A Comparative Study on Framing System (SMRF, IMRF And DUAL SYSTEM) of Multi-Storied (G+7) Residential Building for Different Zones in Bangladesh

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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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Sonargaon University (SU)

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

Section: 26A+27A

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Dedicated

to

"Our Parents and Honorable Teachers"

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ABSTRACT

Moment Resisting Frames (MRFs) are extensively used structural systems in urban construction worldwide due to their superior performance in resisting lateral loads, including wind and seismic forces, while efficiently supporting vertical loads from structures. Conversely, reinforced concrete dual systems integrate the energy-dissipating characteristics of MRFs with the high in-plane stiffness of shear walls. This combination enhances their ability to control lateral loads from wind and earthquakes, making them particularly suitable for high-rise buildings. This study investigates the structural performance of a (G+7) storied residential building across different regions in Bangladesh, using reinforced concrete Special Moment Resisting Frames (SMRFs) and dual systems comprising intermediate MRFs and special shear walls. The analysis was conducted using ETABS software, following the BNBC 2020 standards. Key structural parameters such as story displacement, story drift, story shear, and base shear were assessed to evaluate the structural performance. Additionally, a cost assessment was carried out to analyze cost efficiency and material requirements. The analysis revealed that the dual system can reduce wind-induced story displacement compared to SMRF. These results highlight the potential structural advantages and of dual systems, particularly in wind-prone areas, making them a feasible solution for high-rise residential buildings in such regions.

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CHAPTER 1

INTRODUCTION

1.1 Background and Motivations

Bangladesh's high seismic risk and dense population necessitate safe and cost-effective high-rise buildings. This study compares the structural performance and cost-efficiency of SMRFs and Dual Systems in a 14-storied residential building across four Bangladeshi cities using ETABS and response spectrum analysis. Key parameters such as story drift, displacement, and base shear were evaluated to support optimal seismic design decisions.

1.2 Research Objectives and Overview

The main objective of this research is to compare the structural and seismic performance of different framing systems (SMRF, IMRF, and Dual System) for a G+7 multi-storied residential building located in different seismic zones of Bangladesh in accordance with BNBC 2020. Bangladesh is situated in a seismically active region due to its proximity to major tectonic plate boundaries. With rapid urbanization and the increasing demand for multi-storied residential buildings, ensuring seismic safety has become a critical concern. The Bangladesh National Building Code (BNBC 2020) emphasizes the use of appropriate structural systems to resist lateral loads induced by earthquakes. This research focuses on a G+7 multi-storied reinforced concrete residential building and investigates its seismic behavior using three different structural framing systems: Special Moment Resisting Frame (SMRF), Intermediate Moment Resisting Frame (IMRF), and Dual System. The building is modeled and analyzed for different seismic zones of Bangladesh using structural analysis software in accordance with BNBC 2020 provisions. A comparative analysis is performed based on seismic performance indicators such as story drift, displacement, base shear, and time period. The results aim to highlight the advantages and limitations of each framing system under varying seismic demands. The findings of this study are expected to assist structural engineers and designers in selecting suitable framing systems to enhance seismic performance and safety of residential buildings in Bangladesh.

1.3 Specific Objectives

The specific objectives of this study are as follows:

To model and design a G+7 reinforced concrete residential building using SMRF, IMRF, and Dual System.

1. To analyze the seismic response of each framing system under different seismic zones of Bangladesh as per BNBC 2020.

2. To compare key seismic parameters such as: Story displacement, Story drift, stiffness.

3. To evaluate the structural efficiency and safety of each framing system in resisting earthquake loads.

4. To identify the most suitable and economical framing system for multi-storied residential buildings in different seismic zones of Bangladesh.

5. To provide recommendations for selecting appropriate framing systems for future residential building design in seismic-prone regions of Bangladesh.

1.4 Organization of the thesis:

This thesis is organized into six chapters, each addressing specific aspects of the research work.

Chapter 1: Introduction and Objective. This chapter presents the background of the study, highlighting the seismic vulnerability of Bangladesh and the necessity of appropriate structural framing systems. It includes the problem statement, objectives of the research, scope and limitations, and an overview of the thesis organization.

