A Comparative Study on Column-Beam Dimensions and Reinforcement Percentages of RC Buildings across Different Seismic Zones in Bangladesh

By

MD AL AMIN

KAIUM HASAN

OMAR FARUK

MD. MOSHIUR RAHMAN

MD.MEHEDI HASAN

MD. HASAN MORSHED

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Department of Civil Engineering

Sonargaon University

147/I, Green Road, Dhaka-1215, Bangladesh

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By

MD ALAMIN	CE2202026098
KAIUM HASAN	CE2202026066
OMAR FARUK	CE2202026017
MD MOSHIUR RAHMAN	CE2202026080
MD MEHEDI HASAN	CE2202026107
MD. HASAN MORSHED	CE2202026047

Supervisor
M. A. Bashar Bhuiyan
Assistant Professor
Dept. of Civil Engineering
Sonargaon University (SU)

A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering

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………………………………………

1. M. A. Bashar Bhuiyan — Chairman
   Assistant Professor
   Dept. Of Civil Engineering
   Sonargaon University

………………………………………

2. Internal / External Member — Member

………………………………………

3. Internal / External Member — Member

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STUDENT NAME	STUDENT ID.	SIGNATURE
Md Al Amin	CE2202026098	…………………………
Kaium Hasan	CE2202026066	…………………………
Omar Faruk	CE2202026017	…………………………
Md. Moshiur Rahman	CE2202026080	…………………………
Mehedi Hasan	CE2202026107	…………………………
Md. Hasan Morshed	CE2202026047	…………………………

Dedicated

to

“Our Respectful Teachers & Parents”

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ABSTRACT

According to, the Bangladesh National Building Code (BNBC 2020) divides the country into four seismic zones based on seismic risk levels. This study evaluates the structural response of an 8-story reinforced concrete building across these zones, focusing on the final beam and column section sizes and the required reinforcement percentages. The analysis uses the Equivalent Lateral Force (ELF) procedure, with earthquake, wind, and gravity loads assigned according to BNBC 2020 guidelines. Structural modeling and design are carried out in ETABS based on American Concrete Institute code provisions under a Special Moment Resisting Frame (SMRF) system. Service conditions are checked using property modifiers defined in BNBC 2020 to evaluate story drift limitations, sway, soft story effects, and torsional irregularity. Ultimate strength checks are performed using ACI 318-11 property modifiers. The final section sizes are selected after ensuring that beam-column capacity ratios satisfy both service and ultimate requirements. The comparative results show that structures in Seismic Zone 4 require the highest reinforcement and largest section dimensions, followed by Zones 3, 2, and 1.

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CHAPTER 1

INTRODUCTION

1.1 Background and Motivations

Bangladesh is located near the boundaries of the Indian, Eurasian, and Burmese tectonic plates, making the country vulnerable to seismic activities and earthquake-induced structural damage. In recent years, the rapid urbanization and construction of multi-story reinforced concrete buildings in major cities of Bangladesh have increased the importance of earthquake-resistant structural design. To address seismic safety concerns, BNBC 2020 divides the country into four different seismic zones based on seismic hazard intensity. Each zone has different seismic coefficients and design requirements, which directly influence the dimensions and reinforcement requirements of structural members.

The design of beams and columns is one of the most critical aspects of reinforced concrete structures, particularly in seismic regions. Structural members must be capable of resisting gravity, wind, and earthquake loads while maintaining adequate strength, stiffness, and ductility. As seismic intensity increases, the demand for larger member sizes and higher reinforcement percentages also increases to ensure structural stability and safety. Therefore, understanding how seismic zoning affects beam-column dimensions and reinforcement requirements is essential for economical and safe structural design.

Although several studies have been conducted on seismic analysis and building performance in Bangladesh, limited research has focused on the comparative variation of beam and column dimensions and reinforcement percentages across different seismic zones using the updated BNBC 2020 provisions. Most previous studies mainly concentrated on displacement, base shear, or overall structural behavior. As a result, practicing engineers and researchers still require a clearer understanding of how seismic zoning directly influences member sizing and reinforcement detailing in reinforced concrete buildings.

To address this research gap, the present study investigates an eight-story reinforced concrete building subjected to different seismic zones of Bangladesh using the Equivalent Lateral Force

(ELF) method. The structural analysis and design are performed using ETABS 16.2.1 to evaluate the changes in beam-column dimensions and reinforcement percentages under varying seismic demands. The findings of this study are expected to provide useful guidelines for structural engineers in achieving safe, efficient, and code-compliant building design in different seismic regions of Bangladesh.

1.2 Research Objectives and Overview

The primary objective of this research is to investigate the influence of different seismic zones of Bangladesh on the beam-column dimensions and reinforcement requirements of an eight-story reinforced concrete building designed according to BNBC 2020. The study aims to evaluate how variations in seismic intensity affect the final cross-sectional dimensions and longitudinal reinforcement percentages of structural members.

