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Seismic Analysis of Mass Irregularity and Stiffness Irregularity of G+20 Tilting Building

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Abstract - Vertical irregularities, including uneven mass distribution and variations in stiffness, pose significant challenges for buildings in seismic zones. This study investigates how lateral forces generated by earthquakes affect each level of a building with an uneven vertical structure to evaluate their influence on the building's response. The study adopts the IS 1893:2016 (Part 1) guidelines due to their established standards in seismic analysis and design. The results show that uneven mass distribution causes strong sideways forces and instability in the structure, highlighting the crucial need for accurate mass placement to lower earthquake risks. Additionally, the study finds that buildings with an uneven stiffness distribution are more susceptible to torsional effects during seismic events, further increasing the risk of structural failure. By following the guidelines set forth in IS 1893:2016 (Part 1), engineers can better design buildings to withstand lateral forces and reduce the potential for damage. Overall, this research emphasizes the importance of considering both mass and stiffness distribution in seismic design to ensure the safety and stability of buildings in earthquake-prone areas. This approach can help save lives and reduce the economic impacts of future earthquakes.

Key Words: Seismic design, vertical irregularities, mass distribution, stiffness distribution, earthquake resilience

1. INTRODUCTION

Significant earthquakes have exposed vulnerabilities in various structures, often leading to damage or collapse. Regularly shaped buildings generally perform better during seismic events due to their symmetrical distribution of mass, which helps in maintaining uniform load-bearing capacities and structural stability. However, irregularities such as asymmetrical mass distribution can cause uneven load distribution, which in turn may lead to critical structural failures, compromising the overall stability of the building. This study focuses on a G+20 building with vertical mass irregularities to assess how it reacts to lateral seismic loads. The irregularities are created by intentionally altering the mass properties, such as increasing mass at specific levels, to introduce vertical mass irregularities in accordance with the IS 1893:2016 guidelines.

Fig 1.1: Total horizontal earthquake force in building increases downwards along its height

1. The study could further discuss the specific methods used to intentionally alter the mass properties of the G+20 building in order to create vertical mass irregularities for testing purposes.

2. It would be interesting to explore how the altered mass distribution affects the load-bearing capacities of different sections of the building and what implications this has for structural stability during seismic events.

3. The research could delve into how engineers and architects can mitigate potential risks associated with asymmetrical mass distribution in buildings, especially when designing structures in seismically active regions.

4. Further analysis could be conducted on how different types of irregularities, beyond just vertical mass irregularities, impact a building's ability to withstand lateral seismic loads and maintain structural integrity.

5. The study may also investigate real-life examples of buildings that have experienced structural failures due to uneven load distribution, highlighting the importance of considering these factors in construction design and planning processes.

1.1 Structural Irregularity in Structures

Structural irregularities refer to deviations from a uniform, symmetrical, and regular configuration in the layout and design of buildings. These irregularities can significantly impact the way structures respond to seismic forces, potentially leading to increased damage or collapse during earthquakes. Understanding and addressing these irregularities is crucial for designing resilient structures.

1.2 Types of Structural Irregularities

Structural irregularities are classified based on their location and impact.

- **Vertical Stiffness Irregularity**: This occurs when a story's lateral stiffness is significantly less than that of adjacent stories.
- **Weight (Mass) Irregularities**: Exist when the mass of a story exceeds 150% of the adjacent story's mass.
- **Vertical Geometric Irregularity**: Identified when the horizontal dimension of a story exceeds 130% of that of an adjacent story. Vertical irregularities can lead to substantial twisting forces on the building, causing torsional effects.

2. Problem Formulation

The building's foundational model frame consists of twenty geometrically uneven vertical axes with a 3.0 meter bay width. The building's fundamental specifications include a beam measuring 0.3 m by 0.5 m, a column measuring 0.50 m by 0.30 m, a beam length of 2.5 m, and a column length of 3.0 m. The load combinations are based on IS 1893:2016 (Part-1) article 6.3.1.2.