Chapter 2: Literature Review. This chapter reviews previous research related to seismic behavior and performance of SMRF, IMRF, and Dual structural systems. Relevant national and international codes, including BNBC 2020, are discussed. The chapter also identifies research gaps that justify the present study.

Chapter 3: Methodology and Structural Modeling. This chapter describes the methodology adopted in this study. It includes the description of the building model, material properties, loading conditions, seismic parameters, and assumptions. The modeling and analysis procedures using structural analysis software (such as ETABS/SAP2000) are explained in detail for different seismic zones of Bangladesh.

Chapter 4: Analysis and Results. This chapter presents the analysis results obtained for SMRF, IMRF and Dual systems. Key seismic response parameters such as story displacement, story drift, stiffness distribution are presented in tabular and graphical forms for different seismic zones.

Chapter 5: Discussion and Comparative Evaluation. This chapter provides a detailed comparison and discussion of the results. The performance of each framing system is evaluated in terms of seismic safety, structural efficiency, and code compliance. The advantages and limitations of each system under varying seismic demands are highlighted.

Chapter 6: Conclusions and Recommendations. This final chapter summarizes the major findings of the study and presents conclusions based on the comparative analysis. Practical recommendations for selecting suitable framing systems for multi-storied residential buildings in different seismic zones of Bangladesh are provided. Suggestions for future research are also included. Bangladesh is situated in a seismically active region governed by the interaction of the Indian, Eurasian, and Burmese plates. Recent probabilistic seismic hazard assessments reveal considerable spatial variability in seismic demand across the country, underscoring the importance of zone-based structural evaluation [1]. Such regional variations necessitate the careful selection of appropriate lateral load-resisting systems, particularly for mid-rise residential buildings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Bangladesh is located in a seismically active region influenced by the interaction of the Indian, Eurasian, and Burmese plates. Recent probabilistic seismic hazard assessments indicate significant variations in seismic demand across different regions of the country, emphasizing the need for zone-based structural evaluation [1]. These regional variations necessitate careful selection of lateral load-resisting systems, especially for mid-rise residential buildings.

The Bangladesh National Building Code (BNBC) incorporates response reduction factors to represent the ductility and energy dissipation capacities of different structural systems [2]. Previous studies have examined the influence of BNBC-specified response reduction factors on reinforced concrete moment-resisting frames and shown that Special Moment Resisting Frame (SMRF) systems attract lower design base shear than Intermediate (IMRF) and Ordinary Moment Resisting Frames (OMRF), owing to their superior ductility [3]. These findings highlight the seismic and economic advantages of adopting ductile framing systems in regions of moderate seismicity

2.2 Moment Resisting Frame Systems (SMRF and IMRF)

Moment Resisting Frames (MRFs) are widely adopted structural systems due to their ability to resist both gravity and lateral loads through rigid beam–column connections. Previous studies have provided comprehensive design guidelines for Special Moment Resisting Frame (SMRF) systems, emphasizing their superior ductility, energy dissipation, and drift control when detailed in accordance with seismic provisions [4]. However, these performance advantages are accompanied by increased reinforcement requirements and greater construction complexity. Comparative investigations between Intermediate Moment Resisting Frame (IMRF) and SMRF systems have revealed distinct differences in seismic behavior. Research has shown that SMRF buildings generally exhibit lower storey drift and base shear than IMRF buildings, particularly in mid- to high-rise structures [5]. Similarly, studies on response reduction factors indicate that systems with higher ductility permit lower design seismic forces, although they demand more stringent detailing and quality control [6].

Analyses of reinforced concrete buildings across different seismic zones further demonstrate that seismic demands—such as displacement and inter-storey drift increase markedly with higher seismicity levels [7]. These observations reinforce the importance of zone-specific assessment in evaluating the seismic performance of MRF systems.

2.3 Storey Drift and Displacement Behavior

Storey drift is one of the most critical performance parameters in seismic design, as it is directly associated with structural damage and serviceability limits. A comprehensive review of drift behavior in soft-storey reinforced concrete buildings has identified excessive inter-storey drift as a primary cause of seismic failure [8]. Subsequent investigations further indicated that drift control becomes increasingly difficult in higher seismic zones, particularly in buildings exhibiting stiffness irregularities [9].