To achieve this objective, a comparative analysis is performed using the Equivalent Lateral Force (ELF) method, where the same building configuration is analyzed under Seismic Zones 1, 2, 3, and 4. The structural modeling and design are carried out using ETABS 16.2.1 while maintaining identical material properties, loading conditions, and geometric configurations for all zones to ensure a reliable comparison.

The scope of this study is limited to a regular-shaped eight-story reinforced concrete building subjected to gravity, wind, and earthquake loads as specified in BNBC 2020. The research mainly focuses on the variation of beam and column dimensions, reinforcement percentages, serviceability performance, and beam-column capacity ratio requirements under different seismic demands. Advanced nonlinear dynamic analyses, soil–structure interaction, and irregular building configurations are not included within the scope of this study.

The significance of this research lies in providing a clearer understanding of how seismic zoning influences structural member sizing and reinforcement detailing in Bangladesh. Unlike many previous studies that mainly focused on displacement or base shear response, this study specifically emphasizes the practical design aspects of beam-column dimensions and reinforcement requirements. The findings are expected to serve as a useful reference for practicing structural engineers during preliminary design and optimization of reinforced concrete buildings in different seismic regions.

The specific objectives of the study are summarized as follows:

- To analyze an eight-story RC building in different seismic zones of Bangladesh.
- To compare beam and column sizes for Zones 1–4.
- To evaluate reinforcement percentage variations in structural members.

The expected outcome of this research is a comparative understanding of how seismic zoning affects structural member dimensions and reinforcement demands, which can contribute to safer, more efficient, and code-compliant structural design practices in Bangladesh.

1.3 Organization of the thesis

This thesis is organized into several chapters to present the research systematically and clearly. Each chapter focuses on a specific aspect of the study related to the comparative analysis of beam-column dimensions and reinforcement requirements across different seismic zones of Bangladesh. A brief description of each chapter is provided below:

- **Chapter 1: Introduction**
  This chapter presents the background, motivation, objectives, scope, significance, and overall organization of the research. It also highlights the research problem and the importance of seismic design considerations in Bangladesh.
- **Chapter 2: Literature Review**
  This chapter reviews previous research related to seismic analysis, reinforced concrete building behavior, BNBC seismic provisions, and beam-column design requirements. It also identifies the research gap addressed in this study.
- **Chapter 3: Methodology**
  This chapter describes the analytical procedures adopted in the study, including building modeling, loading conditions, material properties, seismic analysis methods, and design criteria. It also explains the use of ETABS 16.2.1 and the application of BNBC 2020 provisions.

- **Chapter 4: Results and Discussion**

  This chapter discusses the analysis results, including beam and column dimensions, reinforcement percentages, and structural performance across different seismic zones. Comparative discussions and engineering interpretations are also presented.

- **Chapter 5: Conclusion and Recommendations**

  This chapter summarizes the major findings of the study and presents conclusions based on the analysis results. It also includes the limitations of the research and recommendations for future studies.

CHAPTER 2

Literature Review

2.1 Introduction

The geographical position of Bangladesh in the close proximity of active tectonic boundaries—essentially the Indian, Eurasian, and Burmese plates—places it highly susceptible to seismic hazard (e.g., M 7+ earthquakes).(Hossain et al., 2022; Mazumder et al., 2018; Shohag & Mozumder, 2022) In response to such exposure, the Bangladesh National Building Code (BNBC) has been updated extensively, giving rise to the 2020 code (BNBC-2020), which classifies the country into four seismic zones, each defining different ground motion potential.(F. Rahman & Rahman, 2022; Samm-A et al., 2025; Sarraz, 2015) These zones, ranging from low (Zone-1, Z = 0.12 g) to very severe (Zone-4, Z = 0.36 g), provide a more advanced, probabilistic foundation for structural design.(Abdullah et al., 2021; Al-Hussaini et al., 2012)

The shift from BNBC-2006 to BNBC-2020 shows a movement towards more conservative seismic coefficients, i.e., larger zone coefficients, new response modification factors (R), latest importance factors (I), and more stringent detailing requirements for structural frames like SMRFs (Special Moment Resisting Frames).(Mazumder & Khair, 2015; M. Z. Rahman et al., 2015; Steckler et al., 2016) For instance, BNBC-2020 not only includes a fourth seismic zone but also specifies lower values of R, thereby infusing higher design base shearing forces and improving structural resilience outcomes.(Ambraseys & Douglas, 2004; M. Z. Rahman et al., 2018)

Recent research has employed these updated provisions to model and compare building response data for seismic areas. Alam Riad et al. (2023) modeled a G+5 residential building under identical loads, differing only in seismic coefficient and wind load by zone, and observed considerable differences in responses like drift and base shear.(Bhatia et al., 1999) Correspondingly, a study with the use of ETABS to model structures under BNBC-2020 guidelines established that structures in the upper zones—specifically Zone-4—have greater structural requirements, like stiffness, displacement, and reinforcement requirements.(Ansary, 2002; Bilham, 2004; Bilham & England, 2001)

Yet despite such reports, the literature remains deficient in direct comparison of member size—beams and columns—and reinforcement ratios between zones in loading with the same ELF

