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Comparison Between Tall Structure with Intermediate Storey and Void Storey

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Abstract: This research provides a thorough evaluation of the advantages and disadvantages of using intermediate storeys vs void storeys in tall structures. The choice of design features has a major influence on the functioning and sustainability of tall buildings, which have become ubiquitous in contemporary urban landscapes. In this study, we compare and contrast two different design methodologies by exploring their structural contexts and aesthetic qualities. Contrarily, void floors provide open space inside the structure, which may serve a variety of functions including increasing natural ventilation and serving as leisure places. Our research takes a holistic look of tall structures with these design features, taking into account things like structural displacement, drift, and base shear. The purpose of this article is to provide guidance to professionals as they decide between an intermediate level and a void level for a certain project. The structure is modelled in ETABS, loads are applied, and the structural behavior is analyzed.

Keywords: Tall Structures, ETABS, Seismic Analysis, Void Storey.

I. INTRODUCTION

A "soft storey" in a multi-story building refers to one or more floors that are structurally weaker than the others, which affects the building's ability to withstand seismic and wind forces. This characteristic is crucial in earthquake-resistant design, as a building's stiffness impacts its capacity to resist such forces. Soft storeys can arise in several scenarios:

1. **Open Floor Design**: In architecture, "soft storey" and "open floor" are terms used to describe a level in a building that has significantly less stiffness and resistance than the rest. This is often the case when the ground floor is used for purposes like parking, with few or no structural walls.
2. **Stilt Building**: A stilt building is a type of multi-story structure where the first floor is raised above ground, typically used for parking. In this case, the ground level, which often contains the parking garage, is considered the "soft storey."
3. **Sudden Stiffness Change**: A soft storey can also occur when there's a sudden reduction in stiffness at a particular height within the building, creating a noticeable weakness in the structure.

In high-rise buildings, wind loads are a particular concern, as they create lateral stresses that can be more significant than in other types of structures. Although Reinforced Cement Concrete (RCC) provides substantial rigidity, it is not always effective against wind forces. To ensure a high-rise building can endure the larger pressures from wind, specific design adjustments must be made to improve its wind resistance. Wind is essentially moving air, and when buildings or natural features obstruct its path, the kinetic energy of the wind is converted into pressure, resulting in wind load on the structure.

II. OBJECTIVES

To analyse the impact of incorporating a void storey versus an intermediate storey under wind loads performance and overall structural behavior using ETABS.

1. To model a 50-storey reinforced concrete structure in ETABS.
2. To model and analyse a multi-story building with a void storey at a specific location (i.e., the 25th floor) and compare its wind load performance with a similar building having a standard intermediate storey at the same location.
3. To evaluate and compare the results of the two models (with and without the void storey) in terms of displacement, base shear, story drift and its impact on wind loads using ETABS.

In summary, the presence of a void storey significantly impacts the structural behavior of a building under wind loads, leading to increased displacement and drift, while intermediate storeys contribute to increased stiffness and a more uniform distribution of these parameters. The project's objective is to analyse and compare these effects using ETABS, considering parameters like storey displacement, inter-storey drift, and base shear.

III. LITERATURE REVIEW

Achyut S. Naphade et al. (2018) highlighted that as populations grow and urban areas become denser, architects have had to make significant changes to building designs. Architects and engineers are constantly exploring new methods to improve the reliability, safety, and aesthetic appeal of buildings. Two current architectural trends are tall buildings with intermediate soft floors and high-rise buildings with void storeys. This study compares and contrasts these two approaches, focusing on their key differences and similarities to assist in decision-making.

Rahiman G. Khan et al. (2017) emphasized the need for careful planning and design in high-rise buildings. One innovative solution is the use of a soft storey, or a movable floor, at the mid-height of the building. This floor is designed to be less rigid than the floors above and below, which helps to distribute lateral loads and seismic forces more effectively. This design not only strengthens the building's resistance to wind and earthquakes but also provides additional usable space within the building. Another option discussed is the void storey, an open floor level that enhances both the functionality and aesthetic appeal of the structure.

Pramod M. Gajbe et al. (2016), in their study titled *"Analysis of Soft Stories in Multi-Storey Steel Structure Buildings,"* explored the impact of soft-storey floors in more detail. The research, although limited in scope, provided insights into how these floors significantly affect the structural performance and the lateral load-bearing capacity of buildings on a floor-by-floor basis. It also showed that the relative displacements and drift, particularly at the top storey, can be substantially influenced by structural imperfections.