Displacement-based design approaches applied to various reinforced concrete structural systems have demonstrated that displacement demand provides a more reliable measure of seismic performance than force-based parameters alone [10]. These studies emphasize the importance of limiting global displacement and inter-storey drift, rather than relying solely on reductions in design base shear.

2.4 Dual Structural Systems (MRF + Shear Wall)

Dual structural systems combine the ductility of moment-resisting frames with the stiffness provided by shear walls or braced elements, resulting in improved seismic performance. Previous investigations on MRF–CBF dual systems have shown that the incorporation of stiff lateral components significantly reduces storey drift and delays the development of failure mechanisms [11]. Studies evaluating seismic performance factors for dual systems comprising Intermediate Moment Resisting Frames (IMRFs) and cable-cylinder bracing have demonstrated enhanced lateral stiffness and improved displacement control when compared with pure frame systems [12]. However, these systems exhibit lower response reduction factors than Special Moment Resisting

Frames (SMRFs) due to their comparatively reduced ductility. Analyses of podium-type buildings further indicate that dual systems can reduce maximum inter-storey drift by more than 50% relative to SMRF-only configurations, highlighting the effectiveness of stiffness-providing elements in limiting lateral deformations [13].

2.5 Effect of Seismic Zone and Cost Implications

Seismic zone severity has a direct influence on both structural demand and construction cost. Previous studies on the impact of seismic zoning have shown that buildings located in higher seismic regions require greater material quantities and stiffer lateral load–resisting systems, which in turn lead to increased construction costs [14]. Within the context of Bangladesh, comparative investigations of Special Moment Resisting Frame (SMRF) and dual structural systems for residential buildings across different regions have demonstrated that dual systems can significantly reduce building displacement and inter-storey drift in high seismic and wind-prone zones [15]. These studies also reported marginal cost savings for dual systems due to more efficient reinforcement utilization, highlighting their potential as a balanced solution between performance and economy.

2.6 Summary

The literature shows that the seismic performance of reinforced concrete residential buildings in Bangladesh strongly depends on the chosen framing system and seismic zone**.** SMRF systems provide high ductility and reduced design base shear but require greater reinforcement and complex detailing. IMRF systems are more economical but exhibit higher storey displacement and drift, especially in higher seismic zones.

Storey displacement and inter-storey drift are identified as the most critical response parameters influencing structural safety, particularly in buildings with stiffness irregularities. Dual systems, combining moment-resisting frames with shear walls or bracing, significantly improve lateral stiffness and effectively reduce displacement and drift, making them more suitable for moderate to high seismic zones.

However, limited research exists on G+7 residential buildings in Bangladesh that directly compares SMRF, IMRF and dual **sys**tems using displacement, storey drift, and storey stiffness.

CHAPTER 3
METHODOLOY

3.1 Introduction

Bangladesh is located in a seismically active region and is frequently exposed to natural hazards such as earthquakes and strong winds. Rapid urbanization and the increasing demand for multi-storey residential buildings have made structural safety and performance a critical concern for engineers and planners. Ensuring that buildings are capable of resisting lateral loads induced by seismic and wind actions is therefore essential to minimize structural damage and loss of life. In this context, modern seismic design philosophies emphasize ductility, energy dissipation, and controlled structural behavior under extreme loading conditions. Moment Resisting Frames (MRFs) and dual structural systems are widely used in reinforced concrete buildings to enhance lateral load resistance. Special Moment Resisting Frames (SMRFs) are designed to provide high ductility and superior energy dissipation capacity, while Intermediate Moment Resisting Frames (IMRFs) offer moderate ductility with comparatively simpler detailing requirements. Dual systems, which combine moment resisting frames with reinforced concrete shear walls, are often adopted to achieve an optimal balance between strength, stiffness, and ductility. The selection and performance of these systems are strongly influenced by regional seismicity, material properties, member dimensions, and design parameters specified in building codes. This thesis focuses on the structural analysis and design of a reinforced concrete residential building using different lateral force–resisting systems, namely SMRF, IMRF, and a dual system consisting of IMRF with special shear walls. The study is conducted in accordance with the Bangladesh National Building Code (BNBC 2020), considering variations in seismic and wind parameters for four major cities of Bangladesh: Jessore, Dhaka, Chittagong, and Sylhet. These locations represent different seismic zones and wind conditions, providing a comprehensive basis for comparative evaluation. Finite element modeling and analysis are carried out using ETABS software, incorporating realistic material properties, section dimensions, gravity loads, and lateral load combinations as prescribed by BNBC. Key design parameters such as response reduction factors, overstrength factors, and deflection amplification factors are applied to assess the structural performance of each system. The results of this study aim to highlight the effectiveness of different framing systems under varying seismic demands and to provide insights into the suitability of each system for residential buildings in