(Equivalent Lateral Force) method.(Bahuguna & Sil, 2020) Moreover, the influence of serviceability constraints and capacity ratio satisfaction on ACI 318-08 (service) and ACI 318-11 (ultimate) specifications in the background of BNBC-2020 zonal variance is not pursued systematically.(Rana et al., 2023) There are limited studies that compare RC structures using ELF methods and indicate that while BNBC-2020 ensures safety, it can also contribute to increased costs, especially in higher zones like Zone-3.(Riad et al., 2023a)

Thus, in this study, the BNBC-2020-compliant ELF approach—merging gravity, wind, and seismic loads together in ETABS 16.2.1—is used to analyze how seismic zoning affects ultimate section sizes and reinforcement ratios for columns and beams in SMRF systems. Applying ACI-based property modifiers (PM) in both ultimate and serviceability limit states—and capacity ratio compliance—it offers comparative analysis of Zones 1 to 4. The research demonstrates that Zone-4 needs the most reinforcement and member sizes, further proving the need for zone-sensitive design towards ensuring safety and economic equilibrium.

2.2 Content

The literature review presented in this chapter is organized into several sub-sections to provide a clear understanding of previous studies related to seismic analysis and structural design of reinforced concrete buildings. The reviewed studies mainly focus on seismic zoning in Bangladesh, earthquake-resistant design provisions, beam-column behavior, reinforcement detailing, and the structural performance of reinforced concrete buildings under seismic loading.

This chapter also discusses the development and application of BNBC 2020 provisions and their influence on structural analysis and design practices. Different seismic analysis methods, including the Equivalent Lateral Force (ELF) method and advanced dynamic analysis techniques, are reviewed to establish the theoretical background of the present study.

In addition, previous research conducted using ETABS 16.2.1 and similar structural analysis tools is examined to understand the variation of structural response, member dimensions, and reinforcement requirements under different seismic conditions.

The literature review further identifies the limitations and research gaps in earlier studies, particularly regarding the comparative evaluation of beam-column dimensions and reinforcement percentages across different seismic zones of Bangladesh. These research gaps provide the primary motivation and significance of the present thesis work

2.3 Summary

This chapter reviewed the previous studies related to seismic analysis and design of reinforced concrete buildings, particularly under the provisions of BNBC 2020. The reviewed literature highlighted the effects of seismic zoning on structural behavior, beam-column dimensions, and reinforcement requirements. Various seismic analysis approaches and structural modeling techniques using ETABS 16.2.1 and similar tools were also discussed. In addition, the limitations and research gaps identified in previous studies established the motivation and significance of the present research. The findings from the literature review provide the theoretical foundation for the methodology and analysis procedures presented in the following chapter.

CHAPTER 3

Methodology

3.1 Introduction

This chapter presents the methodological framework adopted to evaluate the variation of column and beam dimensions, as well as reinforcement percentages, across different seismic zones of Bangladesh. The analysis is carried out in accordance with the provisions of BNBC 2020, using a systematic and comparative approach.

To ensure consistency in evaluation, a regular eight-story reinforced concrete building is considered as the reference model, where all structural parameters are kept constant except the seismic zone. The seismic analysis is performed using the Equivalent Lateral Force (ELF) method, which is widely accepted in engineering practice for its simplicity and reliability in preliminary design and comparative studies.

The modeling, analysis, and design of the structure are conducted using ETABS 16.2.1. The study incorporates both serviceability and ultimate limit state checks, including irregularity verification and capacity ratio requirements, to ensure code compliance and structural safety.

3.2 Methodology Overview

A regular-shaped building, as illustrated in Figures 3-1, was modeled for this study. The building has a length of 77 ft and a width of 47 ft. The total height of the 8-story structure is 85 ft, where the ground floor height is 5 ft and the typical floor height for the remaining stories is 10 ft. The detailed geometric and modeling parameters are presented in Table 3-1 and 3-2.

3.2.1 Structural Components & Properties

The Modeling parameters and all others components like story height, zone factor, area of building, slab thickness, beam and column details are elaborated in Table 3-1 and 3-2 . Irregularity checks evaluated in table 3-3

Table3-1. Structural Modeling Information

Parameters	Remarks
Diaphragm	Rigid
Mesh Option	Floor Auto Mesh (12) inches
Base Support	Fixed
Stair Slab	6 inches
Floor Slab	5 inches

Table3- 2. Static Analysis Parameters for (ELF)

Parameters	Remarks
Concrete Strength f'_c	4000 psi
Steel Strength Fy	72500 psi
Soil Type	SD
Occupancy Category	IV
Earthquake Load	As per BNBC 2020
Wind Load	As per BNBC 2020
Load combination	As per BNBC 2020
Stiffness Modifier	As per ACI-10.11.1
Design Code	ACI 318-08
Partition load	50 psf
Floor Finish Load	25 psf
Floor Live Load	100 psf

Table3- 3. Irregularity Checks

Checks	Remarks
Serviceability	Ok
Overall Sway	OK
Sway Limitation	No Sway
Torsion Irregularity	No Irregularity
Soft Story	No soft story
Story Drift	No story Drift

