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# "SEISMIC RESPONSE OF MULTI SKYSCRAPER ON A COMMON PODIUM"

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**Abstract:** A building type called a podium building, often referred to as pedestal or platform structure, is defined by horizontal partitions separating an upper tower from a lower "podium." Typically, a steel or concrete podium carries the top stories ofently made of wooden frames. The podium building configurations normally consists of 4 to 5 stories which are mostly meant for residential purposes and towers above the podium utilized for commercial and retail purposes. The project considers the seismic behaviour of podium building in varying seismic zones at different soil conditions to study how the podium construction responses in different seismic parameters and to what extent does the podium building provides structural safety against horizontal loads. The result shows that podium building on zone II on medium soil meets all the safety standards and outperforms among all the seismic zones which are II, III, IV and V on both medium and soft soils and is unarguably the most efficient podium building.
Keywords: Seismic zone, Soil types, Equivalent static method, displacement, drift, Base shear.

## Introduction:

A podium structure represents a construction approach comprising a lower section constructed from either concrete or steel, and an upper portion fashioned from lighter materials like wood. Typically, the lower section, referred to as the 'podium,' accommodates facilities such as parking, retail spaces, or commercial establishments, while the upper part, known as the 'tower,' typically houses residential units. These podium buildings are particularly favored in densely populated urban areas characterized by limited and costly real estate, as they facilitate higher population density and reduced construction expenses compared to conventional edifices.

Podium constructions come with distinct technical complexities and unique considerations that architects and developers must take into account. For instance, ensuring stability and safety during the transition from the podium to the tower necessitates meticulous structural design and detailing. Furthermore, variations in framing systems, such as platform or balloon framing, between the podium and tower sections affect load distribution and fire protection. Additionally, the podium may exhibit distinct architectural styles and functions when compared to the tower, necessitating a harmonious coordination and integration process.

Fig 1.1 Ellesemere Tower,Toronto

Fig 1.2 Burj View Towers,Dubai

These podium structures represent an innovative and efficient approach to developing mixed- use projects tailored to the demands of urban living. They offer a multitude of advantages over conventional buildings, including cost-effectiveness, accelerated construction timelines, design adaptability, and environmental sustainability. Additionally, podium structures contribute to the aesthetic appeal of urban landscapes, enriching them with diversity and character.

The primary objective of studying the seismic response of multi-skyscrapers on a common podium is to assess the structural behaviour and integrity of such interconnected buildings during seismic events, which are inherent risks in many regions worldwide. Earthquakes can exert tremendous forces on tall structures, and understanding how these forces propagate through a system of interconnected towers and a common base is critical for ensuring the safety and resilience of these developments.

This study delves into the intricate dynamics of multi-skyscraper complexes, focusing on their collective response to seismic forces. It investigates how seismic energy is transmitted through the podium and distributed among the towers, impacting their stability and safety. Additionally, it explores the design, engineering, and architectural considerations that must be carefully addressed to mitigate seismic risks in these complex structures.

**LITERATURE REVIEW:**

**2.1 Hardhik B. Rangaani and Dr. Vinubai R.Patel (2022)** studied on “The backstay effect's benefits in IS 16700:2017's design of a podium for tall buildings” This study focuses on how a podium structure affects the contact level under earthquake stress comprised of one tower joined by a common platform. To do this, the ETABs create a simulation model with adjustable podium and tower heights, Comparable- static and response-spectrum testing methods are then used to test the model. This investigation assessed the impact on the displacement at the top of the tower. The study utilized equivalient-statics and response-specturum analysis method to observe behavior of podium building.

**Conclusions are:**

1. When comparison with high buildings, the benefits of the backstays diaphragm for short rise structures were not as substantial due to the stiffness of the building.
2. Base shear increases proportionally as a result of the backstay diaphragm's effect on increasing mass.