Vipin V. Halde et al. (2016) focused their research on understanding how soft storeys affect the structural response of high-rise buildings. The study aimed to identify the factors—such as a building's stiffness, mass, and lateral forces—that influence the lateral displacement of floors. The research confirms that the mass and stiffness characteristics of each floor play a major role in how lateral forces are distributed throughout the building. Consequently, the deflection is most noticeable in areas with soft storeys, leading to greater displacement at those levels.

M. Gu & Y. Quan (2004) referenced the IS code IS 875 Part III, which provides guidelines for designing building structures to withstand wind loads. Their literature review on the performance and behavior of buildings under wind loads highlighted the necessity for a methodology to assess how buildings respond to these forces.

Guoqing Huang & Xinzhong Chen (2007) analyzed the effects of wind loads on 20- and 50-story buildings, measuring detailed dynamic pressure data in three primary directions. Their research contributed to a deeper understanding of how wind interacts with tall buildings.

Michael Kasperski (2009) noted that when designing buildings, multiple design tasks must be addressed, including specifying design values for local, global, and structural loads, all of which must be considered to ensure the building's safety and stability under various conditions.

IV. METHODOLOGY

High-rise buildings are increasingly common in urban environments, and their behavior under lateral loads such as wind is of critical importance in structural engineering. A frequent design feature in tall buildings is the incorporation of void storeys, typically to reduce wind loads and improve aesthetic or functional needs (e.g., sky gardens, mechanical floors).

This study compares a 50-storey building with two configurations:
- Model A: A void storey at the 25th floor (open floor, no walls or lateral resistance).
- Model B: An intermediate (normal) storey at the 25th floor, identical in stiffness and configuration to adjacent storeys.

The aim is to assess how the presence of a void storey affects the structural performance under wind loads in both X and Y directions, as per IS 875 (Part 3): 2015.

4.1 Software and Design Codes

- Software: ETABS 2022 (Extended 3D Analysis of Building Systems)
- Design Code: IS 875 (Part 3): 2015 – Wind Loads
- Structural Design Code: IS 456: 2000

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4.2 Modeling the Structure

4.2.1 Building Geometry

TABLE I GEOMETRY SPECIFICATIONS OF THE MODEL

Parameter	Value
Number of Storeys	50
Floor Height	3.5 m
Plan Dimensions	30 m × 30 m
Grid Spacing	6 m × 6 m
Slab Thickness	150mm

4.3 Storey Configuration

- Model A (Void Storey): Storey 25 modeled with no walls or lateral elements; slabs are removed.
- Model B (Intermediate Storey): Storey 25 modeled identically to other typical floors.

4.4 Structural Elements

TABLE 2 STRUCTURAL SPECIFICATIONS OF THE MODEL

Element	Size	Material
Columns (Base–7)	900 mm × 1000 mm	M25 Concrete
Columns (8–50)	750 mm × 900 mm	M25 Concrete
Beams	230 mm × 570 mm	M25 Concrete
Slab	150 mm thick	M25 Concrete

4.5 Material Properties

- Concrete Grade: M25
- Modulus of Elasticity: As per IS 456:2000
- Poisson’s Ratio: 0.2
- Density of Concrete: 25 kN/m³
- Steel: Fe500 (for reinforcement, though not explicitly modeled in lateral load analysis)

4.6 Load Definitions

4.6.1 Dead Load (DL)

- Self-weight of structure (automatically considered by ETABS)
- Floor finishes: 1.0 kN/m²

4.6.2 Live Load (LL)

- Typical floor: 3.0 kN/m²
- Roof: 1.5 kN/m²

4.6.3 Wind Load (WL)

- Defined as per IS 875 (Part 3): 2015
- Basic Wind Speed (Vb): 44 m/s (example; adjust as per project location)
- Wind Exposure Category: Category C (depending on terrain)
- Risk Coefficient (k1): 1.0
- Terrain, Height and Structure Size Factor (k2): Variable with height
- Topography Factor (k3): 1.0 (flat terrain assumed)

4.7 Load Combinations (as per IS 456:2000 & IS 875)

4.8 Analysis Settings

- Diaphragm: Rigid diaphragm assigned to each floor level
- Meshing: Appropriate slab meshing for accurate lateral analysis
- Solver: ETABS linear static solver used with wind load cases defined separately

4.9 Expected Results & Interpretation

4.9.1 Displacement Profile

- Model A (Void Storey) is expected to show a sudden increase in displacement due to lack of lateral stiffness.
- Model B (Intermediate Storey) should show a smoother, more gradual displacement curve.

4.9.2 Storey Drift

- A sharp spike in drift at Model A may indicate code violation (IS 456 recommends max drift < 0.004 × storey height).
- Model B should exhibit more uniform drift values.

