

# Seismic Performance of Urban Buildings with Absence Seismic Gaps: A Study on the Effects of Concrete Grades and Column Sizes

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**Abstract-** *In today's world, buildings are often found to be constructed with absence seismic gaps because of unplanned urbanization, limited availability of land, and peoples demand. Urban buildings in close proximity are often constructed without adequate seismic separation gaps, resulting in the potential for damaging interactions during earthquakes. This study investigates the seismic performance of urban buildings with absence seismic gaps, focusing specifically on the influence of varying concrete grades and column sizes. Ten structural configurations were modeled, ranging from single buildings of uniform material to adjoining buildings with differing concrete strengths (M20, M25), varied column dimensions (350 × 350 mm, 400 × 400 mm), and height differences. Time history analysis was conducted using the 2015 Gorkha Earthquake ground motion to evaluate storey displacement, inter-storey drift, base shear, and overturning moment for each configuration. Results indicate that adjoining buildings with different concrete grades but identical heights exhibit the highest seismic demands, while single buildings with uniform higher-grade concrete perform best across all measured parameters. The findings highlight the significant influence of material inconsistency and column sizing on seismic response when separation gaps are absence. The study concludes with design recommendations for minimizing seismic vulnerability in dense urban environments and suggests directions for future research on structural interaction mitigation.*

**Index Terms-** *Absence seismic gaps, Inter-storey drift, Time History Analysis, Seismic Performances.*

## I. INTRODUCTION

Nepal is situated on the Alpine-Himalayan belt, a high-seismicity region where the interaction between the Indian and Eurasian plates causes significant crustal stress. The 2015 Gorkha Earthquake (7.8 Mw) highlighted the extreme vulnerability of the country's urban infrastructure, where approximately 9,000 lives were lost due to the collapse of non-engineered and poorly detailed reinforced concrete (RC) structures.

In rapidly urbanizing centers, land scarcity has led to the construction of adjacent buildings with an absolute absence of seismic separation gaps. This practice contradicts international standards (IS 1893, ASCE 7-16) and the Nepal National Building Code (NBC 105:2020), which mandate clear distances to prevent structural pounding. When gaps are absent, adjacent structures with differing dynamic characteristics—such as mass, height, or stiffness—respond asynchronously to ground motion. This leads to complex dynamic coupling, increased lateral demand, and amplified storey drifts that are not accounted for in isolated building designs.

Recent updates to NBC 105:2020 have transitioned material requirements from pre-2015 standards (M10/M15 concrete and 230mm columns) to higher-grade concrete (M20/M25) and larger sections (350mm to 400mm). This study investigates whether these enhanced material properties and geometric configurations can effectively compensate for the absence of seismic gaps. By performing Elastic Time History Analysis (ETHA) based on the 2015 Gorkha Earthquake data, this research quantifies the influence of concrete grade and column sizing on key seismic parameters, including storey displacement, base shear, and overturning moments. The objective is to provide

actionable design recommendations for improving structural resilience in dense, unplanned urban environments where standard seismic separation is no longer feasible.

## II. RESEARCH ELABORATIONS

The methodology of this study is grounded in a systematic evaluation of structural response parameters-including storey displacement, inter-storey drift, base shear, and overturning moments-under dynamic seismic loading. To establish a realistic baseline, Birendranagar, Surkhet was selected as the study area due to its location in a high-risk seismic zone (Zone V) and its characteristic rapid, unplanned urbanization where seismic separation gaps are typically absent.

The core of the research involves the development of ten representative analytical models (M-1 to M-10) using ETABS software, categorized into single-frame and adjoined-frame configurations.

M-1 to M-3: Single isolated buildings (M20/M25, 350mm/400mm columns).

M-4 to M-7:

Adjoined buildings of equal height with varying material properties.

M-8 to M-10: Adjoined buildings of unequal heights (4-storey vs 5-storey) to simulate irregular urban growth.