**2.2 Haotian Zhang , Fuju Li ,Ji Tai , and Jun Zhou (2021)** studied on“An Isolated High-Rised Building in a Highly Dense Area: Expanded Base and Multiple Tower Layer Structural Design” The purpose of this study is to better understand how tall buildings with many tower layers and enlarged bases can improve their seismic performance by implementing interlayer spacing technology in high-intensity zones. After a comprehensive comparison and analysis of structural designs for these kinds of structures, the study selects a seismic isolation scheme and evaluates its performance in terms of seismic response. The results indicate that the application of seismic isolation method significantly enhances the seismic safety of a structure by effectively minimizing its response to seismic forces. For enlarged base multiple tower-layer structures, using the story isolation technique in high-intensity locations makes the most sense given the project's structural features, economic considerations, and building quality enhancement.. In addition, important technical details such as combined seismeic isolation method for larger base storey isolation techniques and other factors such isolator bending moments and tensile device concerns are covered in the study. These results can be quite helpful as pointers for related technical projects.

**Conclusions can be given as**

1. The implementation of isolation technology in high-rise buildings featuring enlarged bases and multiple towers within high-intensity seismic areas significantly reduces seismic response. This proves to be an effective method for enhancing the structural safety against seismic events.
2. Taking into consideration the project's structural attributes, economic factors, and the overall quality of the building, the preferred approach is to incorporate interlayer isolation

technology in the multi-tower structures with expanded bases situated in high- intensity seismic zones.

**2.3 Tejas R. Chaudhari1 & Akash V. Modi (2019)** studied on “Podium Structure Seismic Analysis Taking Bi-Directional Earthquake Force into Account” This study focuses on addressing the pressing issue of space constraints in urban areas, which often leads to the overcrowding of structures, posing significant risks during lateral forces such as earthquakes. To enhance the seismic safety of podium-style structures, it is imperative to conduct seismic analyses for designing earthquake-resistant buildings. The research specifically investigates a 15-story podium-style building situated in seismic zones II, III, IV,& V. Various earthquake time histories, applied at different angles (e.g.,10°, 20°, 30°, 40°), are considered, and the most severe scenarios are thoroughly examined. The study also involves a comparison of different shapes for podium-style buildings. To conduct this analysis, time histories from various locations in India, including Bhuj, Chamoli, and Uttarkashi, are utilized. Structural software, namely SAP 2000, is employed for building analysis, encompassing both Response -Spectrum - analysis and time history techniques. It's important to note that this research adheres to the guidelines and a standard outlined in the Indian standard code IS: 1893-2016.

**Conclusions can be given as**

1. The static method yields nearly identical base shear values across all building configurations.
2. In the static method, the displacement measured at the top node remains consistent for all building configurations.
3. When using the response-spectrum-method, there is a variation of 5% to 10% in both base shear and roof displacement.

**2.4 Wensheng LU And Xilin LU** studied on “Test and Analysis of a Seismic Model for a Multi-Tower High-Rise Structure” The results of experiments employing a shaking table on scaled models of multi-tower high-rise buildings are presented in this article. It emphasizes that when studying multi-tower complexes, it is inappropriate to assume rigid floors. Alternatively, a novel analytical model that considers the influence of flexible transfer floors is proposed. The study contrasts the experimental findings with the theoretical predictions of dynamic behavior. It also explores how the stiffness of the foundation affects the overall structural dynamic behavior and looks at the impact of conjunction floors linking the towers at higher levels.

**Conclusions can be given as:**

1. Multi-tower high-rise buildings exhibit distinct dynamic behaviors compared to traditional high-rise structures. This is primarily due to the uneven sharing of the floor mass and abrupt changes in lateral stiffnes at various levels, leading to the dominance of higher-order vibration modes. Additionally, structural elements near these areas are vulnerable to earthquake-induced damage.
2. Door-like building configurations typically have weak earthquake resistance. This is explained by the inflexible and weighty junction block at peak(top) of structure, which increase towers' dynameic response to earthquakes.