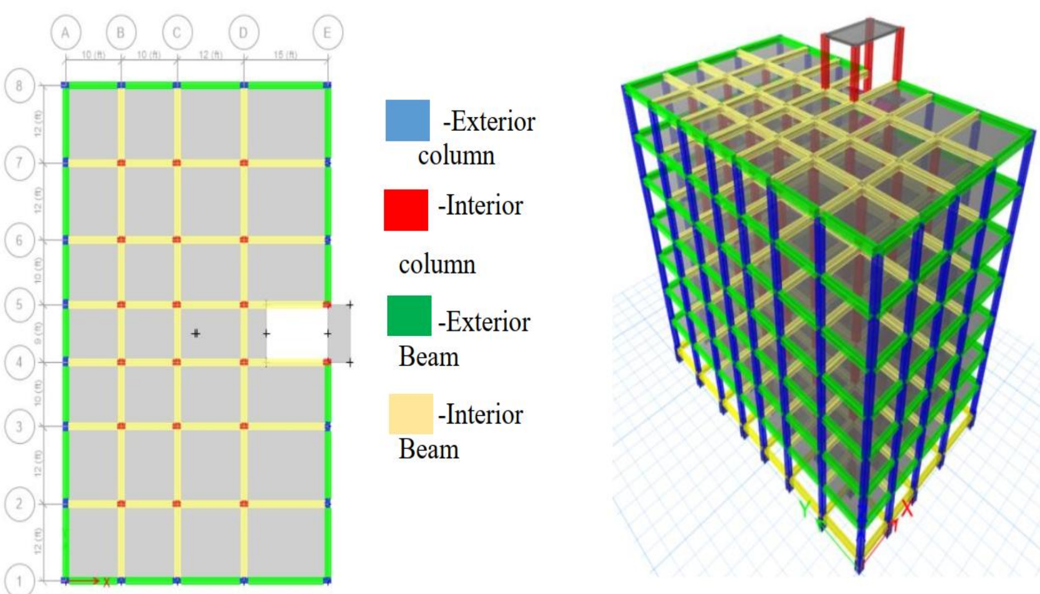

Figure 3-1: Building plan and 3D view

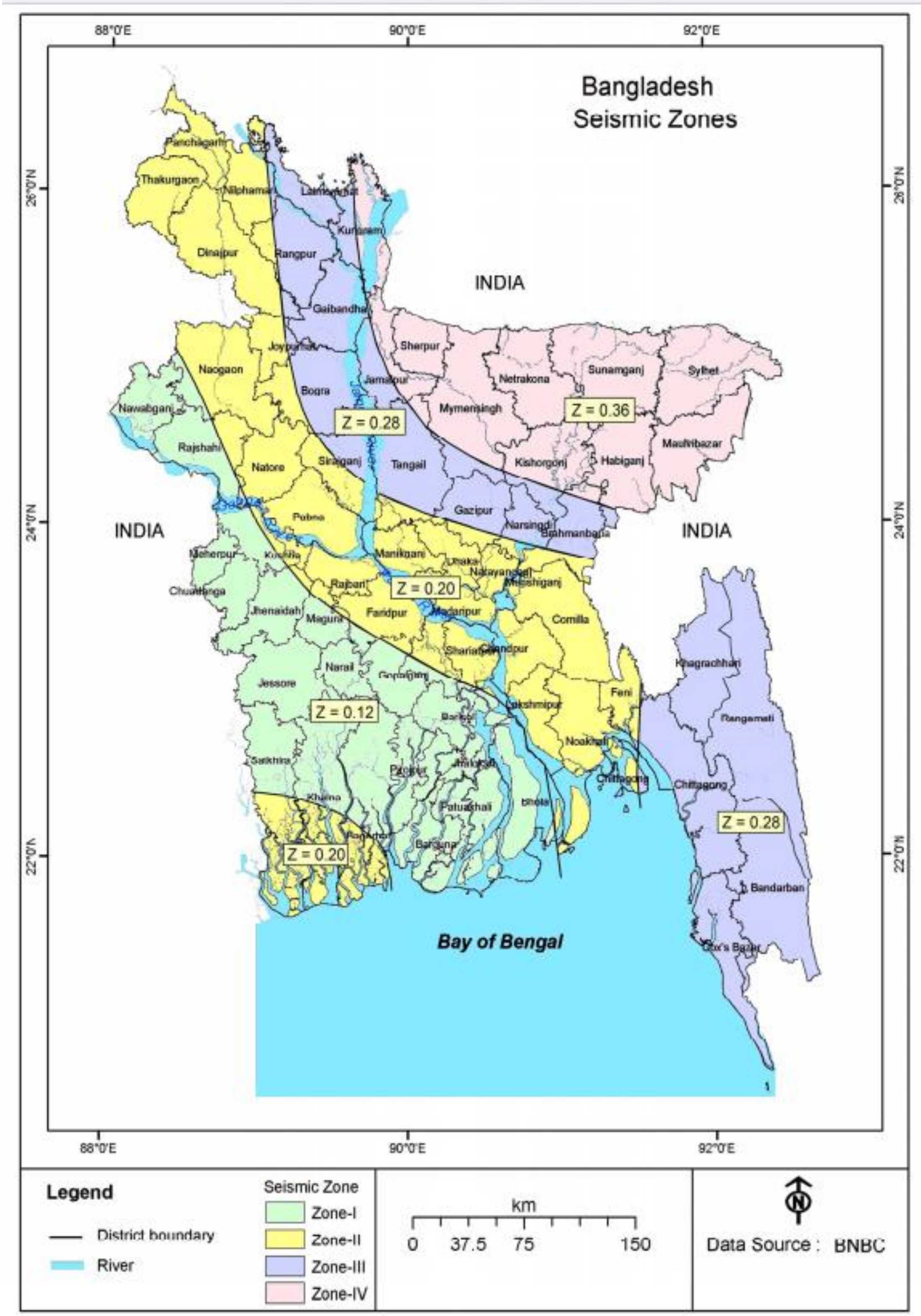

Figure 3-2: Bangladesh Seismic Zones Map

3.3 Summary

This study examines the influence of seismic zoning on the dimensions and reinforcement requirements of structural members in an eight-story reinforced concrete building using the Equivalent Lateral Force (ELF) method in accordance with BNBC 2020. To ensure a consistent and reliable comparison, a regular building configuration is considered, where all design parameters are kept constant except the seismic zone. The structural modeling and analysis are performed using ETABS 16.2.1, and all loading conditions, including gravity, wind, and seismic loads, are applied as per BNBC 2020 provisions. The methodology involves serviceability evaluation, application of property modifiers, and verification of structural irregularities to ensure compliance with code requirements. After completing the analysis, beam–column capacity ratios are checked to confirm proper strength hierarchy and structural safety. Based on these capacity checks, the final beam and column sections are selected, and the corresponding reinforcement ratios are determined considering ultimate limit state requirements, ensuring a safe, efficient, and code-compliant structural design.

CHAPTER 4

Results and Discussion

4.1 Introduction

This chapter presents the results obtained from the structural analysis and design of the selected eight-story reinforced concrete building under different seismic zones of Bangladesh. The primary focus is on evaluating the variation in column and beam cross-sectional dimensions, as well as reinforcement requirements, in response to increasing seismic intensity.

Following the application of ultimate condition property modifiers and verification of beam–column capacity ratios in accordance with BNBC 2020, the final structural member sections were selected. These sections represent the optimized design that satisfies both strength and serviceability requirements.

The results are categorized based on different structural components, including short columns, interior and exterior columns, as well as grade beams and floor beams. A comparative analysis is carried out across Seismic Zones 1 to 4 to identify trends and variations in member sizes and reinforcement demands.