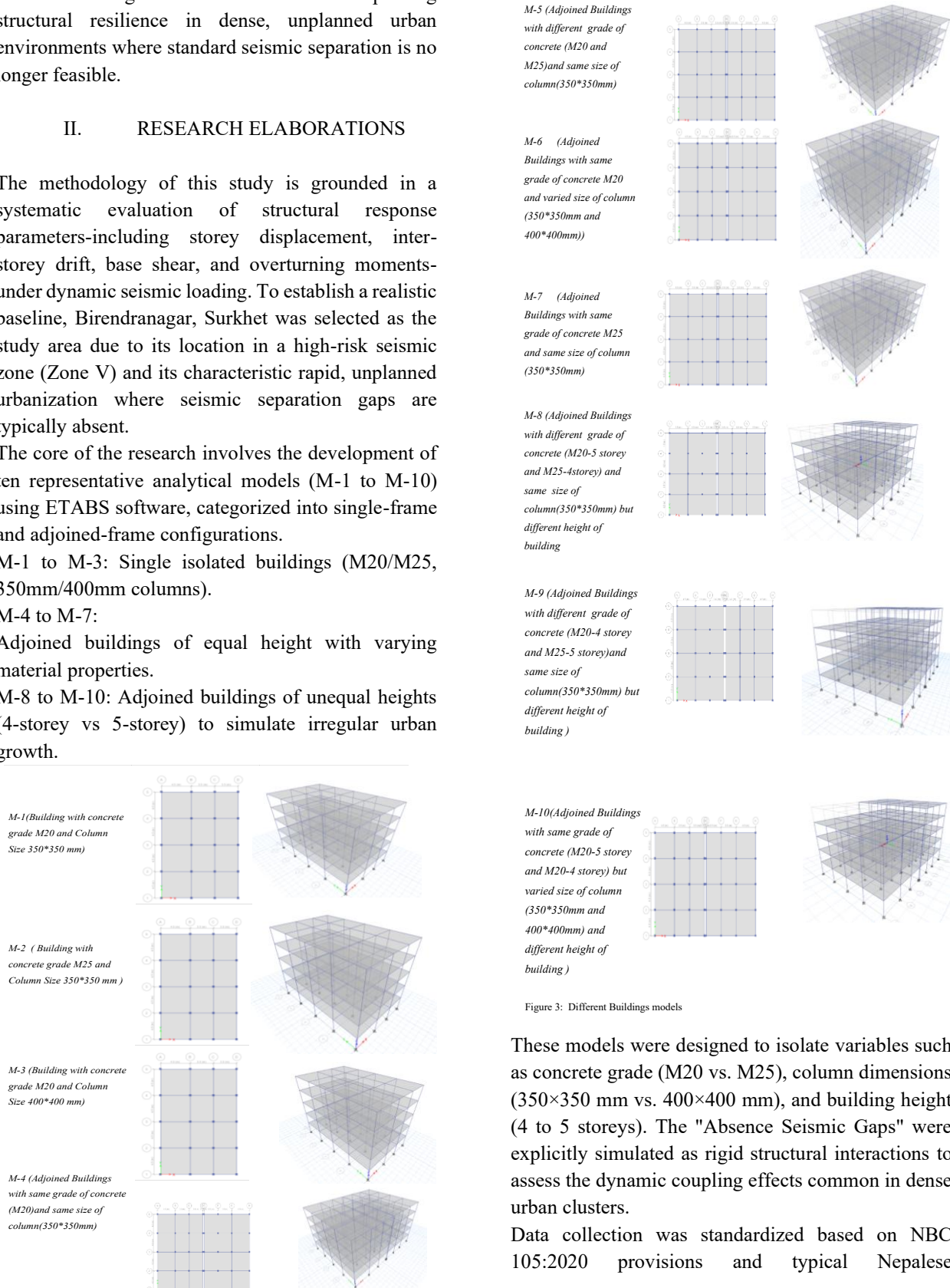


Figure 3: Different Buildings models

These models were designed to isolate variables such as concrete grade (M20 vs. M25), column dimensions (350×350 mm vs. 400×400 mm), and building height (4 to 5 storeys). The "Absence Seismic Gaps" were explicitly simulated as rigid structural interactions to assess the dynamic coupling effects common in dense urban clusters.

Data collection was standardized based on NBC 105:2020 provisions and typical Nepalese

construction practices. Key structural specifications included:

Member Sizes: Beams (230mm x 300mm), Slabs (125mm), and varying Column sections.

Materials: Concrete grades M20/M25 and HYSD-500 grade steel.

Seismic Input: A primary component of this research is the utilization of Elastic Time History Analysis (THA). The accelerogram from the 2015 Gorkha Earthquake was processed and scaled to ensure site-specific accuracy.