**2.5 Cem TURA, Kutay ORAKCAL (2019)** studied on “Analysis of Earthquake Response for Several Towers on a Single Podium” This study aims on the finding of a theoretical tall building structure comprising two towers connected by a shared podium. It investigates the influence of interaction of towers with one another mainly since there are connected podium levels. The study incorporates these interaction effects at the podium level using two approaches: one that assumes upper bound conditions and another that assumes lower bound conditions. These criteria are met by imposing either fixedd or unrestricted end restaraints at the continues boundaries of individual tower-models, respectively. And the outcomes derived from the isolated tower models are contrasted with those of the integrated model, incorporating both towers along with the shared podium and basements are compared in order to evaluate the consequences of these interaction effects. The findings, derived from a variety of linear and nonlinear analytic techniques, show that, while the degree of overestimation is contained within reasonable ranges, single tower models with fixed end restraints have a tendency to overestimate the internal forces encountered at the podium floors.

**Conclusions can be given as:**

When a design-level earthquake (DD2) was applied to both double(two) tower and (isolated)single - fixed tower models, then results of linear elastic analysis methods (RSA and LMTHA) were compared. It was discovered that at the interconnected podium levels, RSA produces diaphragm tensile force outcomes that are only slightly larger than those of LMTHA. Even though the diaphragm shear forces in the double model are quite moderate, this difference rises to 25%.

**2.6 Geetha, Kiran Kamath (2019)** studied on " The Seismic Performance of a Tall, Multistory Building Joined by an extensive Podium" This study focuses on analyzing how seismic stresses affect a single-tower construction connected to a shared platform at the contact level. To do this, ETABS was used to build a simulation model, which was then examined using equivalent-static and response-spectrum approaches while changing the podiums height and tower height. The study primarily looks at how, while using these two analysis methodologies, the podium structure's presence affects the tower's top displacement. The study also explores the backstay force that develop due to the lateral forces gets transferred from the tower structure tothe podium at interfaces in order to balance off lateral overturning pressures.

The study also notices how the podium construction negatively affects how shear pressures are distributed at and above the structural wall's interface level. The difference in displacements between the structural walls is also additionally due to the tower's positioning on the podium construction.

**Conclusions can be given as:**

In a single tower-podium layout, raising the podium's height causes the structure's top displacement to rise. The top displacements does, however, start to drop at a specific increase in podium's height in response-spectrum-analysis, and it then stays constant independent of additional podium height increases after that point.

The presence of the podium structure produces backstay forces at the contact between the podium and tower. The magnitudes of these backstays force at the podium tower interface are seen to raise as number of podium storeys increases.

**2.7 Seung Young Jonga, Thomas H-K Kag a, Jeng Kaun Yonb (2020)** studied "Seismeic performance evaluation of tall buildings" The evaluation ofthe seismic performance of structures with deep basements is the main focus of this study. Maximum(highest) Considerd Earthquake (MCE) and Recorded Earth quake (RE) ground motions are also used in the evaluation. The treatment of basements, hysteresis modeling, and damping are just a few of the practical modeling issues covered in the paper. The study looks into how the building's seismic performance is affected by various modeling factors.

**Conclusions can be given as:**

It is necessary to use suitable hysteretic modeling for coupling beams in tall buildings since they are more vulnerable to seismic stresses. It is advised that for traditionally reinforced coupling beams, the pivot hysteresis model be used with predetermined parameter values in order to account for the pinching effect.

**2.8 Nirav Bhatu, Vishal B. Patel, Pratiti M. Bhatt (2022)** Studied on "Backstays Effect on TallStructures with Podium" This research seeks to investigate modeling approaches for structures featuring multiple towers sharing a unified podium. A primary objective is to comprehend the dynamic behavior of these multi-tower structures under horizontal forces, incorporating the backstays effect as per IS:16700 (2017). The study involves creating diverse models with variations in podiums heights and n.o of towers. Additionally, it includes comprative analysis in between the singly tower having podiums and multiple tower sharing a unified-podium. Factors such as the presence of shear walls at the podium's perimeter, variations in podiums storey, and total number of

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towers are considered. This research employs both equivalient-static-techniqes and response-spectrum approach, utilizing ETABS software for analysis.