The findings are presented through tabulated data and graphical representations to provide a clear understanding of how seismic zoning influences structural design parameters. The subsequent sections discuss these results in detail, highlighting key observations and their engineering implications.

Result are shown in different table and graph table 4-1 show the overall final column and beam dimensions table 4-5 show the square dimension, table 4-6 ,4-7 show column bean reinforcement in zone 1,table 4-8 and 4-9 show the

Table 4-1. Final Column and Beam dimensions for every seismic zone (area dimension)

	Remarks	Zone-1 (In^2)	Zone-2 (In^2)	Zone-3 (In^2)	Zone-4 (In^2)
Column	Exterior Column	180	216	216	252
	Interior Column	225	216	270	315
	Short Column	270	270	270	315
	Elevation A All Grid for Stories 2 And 3 Column			270	
	Elevation of A 4-Storey Column for All Grids				315
Beam	Grade Beam	216	216	216	216
	Interior Floor Beam	180	216	252	252
	Exterior Floor Beam	180	180	180	216

Table 4-2. Final Column and Beam dimensions for every seismic zone (square dimension)

	Remarks	Zone-1(In)	Zone-2(In)	Zone-3(In)	Zone-4(In)
Column	Exterior Column	12 X 15	12 X 18	12 X 18	12 X 21
	Interior Column	15 X 15	12 X 18	15 X 18	15 X 21
	Short Column	15 X 18	15 X 18	15 X 18	15 X 21
	Elevation A All Grid for Story 2 And 3 Column			15 X 18	
	Elevation of A 4-Storey Column for All Grid				15X21
Beam	Grade Beam	12 X 18	12 X 18	12 X 18	12 X 18
	Interior Floor Beam	12 X 15	12 X 18	12 X 21	12 X 21
	Exterior Floor Beam	12 X 15	12 X 15	12 X 15	12 X 18

The design of column and beam reinforcement was performed considering the ultimate condition property modifiers. The results indicate that the highest reinforcement percentages occur in Stories 1 and 2. The reinforcement details for Seismic Zones 1 through 4 are presented in separate tables for clarity.

Among the four zones, Zone 1 requires the smallest column and beam cross-sectional areas, in comparison to Zones 2, 3, and 4. The longitudinal reinforcement ratio for the columns remains approximately 1% for all column sections considered. The reinforcement specifications for the columns and beams are summarized in Tables 4-6 and 4-7, respectively.

