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Effect of Building Height on Seismic Base Shear: An ETABS-Based Analysis

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A B S T R A C T

Multi-storey buildings exhibit different levels of seismic vulnerability as structural height increases. Seismic base shear is a key parameter in earthquake-resistant design and is strongly influenced by the dynamic characteristics of a building. This study evaluates the effect of variations in building height on base shear using ETABS. Reinforced-concrete building models with different numbers of storeys were analyzed using the response-spectrum method in accordance with SNI 1726. The results indicate that increasing building height significantly affects the fundamental natural period and the distribution of seismic forces. Taller buildings tend to exhibit longer vibration periods and relatively lower base shear than shorter buildings. The findings provide a technical reference for the safe and efficient structural design of multi-storey buildings.

INTRODUCTION

Indonesia is characterized by high seismic activity because it lies at the convergence of several major tectonic plates. Interactions among these plates frequently induce movements of the Earth's crust, potentially generating earthquakes of varying magnitudes. Consequently, Indonesia is highly susceptible to seismic hazards (Badan Standarisasi Nasional 2019; Istiono and Ramadhan 2020). These conditions necessitate structural designs specifically capable of resisting earthquake-induced loads. Structures must possess not only adequate strength but also sufficient resilience and reliability under the dynamic forces generated during seismic events. Structural safety is therefore a primary consideration in the design of buildings in earthquake-prone regions. Seismic base shear is a fundamental parameter in earthquake-load analysis because it represents the maximum lateral force that a building structure must resist to prevent failure. A sound understanding of seismic base shear is thus essential for ensuring satisfactory structural performance during an earthquake (Chopra 2017).

Building height is one of the principal factors governing the dynamic response of a structure to seismic loading (Rinaldi and Chairani 2017). Taller buildings generally exhibit vibration characteristics that differ from those of low-rise buildings, resulting in more complex structural behavior under dynamic loads. Building height is therefore an important parameter in structural analysis (Cahyani et al. 2022). As building height increases, the fundamental natural period of the structure generally becomes longer. This period strongly influences the structural response to earthquake excitation, including the magnitude and distribution of the forces that must be resisted (Kusuma 2022). Variations in building height consequently affect the seismic forces acting on the structure. A comprehensive understanding of the relationship between building height and seismic base shear is therefore necessary for earthquake-resistant structural design (Rumbyarso 2024). Appropriate evaluation of these parameters supports the design of buildings that are safer, more stable, and more effective in resisting earthquake loads (Tavio and Kusuma 2018).

Advances in structural-analysis technology have considerably improved the assessment of building behavior under loading, particularly earthquake loading (Takesan, Simatupang, and Bunganaen 2021). Finite-element-based software such as ETABS enables structures to be modeled in greater detail, with improved accuracy and computational efficiency (Sungkana, Prabowo, and Christianto 2025). This capability is important for producing analytical models that adequately represent actual structural conditions. ETABS also supports both static and dynamic analyses in accordance with applicable seismic design standards. Consequently, it is widely used by civil-engineering practitioners and researchers for the analysis and design of safe and reliable earthquake-resistant structures (Computer and Structures 2020).

This study aims to evaluate the effect of building height on seismic base shear using ETABS as the primary analytical tool. The analysis is expected to clarify the relationship between building height and seismic structural response, thereby supporting more effective building design in accordance with applicable technical provisions.

RESEARCH METHODS

1. Structural models

This study employed reinforced-concrete building models with a moment-resisting frame system. Variations in building height were represented through several modeling scenarios, including 5-, 10-, and 15-storey buildings, while the plan configuration and structural-member dimensions were maintained as consistently as practicable across the models.

Table 1. Structural modeling parameters

Plan dimensions	45 m × 30 m
Number of storeys	7 storeys
Storey height	4m
Bay spacing in the X direction	6m
Bay spacing in the Y direction	5m
Structural system	Moment-resisting frame system
Support condition	Laterally restrained
Site classification	SD (medium soil)
Risk category	II
Importance factor	1.0

2. Loading and Seismic parameters

Earthquake loading was determined using response-spectrum analysis in accordance with SNI 1726. Seismic parameters, including spectral acceleration, building risk category, and site soil conditions, were defined in ETABS in accordance with the relevant code provisions.

Table 2. Loading Parameters

Gravity loads	
Dead load (DL)	Automatically calculated by ETABS
Live load (LL)	1.92 kN/m²
Roof live load (Lr)	0.96 kN/m²
Superimposed dead load (SIDL)	
Structural system	1.10 kN/m²
Ceramic tiles and mortar	0.19 kN/m²
Ceiling suspension system	0.10 kN/m²
Waterproofing	0.39 kN/m²

3. Analytical procedure

The analytical procedure comprised structural modeling; assignment of material properties and structural-member dimensions; application of gravity and earthquake loads; and dynamic analysis using ETABS. The principal response parameters evaluated were the natural periods of the structure and the earthquake-induced base shear.