The second frame has twenty bays, G+ twenty storeys, and geometrically uneven vertical irregularities. The lowest level has a storey height of 3.0 meters, while the subsequent floors have 3.0 meters and a bay width of 2.5 meters.

The 7th, 14th, and 21st storeys have increased loading, resulting in an asymmetrical structure with twenty stories and twenty bays. Extra mass is added to the 7th, 14th, and 21st levels to determine how mass irregularity impacts the building's uneven shape.

The 7th, 14th, and 21st floors have corresponding modifications, and structural and seismic data are incorporated to model the base model's plan, elevation, and three-dimensional perspective. The modifications made to the 7th, 14th, and 21st floors are crucial in analyzing the impact of mass irregularity on the building's structural integrity. By incorporating structural and seismic data into the base model, engineers can accurately predict how the asymmetrical design will perform under different loading conditions. This detailed approach ensures that the building will be able to withstand various forces and remain safe for occupants throughout its lifespan.

Furthermore, the analysis of the building's structural integrity also takes into account factors such as wind loads, seismic activity, and potential impacts from nearby structures. By considering these variables, engineers can make informed decisions about the design and construction of the building to ensure its safety and stability. In addition, advanced computer modeling techniques allow for the simulation of various scenarios to test the building's response to different forces and conditions. This comprehensive approach to structural analysis helps to identify any potential weaknesses in the design early on, allowing for adjustments to be made before construction begins. Ultimately, this meticulous attention to detail is essential in creating a building that is not only aesthetically pleasing but also structurally sound and safe for all who inhabit it.

The 500 mm × 300 mm reinforced concrete columns and 200 mm deep slabs that make up the regular-shaped G+20 structure are all made of concrete (M40) and reinforcement (Fe500). In order to guarantee safety and stability, these components are made to withstand seismic forces and include appropriate damping ratios and response reduction factors. These parts are designed to withstand seismic forces in Zone V, which is prone to earthquakes. To guarantee stability and safety, particular damping ratios and response reduction factors are taken into account. These factors are crucial in ensuring that the structure can withstand the potential impact of seismic forces.

Table No. 1: Seismic Information

Type of Soil	Medium
Poisons Ratio	0.15
Time Period	Program computed
Relevance Aspect	1
Zone of Earthquake	V
Factor of Response Reduction	5
Ratio of Damping	5 %

Wind load As per IS 875 (Part 3):1987, the structure should be designed to withstand the wind load as specified in the code. Seismic zone factor: 0.36, and importance factor for seismic loading: 1.2. Considering the specific weight of RCC and infill walls is crucial as it enhances structural stability and safety, especially during seismic events. The input provided includes the response spectra as per IS 1893 (Part 1):2002, the type of soil being medium, and the number of storeys as G+20. The building dimensions are 36 m x 36 m, with a typical floor height of 3.0 m and a base floor height of 3.0 m. The materials used include concrete (M40) and reinforcement (Fe500), with a specific weight of infill of 20 KN/m3. The building is designed for a high-risk seismic zone to guarantee structural stability in the event of earthquakes.