**Conclusions can be given as:**

In the Tower-Podium configuration, increasing the podium's height causes the structure's top-storey displacement to increase at both X& Y-directions.

The comparison of numerous towers sharing a similar podium with and without a shear wall at podium's periphery shows a relatively small difference in the reversal of shear, usually between 3 and 6%.

## OBJECTIVES & SCOPE OF WORK:

### 3.1 Objectives:

1. To analyse the seismic behaviour of G+13 buildings on a common podium.
2. The structure is analysed by utilising multiple towers with a common podium incorporating an entire structure.
3. To analyse the podium building on different soil conditions such as soft soil and medium soil.
4. To study the podium structure into different seismic zones such as zone II, III, IV, &, V.
5. For studying seismic aspects like the base-shears, storey- displacements, & storey- drifts by using equivalent-static-analysis.
6. To obtain and compare results between different soil condition and different seismic zones and bring an outcome as which soil condition and seismic zones is efficient for the optimum podium building structure.

### 3.2 Scope of the Project Work:

In this study, linear models of podium building construction featuring two tower's on a shared podium were developed. The structural analysis involved the examination of a double-tower model. The combined structure, comprising the double tower and the shared podium, forms an integrated podium building structural system. The analysis is conducted across various soil conditions to explore the interactions in between soil and the structures. To study efficiency of the podium building, high seismic zones such as Zone II-V were considered. The combination of these seismic zones with different soil types resulted in a total of 8 models for comprehensive study. The seismic analytical method adopted is equivalent static method.

## METHODOLOGY:

In this study the seismic response of the multiple tall buildings of G+10 stories is constructed on a common podium of 3 stories is analysed combining to form a G+13 story structure building. Total height of the buildings is 47.5m including the heights of the base. Each storey height is 3.5m whereas the height of the base storey is 2m. The buildings are analysed on different soil conditions such as soft and medium soils at different seismic zones i.e., zone II, III, IV,&, V. Total number of 8 models are considered for the analysis on different soil and zones. 4 models are analysed on seismic zones II,III,IV&V on medium soil and 4 models are analysed on seismic zones II,III,IV& V on soft soil. Calculation of Dead load for different members using IS:875(Part I) Calculation of Live-loads using IS : 875 (Part II) Calculation of seismic-loads using IS: 1893-2016. The analysing software utilized is Etabs (2020). The method adopted for the analysis is equivalent static method.

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**4.1 PRELIMINARY DATA:**

| | |
|---|---|
| Number of stories | G+13 (including podium) |
| Overall height of the building | 47.5m |
| Height of each storeys | 3.5m |
| Building type | commercial building |
| Live load | 3kN/ m3 |
| Column size | 600x600mm |
| Beams size | 230x450mm |
| Thickness of slab | 150mm |
| Grade of the concrete | M25 |
| The Grade of steel | HYSD 550 |
| Unit weight of PCC | 24 KN/m3 |
| Unit weight of brick walls | 20 |
| The Unit weight of RCC | 25 |
| Modulus of elasticity for brick wall | 11.5 KN/m2 |
| Modulus of elasticity for steel | 2 x $10^{11}$ N/m |
| Seismic zones | II,III,IV& V |
| Soil type(site type) | Medium and Soft |
| Importance factor | 1.2 |
| Response -reduction- factor | 5 |
| Seismic parameters considered | Base-shear , storey-displacements and the storey-drifts |

Analysis results such as Base shear, story displacements, and storey drifts are evaluated and compared on basis of different soil conditions and different seismic zones to obtain an outcome which would determine the most efficient podium building.