RESULTS AND DISCUSSION

The analytical results demonstrate that increasing building height is associated with a longer fundamental natural period. A taller building requires more time to complete one cycle of vibration than a shorter building; consequently, models with a greater number of storeys exhibit longer vibration periods. This response indicates that taller structures are generally more flexible than low-rise structures and therefore respond differently to dynamic actions, particularly earthquake loading (Fauziah et al. 2013).

This behavior affects the spectral acceleration experienced by the structure. As the natural period increases, spectral acceleration generally decreases within the relevant region of the response spectrum, resulting in a relative reduction in base shear. Taller buildings therefore exhibit a distribution of earthquake-induced forces that differs from that of shorter buildings (Zebua 2018).

Despite the relative reduction in base shear, the storey-wise distribution of shear forces in taller buildings becomes more complex. This variation requires careful design of vertical structural elements to ensure that loads are resisted safely and effectively. The increased complexity arises from the progressively stronger interaction among storeys as building height increases. Consequently, the structural response to lateral loading, particularly earthquake loading, is neither simple nor uniform but instead exhibits a more dynamic and uneven force distribution. This observation is consistent with previous findings that taller buildings require stricter control of deformation and interstorey drift to maintain satisfactory structural performance and comply with safety requirements (Tavio and Kusuma 2018).

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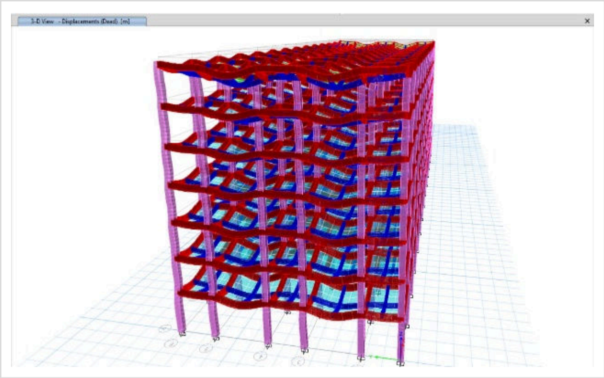

Figure 1. Building structural model in ETABS (CSI 2021)

Figure 1 presents the structural model of an office building planned for Bima City. The floor slabs were designed with a thickness of 12 cm, while the columns and beams were assigned cross-sectional dimensions of 40 × 40 cm and 30 × 50 cm, respectively. These dimensions were not adopted arbitrarily but were adjusted during the structural-design process to ensure that each component could perform adequately under the anticipated loading conditions.

The structural design considered dead loads, live loads, and superimposed dead loads. The member dimensions were therefore modified to provide adequate capacity for safely resisting all applicable loads in accordance with the relevant design standards (Nuranita, Desimaliana, and Sobana 2022).

Name	
Name	Pushover1
Plot Definition	
Plot Type	FEMA 440 EL
Load Case	Pushover
Legend Type	Integrated
Plot Settings	
Plot Axis Type	Sa - Sd
Show Associated Demand	Yes
Demand Spectrum	
Spectrum Source	ASCE 7-10 General
Acceleration Ss	1
Acceleration S1	0,4
Site Class	D
Long Period, Tl (sec)	8
Damping Parameters	
Damping Ratio	0,05
Effective Damping	Default Value
Period Parameters	
Effective Period	Default Value
Capacity Spectrum Curve	
Family of Demand Spectra	
Single Demand Spectrum	
Constant Period Lines	
Performance Point	
Point Found	Yes
Shear (kN)	28467,9376
Displacement (m)	0,423461
Sa (g)	0,30152
Sd (m)	0,342529
T secant (sec)	2,139
T effective (sec)	2,164
Ductility Ratio	1,239052
Damping Ratio, Beff	0,0529
Modification Factor, M	1,024368

Plot Type
The current pushover plot type. This may be V vs Displ (Resultant Base Shear vs Monitored Displacement), FEMA 440 EL (FEMA 440 Equivalent Linearization) or...

Figure 2. FEMA 440 equivalent linearization results

Figure 2 shows that the parameters adopted in the FEMA 440 Equivalent Linearization procedure were consistent with the input values derived from field data and manual calculations. This agreement indicates that the analytical model adequately represented the actual structural conditions and could therefore provide reliable results for structural-performance evaluation. The consistency among field observations, manual calculations, and the FEMA 440 parameters further supports the validity of the analysis and the use of this method as a basis for structural evaluation and design (Desimaliana, Diredja, and Syahputra 2022).