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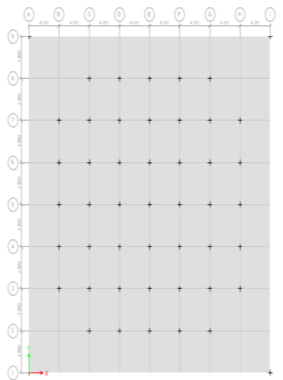
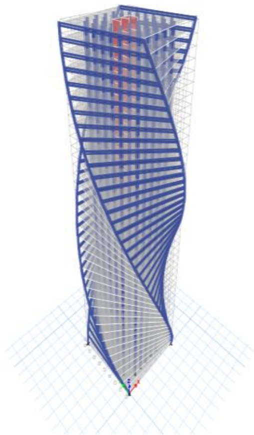
The design incorporates flexibility measures, including moment-resisting frames with detailed beam-column connections and secure reinforcement anchorage, to enhance the building's capacity to resist seismic forces effectively. Furthermore, the structure incorporates essential elements like shear walls and bracings designed to resist horizontal loads, enhancing the building's seismic performance by effectively absorbing forces and improving overall stability. Furthermore, the design incorporates features like ductile materials and energy dissipation mechanisms, essential for reducing damage and improving resilience during seismic events. Furthermore, the structure features meticulous design elements and robust connections, significantly enhancing performance and resilience against seismic forces. Furthermore, the design underscores the critical role of proper foundation design and detailing in effectively resisting seismic forces and maintaining structural integrity, ensuring the building's stability and safety. Furthermore, the structure incorporates flexibility and meticulous design to effectively dissipate energy during seismic events, enhancing the building's capacity to withstand such forces.

Table No. 2: The structural makeup of a G+20 structure with a regular form is shown below.

Specification	Details
Type of structure	RCC
Size of Column	500 mm × 300 mm
Size of Beam	500 mm × 300 mm
Depth of slab	200 mm
Specific weight of RCC	25 KN/m3
Type of soil	Medium soil
Number of storey	G+20
Dimension of building	36 m x 36 m
Floor Height (Typical)	3.0 m
Base floor height	3.0 m
Infill wall	230 mm thick wall
Impose load	5 KN/m2
Materials	Concrete (M40) and Reinforcement (Fe500)
Specific weight of infill	20 KN/m3
Seismic zone	V
Importance factor	1.00
Response spectra	As per IS 1893 (part 1):2002