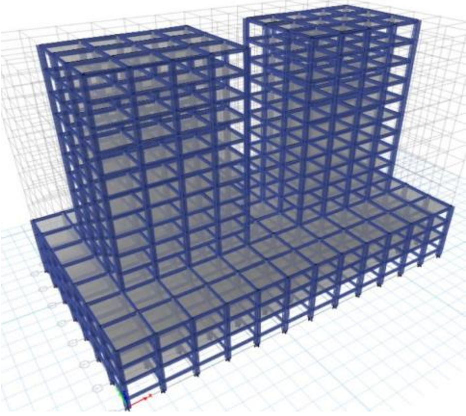
**4.2 MODELLING AND ANALYSIS:**

G+13 Podium building of plan size 60m X 35m and height 47.5m including podium structure and base storey, while the multi skyscraper plan size happens to be 20m x 15m of each tower.

The columns size is 600 X 600mm and the span between these columns is 5m c/c in both X & Y-direction.

The beam size is 230 X 450mm. The slab thickness is 150mm and the wall thickness is 230mm. The clear cover for beams is 40mm. Wall load = 12.63 KN/m. Floor-finish = 1 KN/$m^2$. Live-load = 3KN/$m^2$.

**Modelling and analysis of Podium Building on Medium Soil and soft soil:**



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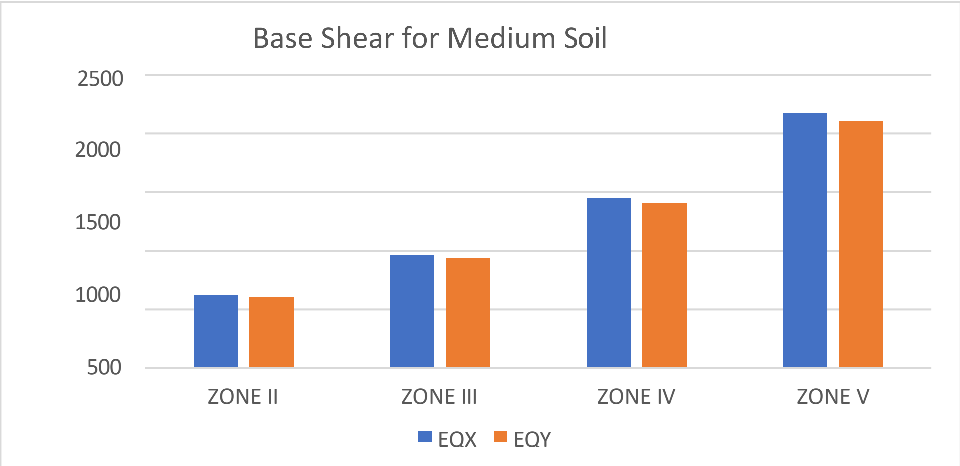
**RESULTS AND DISCUSSION:**

**5.1 Equivalent Static Analysis:** Equivalent static analysis, also known as simplified seismic analysis or static equivalent method, is a common approach in earthquake engineering used to estimate the response of a structure to seismic forces without explicitly considering the dynamic characteristics of the earthquake. Instead of analyzing the structure's response to the actual ground motion time history, equivalent static analysis simplify the process by using a singly-static-forces, known as equivalent static lateral load or lateral force, to represent the effects of the earthquake.

**5.2 Base shear:** Base shear is a fundamental concept in structural engineering and earthquake engineering. It represents the total lateral force or shear force that a building or structure experiences at its base during an earthquake or other lateral load conditions. Base shear is a critical parameter used into the design of structures to ensure they can withstand the forces generated by seismic activity or wind loads.