4.9.3 Base Shear

- Both models may experience similar or closer base shear values if mass distribution is constant.
- However, modal participation and distribution of stiffness may affect base shear slightly.

This methodology sets the stage for a detailed analytical comparison between a void and intermediate storey configuration in a high-rise building. The modeling approach in ETABS follows best practices using IS 875:2015 for wind load application. The results will help assess:

- Structural performance under lateral loads
- Effectiveness of void storey placement
- Code compliance in terms of drift and displacement

Ultimately, this study will guide safe and efficient design of tall buildings that incorporate architectural features like sky gardens or mechanical voids without compromising structural integrity.

V. RESULTS AND DISCUSSION

5.1 Void Storey Results

The below graphs show the results obtained for Maximum Storey Displacement of Wind Load in X Direction, Max Storey Drift Plot of Wind Load in X Direction and Base Shear for Wind Load in X Direction for Model-A

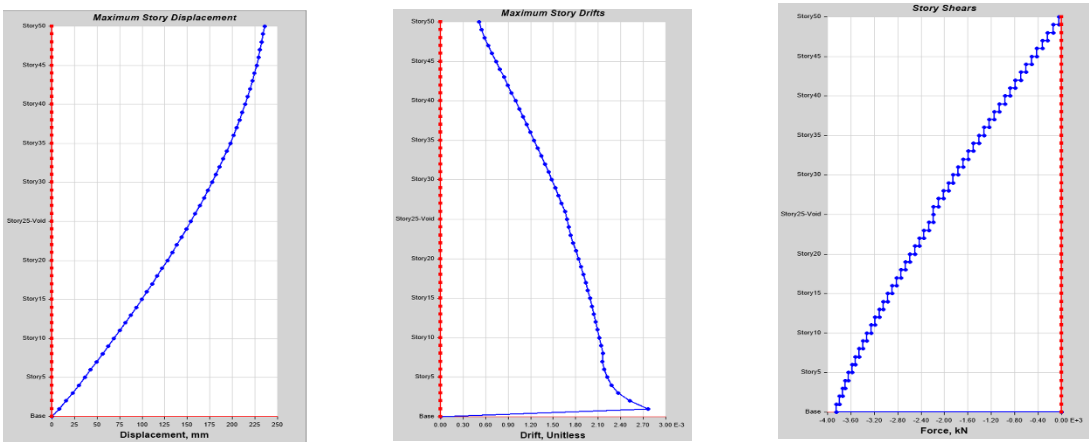

Fig. 1 Maximum Storey Displacement of Wind Load in X Direction, Max Storey Drift Plot of Wind Load in X Direction and Base Shear for Wind Load in X Direction for Model-A

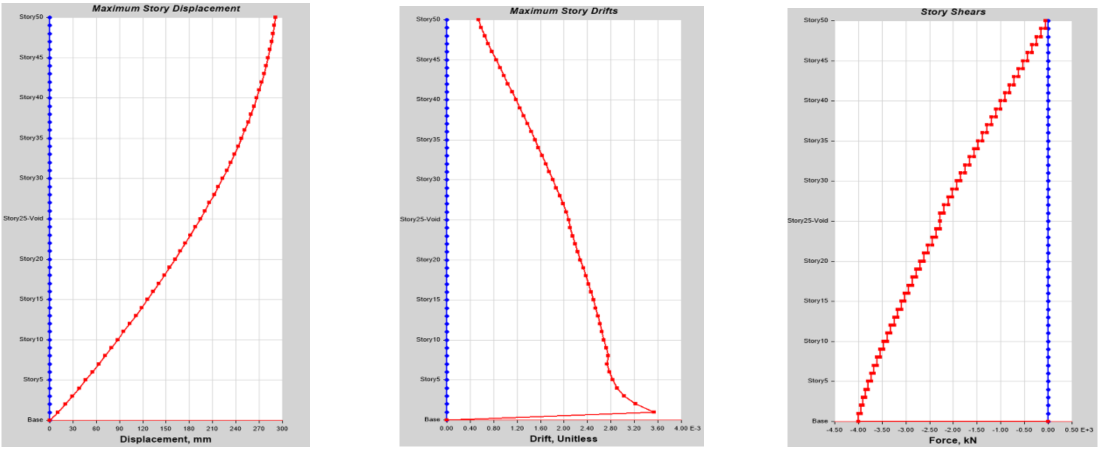

Fig. 2 Maximum Storey Displacement of Wind Load in Y Direction, Max Storey Drift Plot of Wind Load in Y Direction and Base Shear for Wind Load in Y Direction for Model-B

This study evaluates the structural performance of a 50-storey reinforced concrete structure with two distinct design strategies at the mid-height level (25th floor): one with a void storey and another with a regular intermediate storey. Using

ETABS modeling and analysis, the structures were subjected to wind loads in two orthogonal directions (WINDX and WINDY), and their behavior was assessed in terms of displacement, story drift, and base shear.