(a)Plan view of G+20 building *(b)* 3D solid view of G+20 building

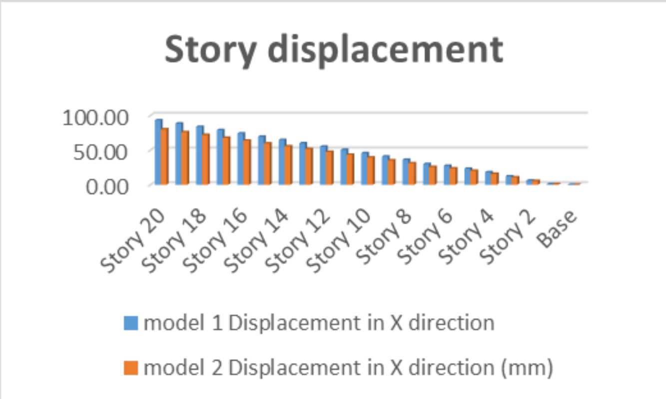


Chart -1: Story displacement in X direction

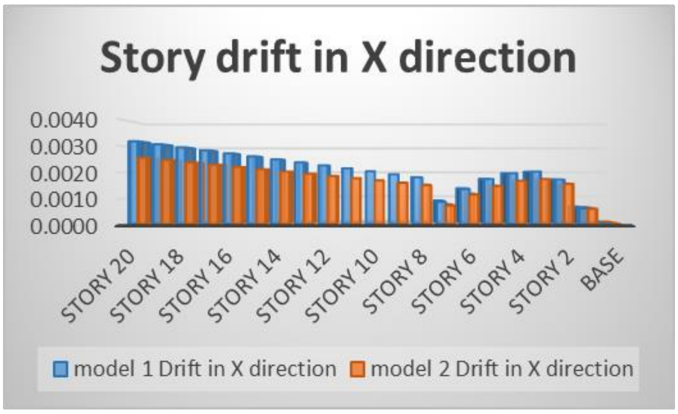


Chart -2: Story drift in X direction

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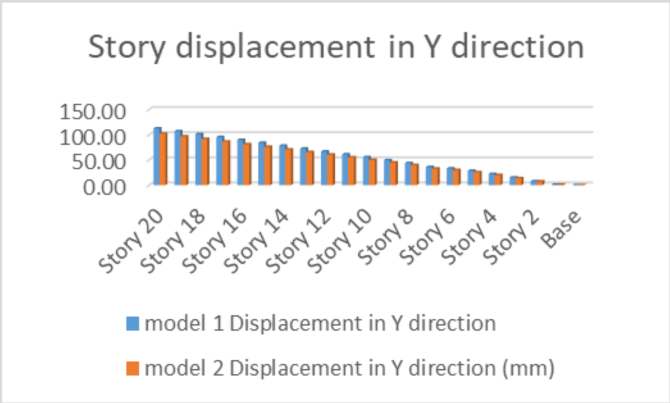

Chart -3: Story displacement in Y direction

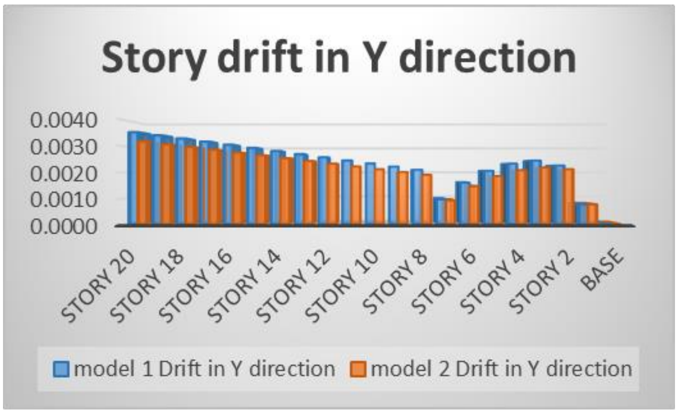

Chart -4: Story drift in Y direction

3. CONCLUSIONS

The study emphasizes the critical importance of considering vertical irregularities, such as uneven mass and stiffness distributions, in the seismic design of buildings. Key conclusions include:

1. **Impact of Mass Distribution:**

- Uneven mass distribution in a building can lead to significant lateral forces and instability during seismic events. This underscores the necessity for precise mass placement to mitigate earthquake risks.

2. **Effect of Stiffness Distribution:**

- Buildings with uneven stiffness distribution are more prone to torsional effects during earthquakes, increasing the likelihood of structural failure.

3. **Adherence to Guidelines:**

- By following the IS 1893:2016 (Part 1) guidelines, engineers can design buildings that better withstand lateral seismic forces, thereby reducing potential damage.

4. **Safety and Stability:**

- The research highlights that careful consideration of both mass and stiffness distribution is vital for the safety and stability of buildings in earthquake-prone areas. This approach can help save lives and minimize economic impacts during future seismic events.

4 Results

1. **Seismic Response:**

- The study found that uneven mass distribution causes strong lateral forces, leading to instability in structures. Accurate mass placement is crucial for reducing earthquake risks.
- Buildings with uneven stiffness distribution experience significant torsional effects during seismic events, which further increases the risk of structural failure.

2. **Model Analysis:**

- The analysis of a G+20 building with intentional mass irregularities (increased mass at the 7th, 14th, and 21st levels) showed how such irregularities impact the building's response to seismic loads. This included detailed modeling of structural and seismic data to predict performance under various conditions.

3. **Design Recommendations:**

- The study provides design recommendations in line with IS 1893:2016 guidelines to enhance the seismic performance of buildings. This includes considerations for damping ratios, response reduction factors, and the use of moment-resisting frames, shear walls, and bracings to improve structural stability.

Key Points

- Mass and stiffness distribution are crucial in seismic design.
- Accurate placement of mass and consideration of stiffness can mitigate risks.
- Adherence to established guidelines (IS 1893:2016) enhances building resilience.
- Detailed structural analysis and design adjustments are essential for safety.

This comprehensive approach to understanding and mitigating the effects of vertical irregularities in building structures helps ensure safer and more resilient buildings in seismically active regions.

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