Table-1: Base Shear of Podium Building in Medium Soil

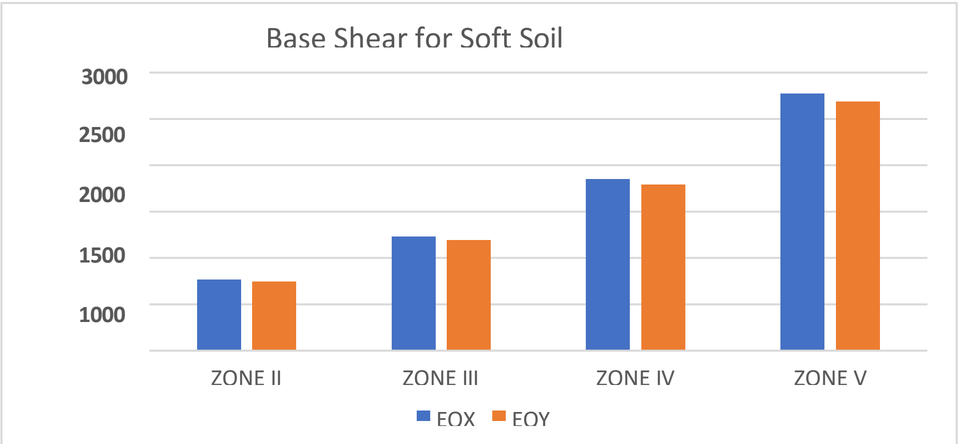
| **BASESHEAR** | **ZONEII** | **ZONEIII** | **ZONEIV** | **ZONEV** |
|---|---|---|---|---|
| EQX (KN) | 626.9745 | 964.6327 | 1446.949 | 2170.424 |
| EQY (KN) | 608.0437 | 935.4242 | 1402.834 | 2104.252 |




Graph 5.1 Tabular Chart of Base Shear of Podium Building In Medium Soil

Table-2: Base Shear of Podium Building In Soft Soil

| **BASESHEAR** | **ZONEII** | **ZONEIII** | **ZONEIV** | **ZONEV** |
|---|---|---|---|---|
| EQX(KN) | 769.8878 | 1231.82 | 1847.731 | 2771.596 |
| EQY(KN) | 746.6419 | 1194.627 | 1791.941 | 2687.911 |




