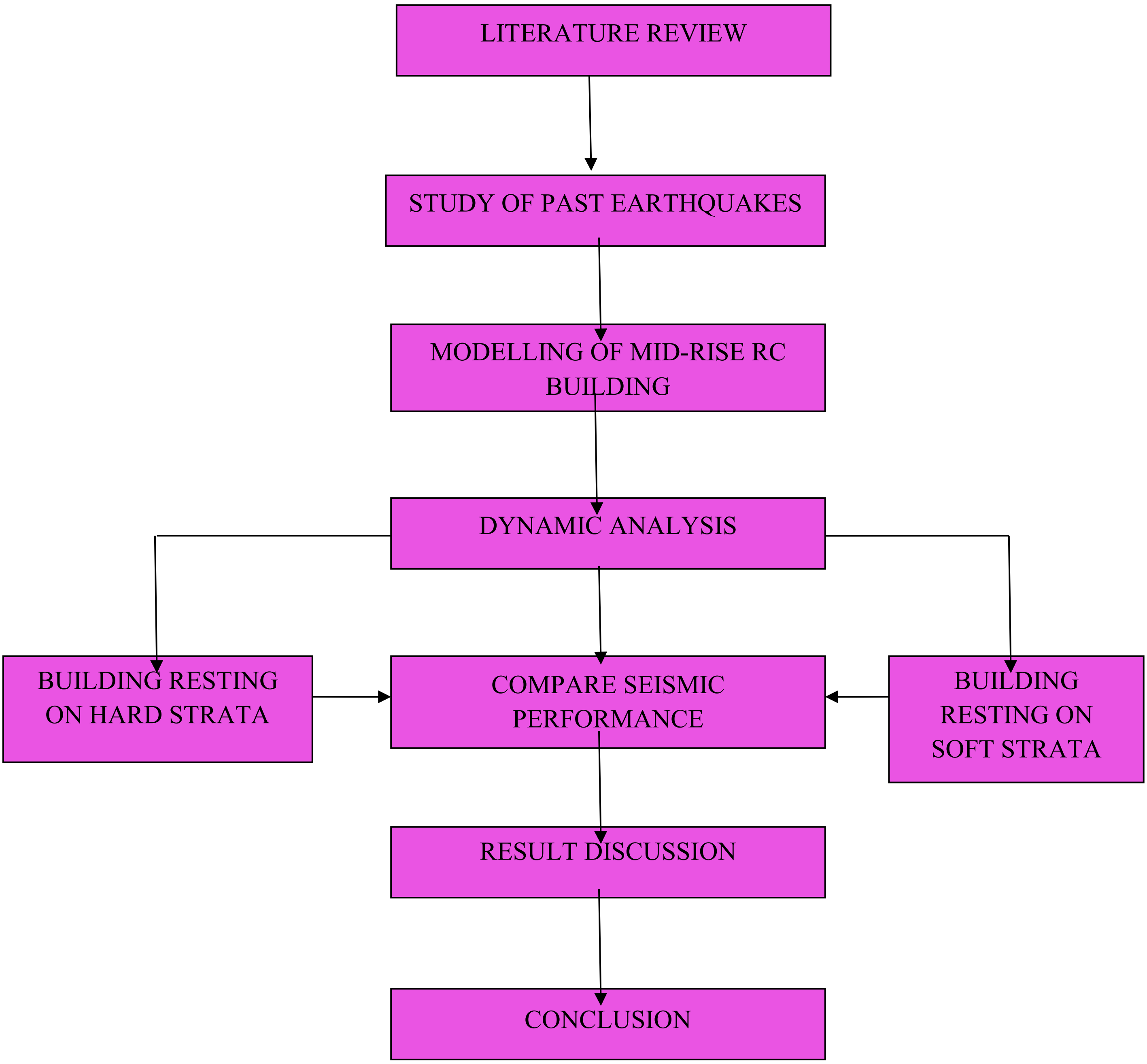
1. To compare dynamic properties of the structure resting on hard/soft strata. 2. To compare element forces in the structure resting on hard/soft strata. 3. To investigate globe response of the structure on hard/ soft strata.

• SCOPE OF WORK

1.The Study is for mid-rise RC building.

2.The study is for a symmetric building (Plan, Area & Stiffness regular building)

METHODOLOGY



• TENTATIVE CHAPTER SCHEME

Chapter No.	Chapter Name
1	Relevance
2	Review of the relevant literature
3	Objectives, Scope
4	Methodology
5	Results and Discussion
6	Conclusions.
7	Appendix
8	References

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