Table 4-3. Column reinforcement for Zone-1

Section	Name	Size (Inch)	Maximum Longitudinal Reinforcement Percentage
Column	Short Column	15X18	1%
	Interior Column	15X15	1%
	Exterior Column	12X15	1%

Table 4-4. Beam reinforcement for Zone-1

Section	Name	Size (inch)	Phase of Beam	Maximum longitudinal reinforcement percentage		
				Left side	Middle side	Right side
Beam	Grade Beam	12X18	Top phase	0.49%	0.22%	0.16%
			Bottom phase	0.41%	0.23%	0.16%
	Interior beam	12X15	Top phase	0.48%	0.15%	0.40%
			Bottom phase	0.23%	0.30%	0.23%
	Exterior Beam	12X15	Top phase	0.39%	0.19%	0.33%
			Bottom phase	0.31%	0.23%	0.27%

Zone 2 exhibits the smallest reinforcement area when compared to Zones 3 and 4. The detailed reinforcement requirements, along with the corresponding beam and column cross-sectional areas, are presented in Tables 4-8 and 4-9.

Table 4-5. Column and reinforcement for Zone-2

Section	Name	Size (Inch)	Maximum Longitudinal Reinforcement Percentage
Column	Short Column	15x18	1%
	Interior Column	12X18	1.16%
	Exterior Column	12X18	1%

Zone 3 requires larger beam and column cross-sectional areas compared to Zone 2; however, these areas remain smaller than those required in Zone 4. The corresponding beam and column dimensions, along with their reinforcement details, are provided in Tables 4-10 and 4-11.

Table 4-6. Beam reinforcement percentage Zone-2

Section	Name	Size (Inch)	Phase of Beam	Maximum Longitudinal Reinforcement Percentage		
				Left Side	Middle Side	Right Side
Beam	Grade Beam	12X18	Top Phase	0.27%	0.09%	0.26%
			Bottom Phase	0.27%	0.11%	0.24%
	Interior Beam	12X18	Top Phase	0.52%	0.17%	0.42%
			Bottom Phase	0.25%	0.28%	0.26%
	Exterior Beam	12X15	Top Phase	0.77%	0.23%	0.73%
			Bottom Phase	0.66%	0.31%	0.61%

Table 4-7. Column reinforcement for Zone-3

Section	Name	Size (inch)	Maximum Longitudinal Reinforcement Percentage
Column	Short Column	15X18	1.45%
	Interior Column	15X18	1%
	Exterior Column	12X18	1%
	Elevation A Under A 3-Story Column	15X18	1%

Table 4-8. Beam reinforcement of Zone -3

Section	Name	Size (Inch)	Phase of Beam	Maximum Longitudinal Reinforcement Percentage		
				Left Side	Middle Side	Right Side
Beam	Grade Beam	12X18	Top Phase	0.57%	0.31%	0.63%
			Bottom Phase	0.54%	0.30%	0.54%
	Interior Beam	12X21	Top Phase	0.55%	0.24%	0.54%
			Bottom Phase	0.44%	0.25%	0.44%
	Exterior Beam	12X15	Top Phase	1.02%	0.28%	0.96%
			Bottom Phase	0.87%	0.35%	0.86%

In Seismic Zone 4, the beam and column dimensions exhibit the most significant increase compared to all other zones. Notably, the columns in Zone 4 undergo substantial dimensional modifications beginning from the fourth story, whereas the column dimensions in the other seismic zones remain unchanged throughout the building height. These variations are presented in detail in Tables 4-12 and 4-13.

Table 4-9. Column and reinforcement for Zone 4

Section	Name	Size (inch)	Maximum Longitudinal Reinforcement Percentage
Column	Short column	15X21	1.86%
	Interior column	15X21	1%
	Exterior column	12X21	1%
	Elevation A under a 4-story column	15X21	1.45%

Table 4-10. Beam reinforcement of Zone-4

Section	Name	Size (inch)	Phase of Beam	Maximum longitudinal reinforcement percentage		
				Left side	Middle side	Right side
Beam	Grade Beam	12X18	Top phase	1.05%	0.35%	1.02%
			Bottom phase	0.99%	0.40%	0.94%
	Interior beam	12X21	Top phase	0.71%	0.24%	0.66%
			Bottom phase	0.49%	0.35%	0.48%
	Exterior Beam	12X18	Top phase	1.02%	0.28%	0.96%
			Bottom phase	0.87%	0.35%	0.86%

For graphical interpretation of the reinforcement requirements, Figures 4-1 through 4-6 illustrate the beam reinforcement distribution. Each graph is divided into four seismic zones (Zone 1 to Zone 4), where the blue, orange, grey, and yellow bars represent the reinforcement quantities at the left, middle, and right regions of the beams, respectively.