Graph 5.2 Tabular Chart of the Base Shear Of Podium Building In Soft Soil

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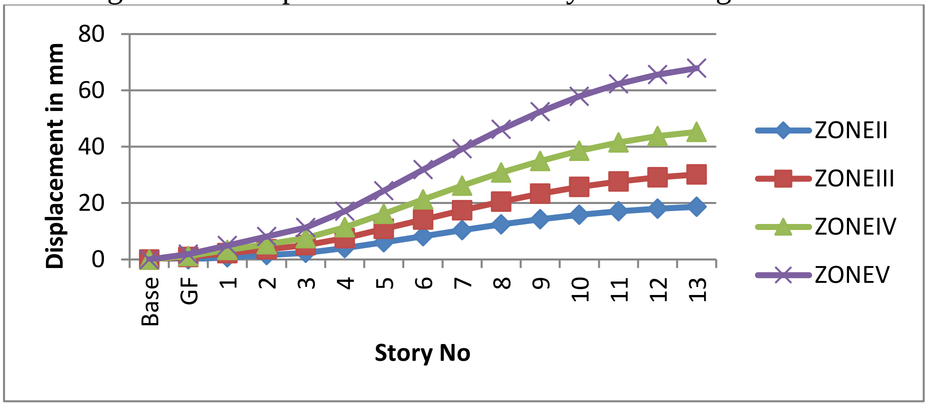
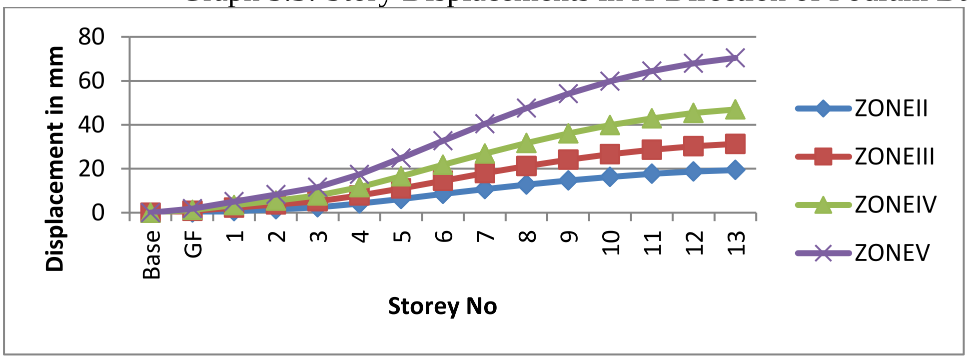
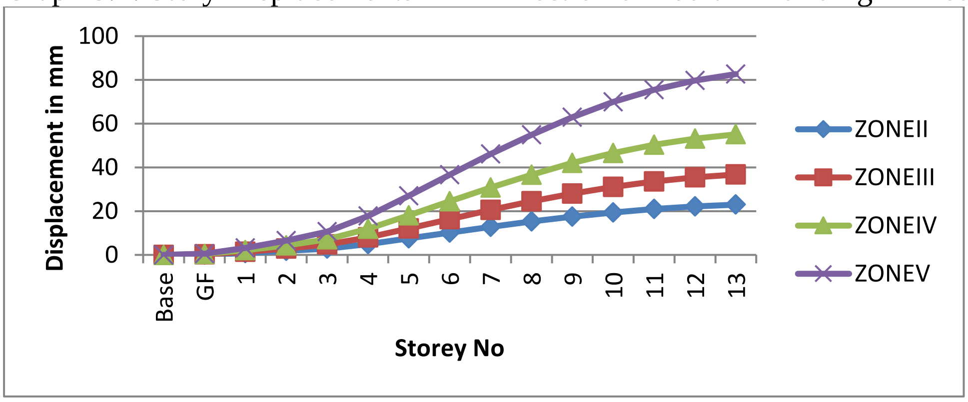
**5.3 Storey Displacement:** "Storey displacement" typically refers to the vertical displacement or movement of a building's storeys or floors during an earthquake or other ground-shaking event. It is an important parameter in structural engineering and earthquake engineering, particularly in assessing the seismic performance and safety of buildings and structures.