The dynamic equilibrium of the systems was analyzed using the governing equation of motion

$[M]\{u''(t)\} + [C]\{u'(t)\} + [K]\{u(t)\} = -[M]\{r\}u''g(t)$  where damping properties were approximated using Rayleigh damping coefficients to achieve a 5% target ratio for RC structures. This comprehensive modeling approach allows for a controlled parametric comparison of how modern material standards (M25, 400mm columns) perform against older, gap-deficient structural configurations.

### III. RESULTS AND FINDINGS

The seismic performance of ten structural configurations was evaluated using Elastic Time History Analysis (THA). The results focus on four critical parameters: Maximum Storey Displacement, Storey Drift, Base Shear, and Overturning Moment:

#### A) Seismic Response Parameter

The results indicate that the absence of seismic gaps leads to a substantial increase in seismic demand. Model M-4 (adjoined buildings with M20 concrete) exhibited the highest vulnerability across all parameters.

1) Storey Displacement: Single buildings using M25 concrete (M-2) recorded a roof displacement of 28.50 mm, significantly lower than the 42.09 mm recorded for M20 concrete (M-1). However, when two M20 buildings were adjoined without a gap (M-4), displacement surged to 51.07 mm—a 21.3% increase over the isolated model.

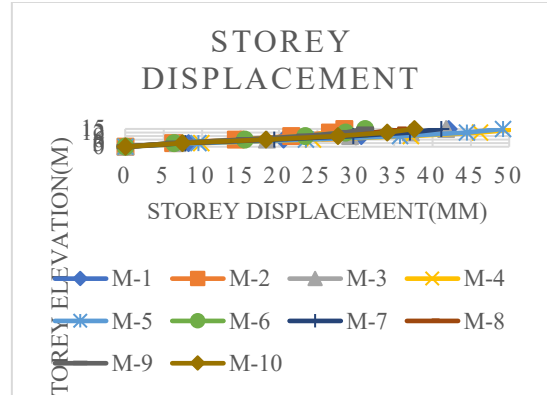


Figure 1: Storey Displacement

2) Storey Drift: The peak storey drift was observed in Model M-4 at 0.00485 (Story 2). In contrast, increasing the column size to 400x400 mm in adjoined configurations (M-6) effectively reduced the drift to 0.00308, bringing the structure within safer performance limits.

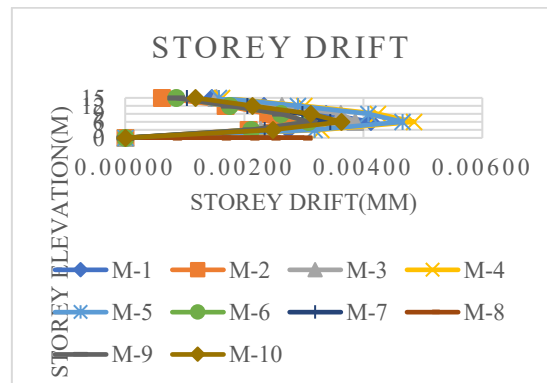


Figure 1: Storey Drift

3) Base Shear and Overturning Moment: Adjoining structures attracted significantly higher seismic forces. M-4 recorded a maximum base shear of 1468.60 KN, which is a 123% increase compared to the isolated M-1 (656.89 KN). Similarly, the overturning moment peaked in M-4 at 15072.29 KN-m. The introduction of 400x400 mm columns in Model M-6 successfully mitigated this, reducing the moment to 4914.24 KN-m