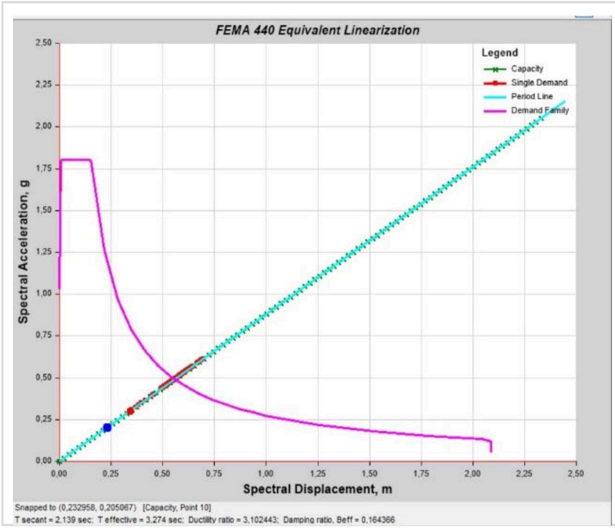

Figure 3. FEMA 440 equivalent linearization capacity curve generated in ETABS (CSI 2021)

The capacity curve presented in Figure 3 indicates that the load-resisting capacity of the building can be improved by strengthening its column elements. As the principal vertical structural components, columns play a critical role in enhancing the ability of the structure to resist applied loads. The addition or modification of columns can significantly increase structural stiffness and strength (Nofri and Mulyani 2026), thereby improving the response to lateral loads and reducing the risk of damage. Structural performance was evaluated through nonlinear pushover analysis. This approach enables a detailed assessment of structural capacity and behavior up to the ultimate condition, allowing the effectiveness of the strengthening system in improving building performance to be determined (Siregar 2026).

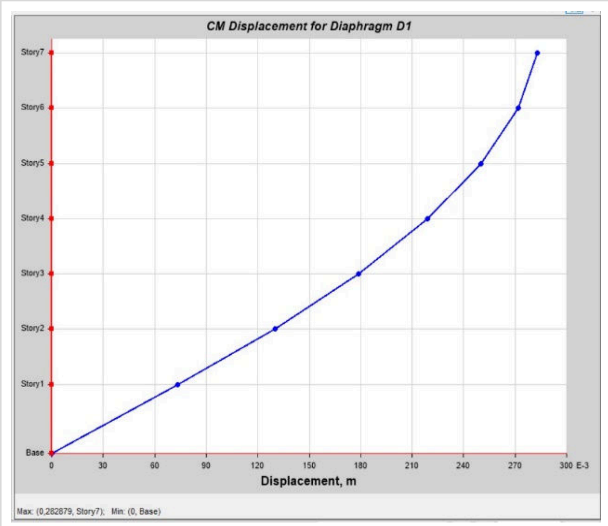

Figure 4. Center-of-Mass Displacement of the Diaphragm

Figure 4 shows that structural displacement increases from the base to the roof, which is consistent with the expected mechanical behavior of a building subjected to lateral loading. This trend indicates that the structure responds elastically to earthquake- or wind-induced forces in accordance with the distribution of storey shear.

1. Characteristics of Lateral Displacement
In a building structural system, lateral displacement accumulates with height. The base (Level 0) is typically idealized as a fixed support with zero displacement. At progressively higher storeys, the accumulated flexibility of the columns and beams below produces a greater absolute displacement, with the maximum value generally occurring at roof level. A smooth, approximately linear or mildly parabolic displacement profile depending on structural stiffness indicates a reasonably regular distribution of interstorey stiffness. The total lateral displacement at the roof is referred to as roof displacement, whereas the relative displacement between two adjacent floors is termed interstorey drift.

2. Compliance with the Interstorey Drift Limit
Although the graph indicates increasing displacement with height, SNI 1726:2019 requires the design interstorey drift to remain below the allowable limit (Δa). This requirement is intended to prevent damage to nonstructural components, such as glazing and partition walls, and to preserve occupant comfort and safety.

According to the standard, the design interstorey drift (Δ) must satisfy the following requirement:
A = Δ≤Δ

where Δa generally ranges from 1% to 2% of the storey height, depending on the building risk category and structural system.

3. Distribution of Forces and Structural Stiffness
A displacement profile that conforms to the expected structural response reflects two principal considerations. First, the P–Delta effect indicates that the analysis accounts for the influence of gravity loads acting on a laterally deformed structure. Second, the relationship between the center of mass and the center of rigidity governs torsional response. Relatively uniform floor displacements without excessive torsion suggest that these centers are sufficiently close, which is a fundamental consideration in earthquake-resistant structural design (Istiono et al. 2023).

CONCLUSIONS

The results demonstrate that building height significantly influences the fundamental natural period of a structure: increasing height generally produces a longer vibration period. The increase in building height is also associated with a relative reduction in seismic base shear because the longer structural period modifies the dynamic response. ETABS proved useful for evaluating the seismic response of multi-storey buildings accurately and efficiently. These findings may serve as a reference for the design of multi-storey building structures, particularly for satisfying structural-safety requirements under earthquake loading.

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