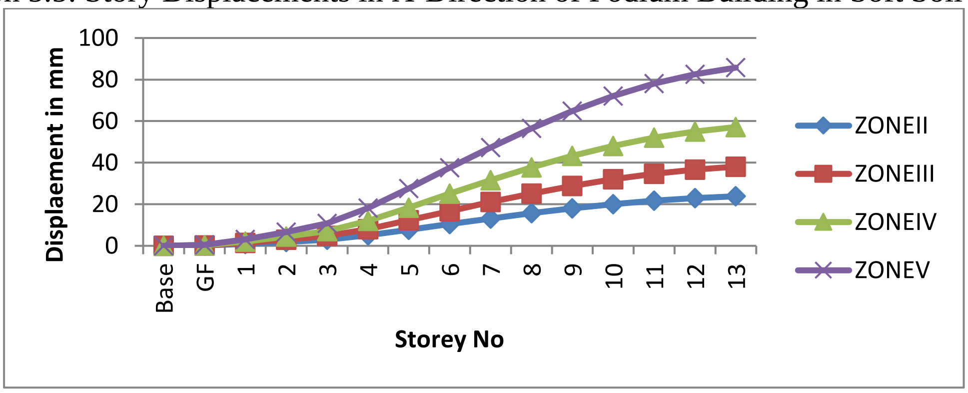

Graph 5.3: Story Displacements in X-Direction of Podium Building in Medium Soil




Graph 5.4: Story Displacements in Y-Direction of Podium Building in Medium Soil




Graph 5.5: Story Displacements in X-Direction of Podium Building in Soft Soil




Graph 5.6: Story Displacements in Y-Direction of Podium Building in Soft Soil

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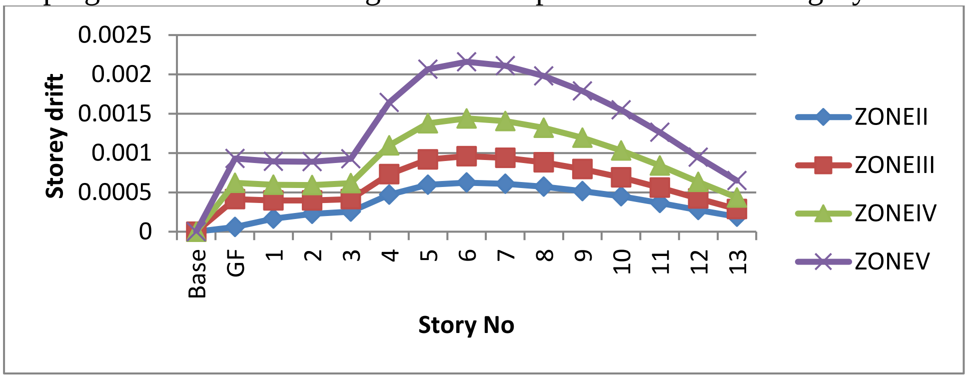
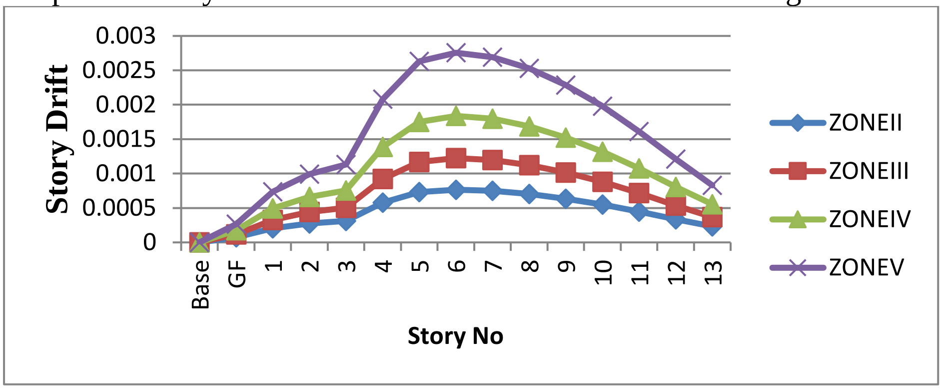
**5.4 Storey Drift:** Storey drift, also known as inter-storey drift, refers to the relative-lateral-displacment or movement between the adjacent floors or storeys in a building during an earthquake or other lateral loading events. It is a critical parameter in structural engineering and seismic-design, helping to assess the building's structural performance and integrity under lateral forces.




Graph 5.7: Story Drift in the X -Direction of Podium Building in Medium Soil




Graph 5.8: Story Drift in the X -Direction of Podium Building in Soft Soil

**OBSERVATION AND CONCLUSION:**

**6.1 Observations and Conclusion:**

1. The podium building located in zone-II on medium soil has the least base shear reaction among all the podium buildings located in zone-III, IV and V on both medium and soft soils. Therefore, zone-II building on medium soil is the most efficient building having less base reaction and hence can attract fewer lateral displacements and building deformations.
2. The podium building located in zone-II on medium soil has the least storey displacement comparing the buildings in all seismic zones on both medium and soft soils therefore the seismic zone-II podium building is found to be safer and sounder and considerably the best podium building having least storey displacement and least base shear reactions.
3. The podium building located in zone-II on medium soil has the least storey drift comparing the buildings in all seismic zones on both medium and soft soils indicating that the building is stiffer and less susceptible to lateral movements.
4. Therefore, this podium building on zone-II on medium soil meeting all the safety standards and outperforming among all of the seismic zones which are II, III, and IV& V on both medium and soft soils is unarguably the most efficient podium building.

**6.2 Scope for Future Study:**

1. There is need to study response of podium buildings by utilizing shear wall systems along the height of the building excluding podium stories.
2. Podium buildings requires strong and stiff base stories which can be met by adopting framed steel tubes on the perimeter of the podium stories which would eliminate the feared effects of large lateral loads on the building.

3. When the structural design requirements don't allow for adopting structural systems due to economic factors in such cases the storey heights of the podium structure can be reduced as compared to the storey heights of tower which lies on the podium thereby increasing the overall building stiffness and distribution of loads.

4. When the podium building is required to be raised to greater heights such 30+ stories in such cases adopting diagrid structural system can prove very proficient in resisting horizontal loads in which braces at certain angles increases the efficiency of distributing loads effectively than bare frame structures.

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