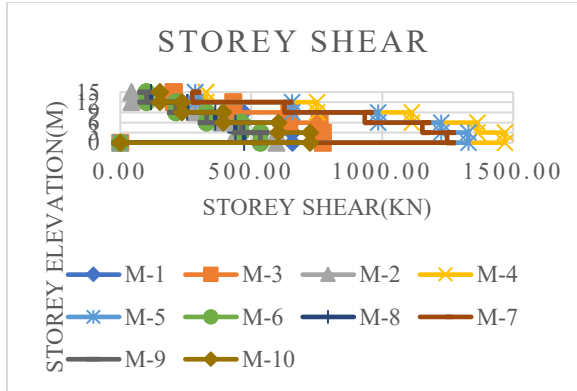


Figure 1: Storey Shear

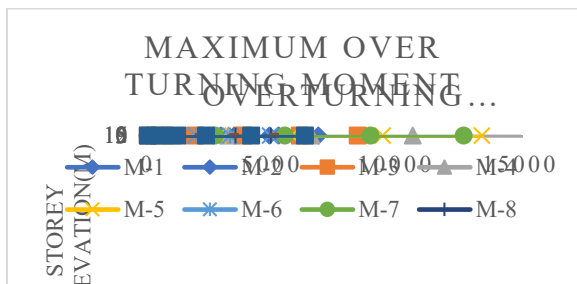


Figure 1: Over Turning Moment

*B)Comparative Analysis and Discussion*

The findings highlight three primary factors influencing structural behavior in dense urban environments:

**Effect of Adjoining Structures:** The absence of separation gaps forces buildings to act as a coupled system, significantly amplifying lateral demand. The mismatch in stiffness between adjoining units (M-5) leads to asynchronous vibration, exacerbating drift.

**Influence of Concrete Grade:** Upgrading from M20 to M25 concrete increases the elastic modulus and structural stiffness. This study confirms that M25 grade concrete is a critical requirement for reducing flexibility in buildings where physical gaps are missing.

**Role of Column Size:** Increasing column dimensions from 350x350 mm to 400x400 mm proved to be the most effective intervention. Even in adjoining models (M-6), the larger columns acted as a structural "buffer," reducing displacement and providing the

stability necessary to prevent collapse during high-intensity shaking.

**Vertical Irregularity (Step-back Models):** Models M-8 through M-10 showed that height asymmetry disrupts resonant vibration. While this can sometimes reduce global displacement compared to equal-height adjoined models, material mismatch (M-10) can still lead to localized stress concentrations at the roof level of the shorter building.

**VI.CONCLUSION AND RECOMMENDATIONS**

The analytical study on the seismic performance of urban reinforced concrete buildings with absence seismic gaps leads to several critical conclusions regarding structural resilience in dense urban environments

**A. Conclusions**

- 1) **Concrete Grade Efficiency:** A single, isolated building utilizing M25 grade concrete (Model M-2) demonstrated superior seismic performance. Increasing the concrete grade from M20 to M25 resulted in a 32.2% reduction in maximum roof displacement, confirming that higher material stiffness significantly mitigates lateral flexibility.
- 2) **Vulnerability of Adjoined Structures:** The absence of seismic separation gaps (Model M-4) drastically amplifies structural vulnerability. Adjoined buildings with identical low-strength properties (M20) experienced the highest seismic demands, recording the maximum storey displacement and base shear across all configurations.
- 3) **Column Size Optimization:** In configurations where seismic gaps are deficient, increasing the column size proved to be the most effective intervention. Model M-6 (varied column sizes) achieved a displacement reduction of nearly 38% compared to the adjoined baseline (M-4), outperforming models that only varied concrete grades.
- 4) **Impact of Vertical Irregularity:** Vertically irregular adjoined structures (Step-back models like M-8) recorded lower top-storey displacements than equal-height configurations. This is attributed to the shifting of the pounding interface and the disruption of resonant

frequencies; however, these models still exhibit significant localized stress at the junction level.

- 5) Foundation Demands: Adjoining structures consistently produced significantly higher base shear (up to 123% increase) and overturning moments compared to isolated buildings. This necessitates more robust foundation designs for buildings constructed in close proximity.

#### B. Recommendations

Based on the results of the Time History Analysis, the following recommendations are proposed for urban construction in high-seismicity regions like Nepal:

- 1) Material Uniformity: For new construction in dense urban clusters, a uniform grade of high-strength concrete (minimum M25) should be adopted across adjoining buildings to minimize stiffness mismatch and asynchronous vibration.
- 2) Structural Sizing: In land-scarce areas where standard seismic gaps are impractical, designers should utilize larger column sections (minimum 400x400 mm) to act as a structural buffer against increased lateral loads.
- 3) Advanced Mitigation: Future research and high-occupancy projects should explore the integration of base isolation systems or energy dissipation devices to decouple structural response from ground motion in gap-deficient sites.
- 4) Future Scope: Subsequent studies should incorporate soil-structure interaction (SSI) and nonlinear pounding effects to further refine the safety parameters for unplanned urban developments.

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