1. Displacement Comparison

- **Void Storey:**
  - WINDX: 235.54 mm
  - WINDY: 291.35 mm
- **Intermediate Storey:**
  - WINDX: 170.45 mm
  - WINDY: 80.34 mm

Displacement in both WINDX and WINDY directions is significantly lower in the intermediate storey model. Particularly under WINDY, the void storey shows nearly 3.6x more displacement, indicating a loss in lateral stiffness due to the absence of slab continuity.

2. Story Drift Evaluation

From the shared story drift diagrams:

- WINDX: The void storey shows maximum drift (0.002763) between the Base and Story5, whereas the intermediate storey shows a peak (0.001627) between Story5 and Story10 — demonstrating a more uniform and controlled drift profile.
- WINDY: The void storey again shows the highest drift (0.003539), especially concentrated in lower stories, while the intermediate storey maintains a lower peak (0.00237) with better distribution.

3. Base Shear Comparison

- **Void Storey:**
  - WINDX: -3843.56 kN
  - WINDY: -4003.71 kN
- **Intermediate Storey:**
  - WINDX: -3242.75 kN
  - WINDY: -1312.71 kN

The base shear values are considerably higher in the void model, especially under WINDY, showing more than 3 times the force experienced compared to the intermediate option. This suggests the void storey experiences greater dynamic amplification, leading to larger inertial forces.

In summary, the comparison clearly illustrates that the intermediate storey model exhibits better performance across all parameters:

- Reduced lateral displacements
- Lower base shear values
- More favorable drift distribution

Although void storeys may offer architectural and functional advantages (e.g., ventilation, aesthetics), they compromise structural performance, particularly under wind loads. Based on the data, the intermediate storey provides superior lateral stability, especially in the WINDY direction where the void model shows excessive displacement and drift.

Hence, from a structural engineering standpoint, it is recommended to adopt the intermediate storey configuration in tall buildings to ensure better wind performance, safety, and serviceability.

VI. COMPARISION

The comparative analysis of a 50-storey building with a void storey (Model A) and an intermediate storey (Model B) at the 25th floor under wind loads in X and Y directions (WINDX and WINDY) has yielded the following observations:

6.1 Storey Displacement

- Model A (Void Storey) exhibited a significant increase in lateral displacement at top storey in both WINDX and WINDY load cases. This is attributed to the abrupt reduction in lateral stiffness due to the absence of vertical structural elements at the void storey.
- Model B (Intermediate Storey) demonstrated a more uniform and smoother displacement profile throughout the height of the structure, indicating better distribution of lateral stiffness.

6.2 Storey Drift

- The storey drift in Model A peaked sharply at the transition around the void storey (storey 25 and storey 26), particularly under WINDX and WINDY, where lateral loads act along the longer building dimension.
- In contrast, Model B maintained storey drift within acceptable codal limits as per IS 456:2000 across all storeys, ensuring greater structural stability and comfort.
- Excessive drift in Model A may lead to non-structural damage, facade issues, and even progressive stiffness degradation over time.

6.3 Base Shear

- Both models experienced comparable base shear magnitudes, as the total seismic weight was nearly identical. However, Model B showed slightly better lateral force distribution due to continuous stiffness, which can lead to more efficient energy dissipation.
- Model A's irregular stiffness profile due to the void storey caused concentration of forces in adjacent storeys, increasing the demand on certain structural elements.

6.4 Directional Effects

- The effects of the void storey were more pronounced in the WINDX direction, where greater lateral displacements and drift were observed.
- Although both directions showed similar trends, Model A's vulnerability in WINDX was significantly higher than in WINDY, underlining the importance of stiffness continuity along the principal wind direction.

VII. CONCLUSION

Based on the analysis of displacement, storey drift, and base shear under wind loading conditions:

1. The intermediate storey model (Model B) provides superior structural performance, better compliance with codal requirements, and greater overall stability.
2. The presence of a void storey introduces significant stiffness irregularities, negatively impacting drift control and displacement response.
3. Therefore, for high-rise buildings subjected to substantial wind forces, maintaining an intermediate storey with consistent lateral resistance is structurally more efficient and safer than incorporating a void storey at mid-height.

REFERENCES

[1]. Achyut S. Naphade, G. R. Patil ; Pushover Analysis Of RCC Building With Soft Storey At Different Levels; IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN :2278-1684, p-ISSN : 2320–334X PP 100-108.