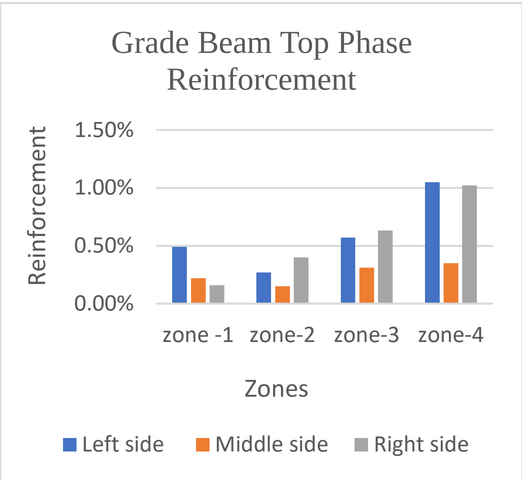

Figure 4-1. Grade Beam Top Phase Reinforcement

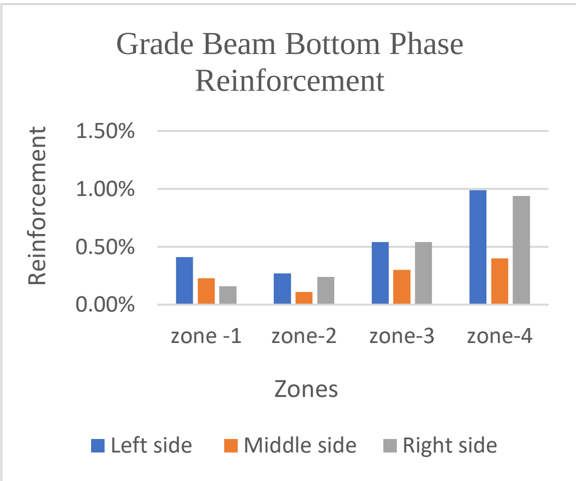

Figure 4-2. Grade Beam Bottom Phase Reinforcement

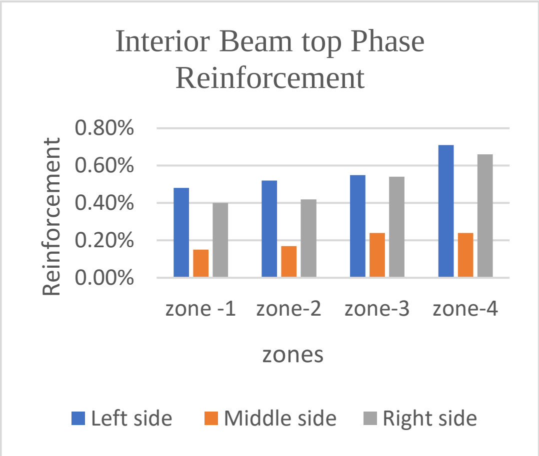

Figure 4-3. Interior Beam top Phase Reinforcement

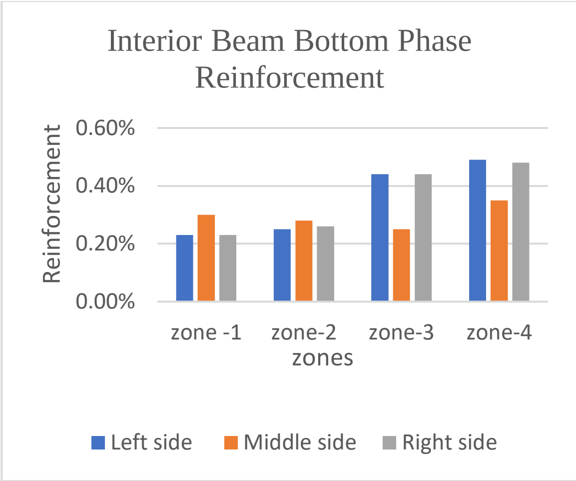

Figure 4-4. Interior Beam Bottom Phase Reinforcement

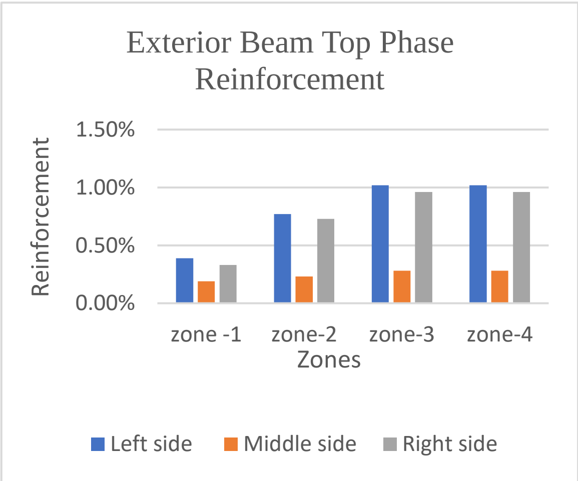

Figure 4-5. Exterior Beam Top Phase Reinforcement

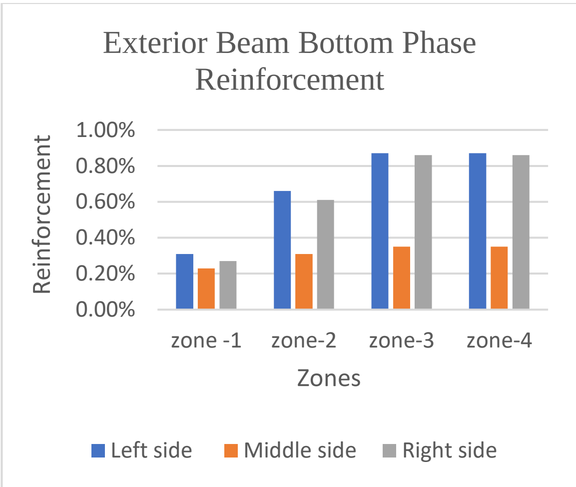

Figure 4-6. Exterior Beam Bottom Phase Reinforcement

4.2 Summary

Among the four seismic zones, Zone 1 requires the smallest beam and column cross-sectional areas compared to the other zones, while the longitudinal reinforcement ratio for columns remains approximately 1% across all sections, indicating relatively uniform reinforcement demand at lower seismic intensity. Zone 2 shows slightly increased structural requirements compared to Zone 1 but still maintains lower reinforcement and section sizes than Zones 3 and 4. In Zone 3, both beam and column dimensions increase further due to higher seismic effects, although they remain smaller than those required in Zone 4. Seismic Zone 4 exhibits the most significant increase in both member dimensions and reinforcement requirements as a result of the highest seismic demand. Notably, column dimensions in Zone 4 undergo considerable changes from the fourth story onward, whereas in other zones, the dimensions remain mostly consistent along the building height. Overall, the results demonstrate a clear trend of increasing structural demand with increasing seismic zone intensity.

CHAPTER 5

Conclusions and Future Works

5.1 Conclusions

The results show a progressive increase in both column and beam dimensions with higher seismic zones. For columns, the exterior column area increased from 180 in² in Zone 1 to 252 in² in Zone 4, representing an approximate 40% increase. The interior column area rose from 225 in² to 315 in² (about 40%), and the short column area increased from 270 in² to 315 in² (around 17%).

For beams, the interior floor beam area increased from 180 in² in Zone 1 to 252 in² in Zone 4 (about 40% increase), while the exterior floor beam rose from 180 in² to 216 in² (20% increase). The grade beams remained constant at 216 in² across all zones, indicating that seismic zone variation mainly influences the upper-story beams and columns rather than foundation-level elements.