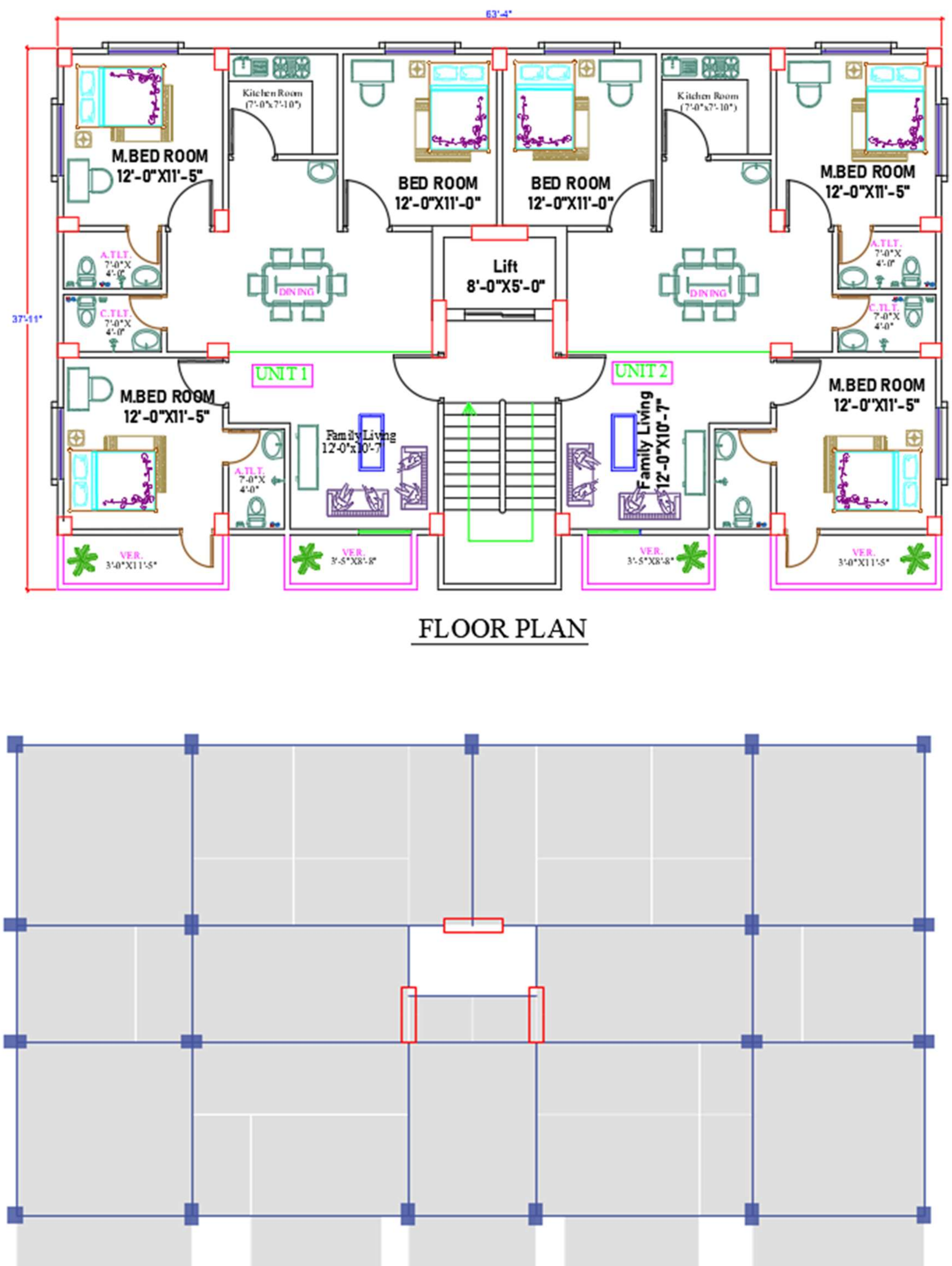