[2]. Rahiman G. Khan, M. R. Vyawahare; Push Over Analysis of the Tall Building with Soft Stories at Different Levels; International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 3, Issue 4, Jul Aug 2013, pp.176- 185.

[3]. Pramod M Gajbe, R. V. R. K. Prasad; analysis of soft storey multistoried steel structure building; International journal of engineering sciences & Research Technology; ISSN: 2277-9655 Impact Factor: 4.116.

[4]. Vipin V Halde, Aditi H. Deshmukh; Effect of Soft Storey on Structural Response of HighRise Building; International Journal of Innovative Research in Science, Engineering and Technology Vol.5, Issue1, January 2016.

[5]. M. Gu, Y. Quan(2004)," Across-wind loads of typical tall buildings", Wind Energy and Industrial Aerodynamics , doi:10.1016/j.jweia.2004.06.004

[6]. Guoqing Huang, Xinzhong Chen(2007)," Wind load effects and equivalent static wind loads of tall buildings", Engineering Structure , doi:10.1016/j.engstruct.2007.01.011

[7]. Michael Kasperski (2009)," Specification of the design wind load", Journal of Wind Engineering and Industrial Aerodynamic, doi:10.1016/j.jweia.2009.05.002

[8]. Aly Mousaad Aly and Srinivasa Abburu(2011)," Dynamics and Control of High-Rise Buildings under Multidirectional Wind Loads", Smart Material Research, doi:10.1155/2011/549621

[9]. K. Vishnu Haritha, Dr.I. Yamini Srivalli(2013)," Effect of Wind on Tall Building Frames", International Journal of Research in Civil Engineering, ISSN Online: 2347-2855, Print: 2347-8284

[10]. F. Cluni , M. Gioffrè, V. Gusella (2013)," Dynamic response of tall buildings to wind loads by reduced order equivalent shear-beam models", Journal of Wind Engineering and Industrial Aerodynamics, http://dx.doi.org/10.1016/j.jweia.2013.09.012

[11]. Ki-PyoYou, Jang-YoulYou andYoung-MoonKim(2014)," LQG Control of Along-Wind Response of a Tall Building with an ATMD", Mathematical Problems in Engineering, http://dx.doi.org/10.1155/2014/206786

[12]. Vikram.M.B, Chandradhara G. P , Keerthi Gowda B.S.(2014)," A Study on Effect of Wind on the Static and Dynamic Analysis", International Journal of Emerging Trends in Engineering and Development, ISSN 2249-6149

[13]. Umakant Arya, Aslam Hussain, Waseem Khan (2014)," Wind Analysis of Building Frames on Sloping Ground", International Journal of Scientific and Research Publications, ISSN 2250-3153

[14]. Aly Mousaad Aly and Srinivasa Abburu (2015)," On the Design of High-Rise Buildings for Multihazard", Shok and Vibration, http://dx.doi.org/10.1155/2015/148681

[15]. Djamal Hissein Didane, Nurhayati Rosly, Mohd Fadhli Zulkafli, and Syariful Syafiq Shamsudin(2017)," Evaluation of Wind Energy Potential as a Power Generation Source in Chad", International journal of rotating machinery, https://doi.org/10.1155/2017/3121875

[16]. Nicola Longarini, Luigi Cabras, Marco Zucca, Suvash Chapain, Aly Mousaad Aly(2017),” structural Improvements for Tall Buildings under Wind Loads: Comparative Study”, Shock and Vibration, https://doi.org/10.1155/2017/2031248

[17]. Rabi Akhtar, Shree Prakash, Mirza Aamir Baig(2017),” Study of comparison between Static and Dynamic Analysis Subjected to Wind and Earthquake Load”, International Research Journal of Engineering and Technolog, e-ISSN: 2395-0056 , p-ISSN: 2395-0072

[18]. Huili Xue, Kun Lin, Yin Luo, Hongjun Liu (2017),” Time-Varying Wind Load Identification Based on Minimum-Variance Unbiased Estimation”, Shock and Vibration, https://doi.org/10.1155/2017/9301876

[19]. [19] Ashish Sadh, Ankit Pal (2018), “A Literature Study of Wind Analysis on High Rise Building”,International Journal of Advanced Engineering Research and Science,ISSN: 2349-6495(P) | 2456-1908(O), https://dx.doi.org/10.22161/ijaers.5.11.36

[20]. A. Joseph Andrew, N Parthasarathi, S Selvi Rajan, Prakash(2018),” Dynamic response of tall buildings to wind loads by reduced order equivalent shear-beam models”, Materials Today, Materials Today: Proceeding: 5 (2018) 8923-8932