This research indicates that the seismic zone significantly influences the dimensions of columns, beams, and the percentage of reinforcement. Zone 4 necessitates the largest sizes and the highest level of reinforcement, while Zone 1 requires the smallest. Zones 2 and 3 are positioned between. These findings underscore the necessity of designing structures in accordance with BNBC-2020 to guarantee safety and stability across varying seismic zones in Bangladesh. .

5.2 Limitations

- The analysis is performed using the Equivalent Lateral Force (ELF) method based on BNBC 2020, which is a simplified approach and may not capture the full dynamic behavior of structures.
- Only a regular-shaped eight-story building is considered, which does not represent irregular or complex real-life structures.
- Soil–structure interaction effects are not included, which may influence the actual seismic response.
- The study is limited to a single building configuration with fixed material properties and loading conditions.
- The results may vary for different building heights, layouts, and structural systems.
- The analysis depends on a single software platform, which may introduce modeling assumptions and limitations.

5.3 Future work

- Advanced dynamic analysis methods, such as response spectrum and time history analysis, can be incorporated for more accurate results.
- Considering different types of irregular buildings and varying heights can provide a better understanding.
- Soil–structure interaction and foundation flexibility can be included in future studies.
- Nonlinear analysis and performance-based design approaches can be used for a deeper evaluation.
- Further research can focus on cost optimization and material efficiency.

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APPENDIX

PART VI
Appendix C
Seismic Design Parameters for Alternative Method of Base Shear Calculation

Table 6.C.1: Spectral Response Acceleration Parameter S_S and S_1 for Different Seismic Zone

Parameters	Zone-1	Zone-2	Zone-3	Zone-4
S_S	0.3	0.5	0.7	0.9
S_1	0.12	0.2	0.28	0.36

Table 6.C.2: Site Coefficient F_a for Different Seismic Zone and Soil Type

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	1.0	1.0	1.0	1.0
SB	1.2	1.2	1.2	1.2
SC	1.15	1.15	1.15	1.15
SD	1.35	1.35	1.35	1.35
SE	1.4	1.4	1.4	1.4

Table 6.C.3: Site Coefficient F_v for Different Seismic Zone and Soil Type

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	1.0	1.0	1.0	1.0
SB	1.5	1.5	1.5	1.5
SC	1.725	1.725	1.725	1.725
SD	2.7	2.7	2.7	2.7
SE	1.75	1.75	1.75	1.75

Table 6.C.4: Spectral Response Acceleration Parameter S_{DS} for Different Seismic Zone and Soil Type

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	0.2	0.333	0.466	0.6
SB	0.24	0.4	0.56	0.72
SC	0.23	0.383	0.536	0.69
SD	0.27	0.45	0.63	0.81
SE	0.28	0.466	0.653	0.84