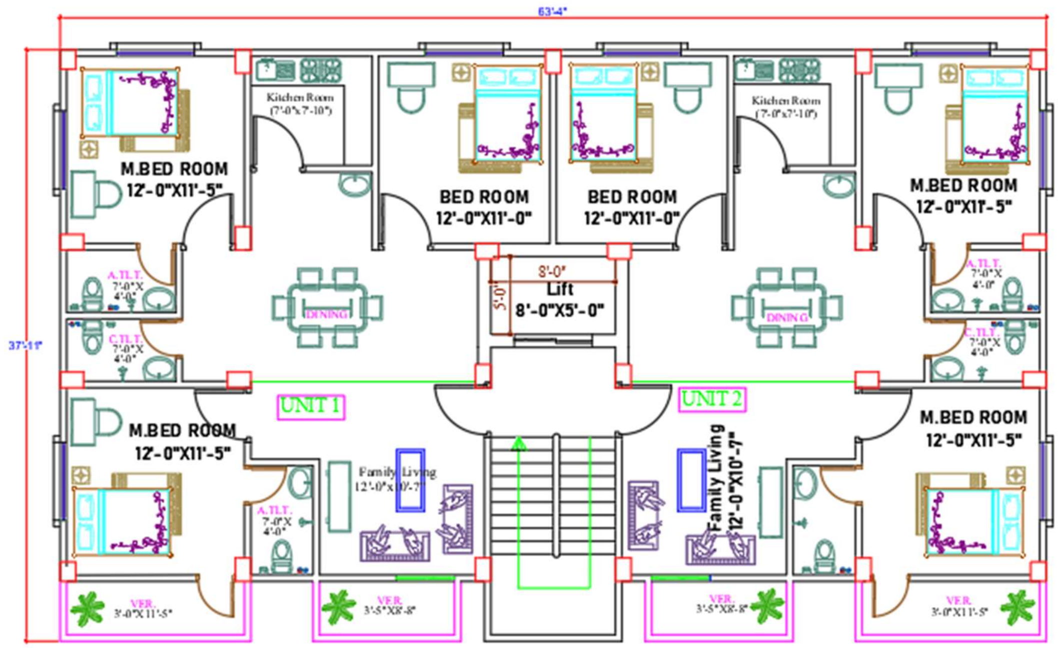


Figure 3-1. Intermediate Moment Resisting Frame with Special Shear Wall



FLOOR PLAN

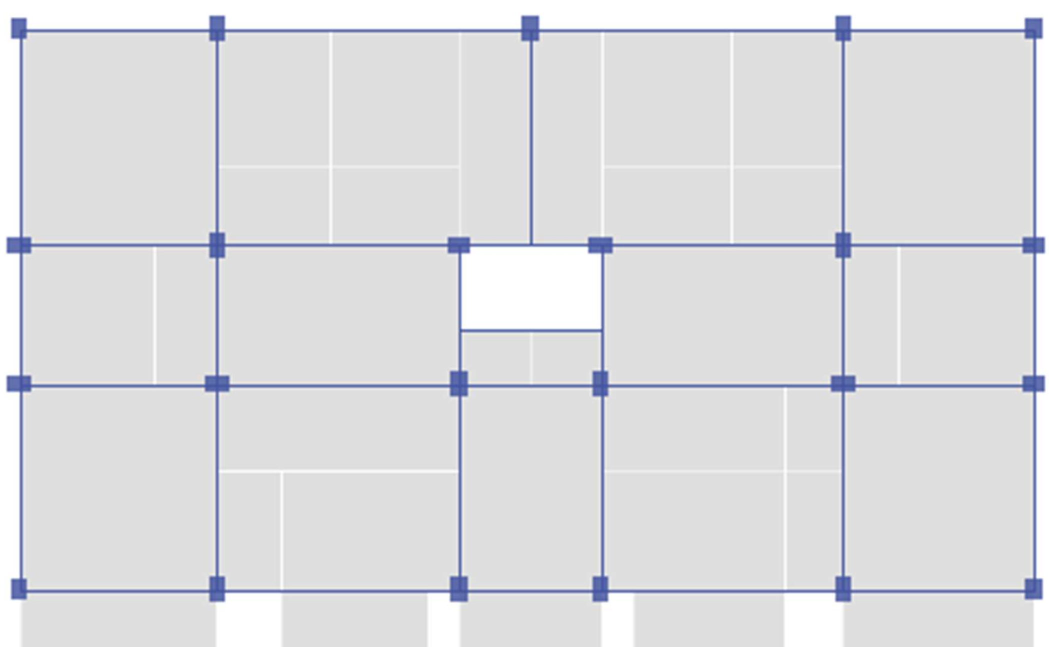


Figure 3-2. Special Moment Resisting Frame

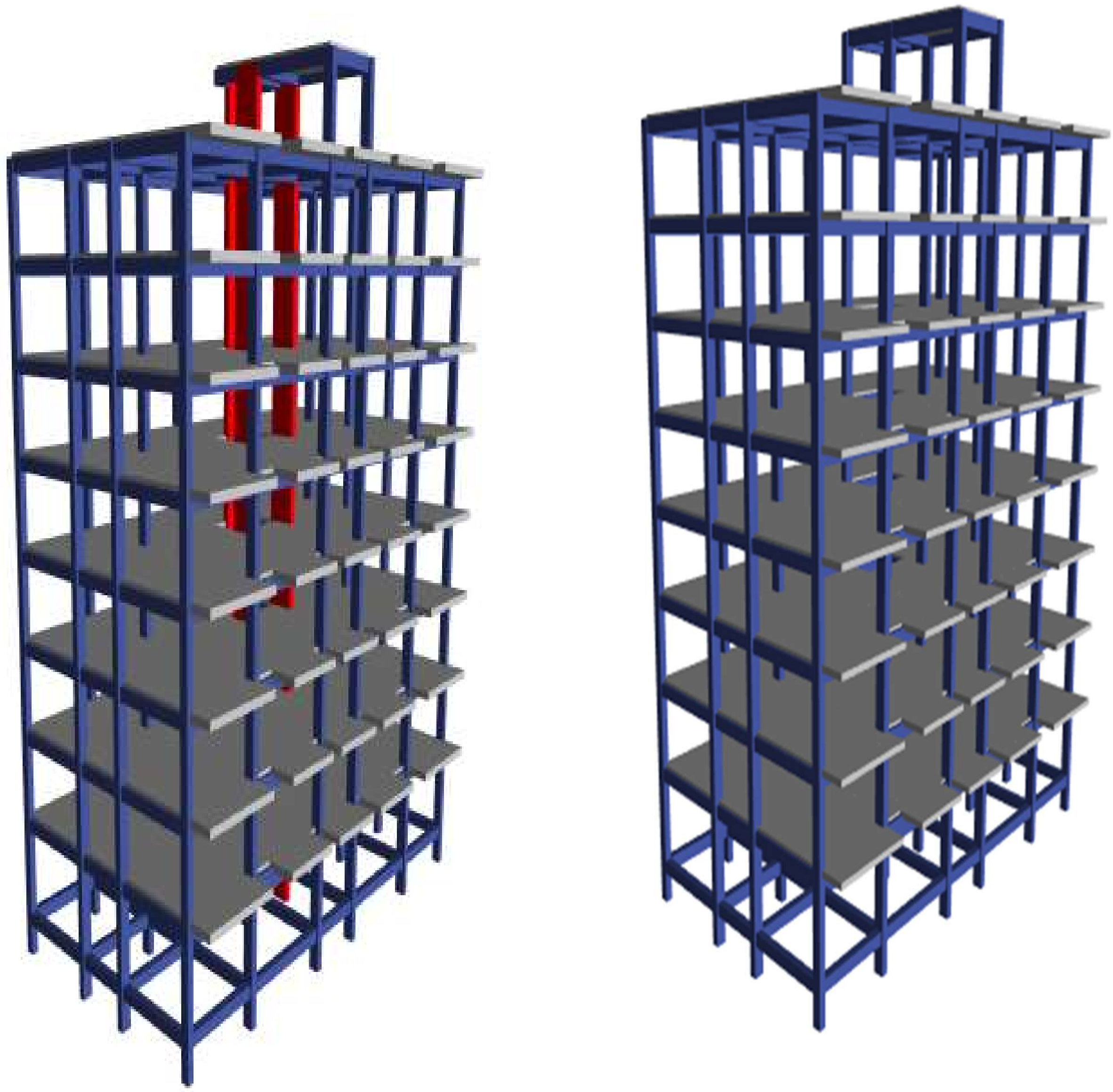


Figure 3-3. Moment Resisting Frame and Dual System 3D view

3.2 Materials Property

The material specifications for the concrete and rebar used in the building according to BNBC specifications. The concrete has a compressive strength of 3500 psi, and rebar with a yield strength of 60 ksi is used in all structural members.

Table 3-1. Materials Property

Type	Corresponding Value
Concrete Compressive Strength (Columns, Shear Walls)	3500 psi
Concrete Compressive Strength (Beams and Slabs)	3000 psi
Rebar Yield Strength	60 psi

3.3 Section Property

The dimensions and thicknesses of the structural members for both the Special Moment Resisting Frame (SMRF), Intermediate Moment Resisting Frame (IMRF) and the Dual System are presented in Table 2. The sections of the columns and beams were selected through trial and error, with the joint shear and beam-column capacity ratios checked to ensure compliance with the criteria for the SMRF.

Table 3-2. Section Property

Location	**Jessore**	**Dhaka**	**Chittagong**	**Sylhet**
Column (in)	12 x 18	12 x 18	12 x 18	12 x 18
Floor Beams (in)	10 x 20	10 x 20	10 x 20	10 x 20
Grade Beams (in)	12 x 20	12 x 20	12 x 20	12 x 20
Shear Wall (in)	12	12	12	12
Thickness of Floor Slab (in)	6	6	6	6
Thickness of Stair Slab (in)	8	8	8	8

3.4 Loads Considerations

The dead and live load used for analyzing the building was determined in accordance with the BNBC (2020) guidelines. Table 1 presents the minimum uniformly distributed live loads considered for the different occupancies outlined in the architectural plan of the residential building. Building analysis has done considering the following load cases

- Dead Load
- Live load
- Wind load
- Earthquake load

The loads have been applied according to BNBC-2020

3.4.1 Dead Loads

Unit weight of materials and the calculation of design dead loads are according to Table: 6.2.1, Section-2.2.4, Chapter-2, part-6, BNBC-2020

- Floor finish, FF=25 psf
- Toilet Build up Average 5inch= (6/12) *120 =60 psf
- Partition wall= (5/12) *120=50 Ib/ft/ft height for 5-inch wall
- Partition wall= (10/12) *120=100 Ib/ft/ft height for 10-inch wall

3.4.2 Live Loads

Live load is the load superimposed by the use or occupancy of the building not including the environmental loads such as wind load, rain load, earthquake load or dead load.

Floor live load taken according to the live load table in BNBC2020 Article 2.3, Table 6.2.3. In addition, Roof live loads taken according to the live load table in BNBC2020 Article 2.3.8 and Table 6.2.4 for this project only the roof live load taken as 30 psf

However, it should be not less than the minimum floor live load. (BNBC2020)

Table 3-3. Loads Consideration For the structure

Types of Live Loads	Corresponding Values
Live Load at Bedroom	42 psf
Live Load at Kitchen	42 psf
Live Load at Dining and Living Room	42 psf
Live Load at Toilet	42 psf
Live Load at Stairs and Lobbies	100 psf
Live Load at Corridors and Exit-ways	100 psf
Live Load at Roofs used for promenade purposes	30 psf

3.4.3 Wind Loads

The calculation of wind load confirms the sub-clause 2.4, Chapter 2, Part-6 of BNBC2020. The following equation has used to calculate sustained wind pressure of the structure.

Velocity pressure evaluated at height Z shall be calculated by the following equation:

QZ/h=0.000613KzKztKdV2I; (KN/m2) V in m/s

I=Importance factor (Table: 6.2.9)

V= Basic Wind Speed (Table: 6.2.8)

Kd= Directionally Factor (Table: 6.2.12)

Kz= Velocity Pressure Exposure Co-efficient (Table: 6.2.11)

Kzt= Topographic Factor (Sec: 2.4.7.2)

Wind load applied in two orthogonal directions X and Y.

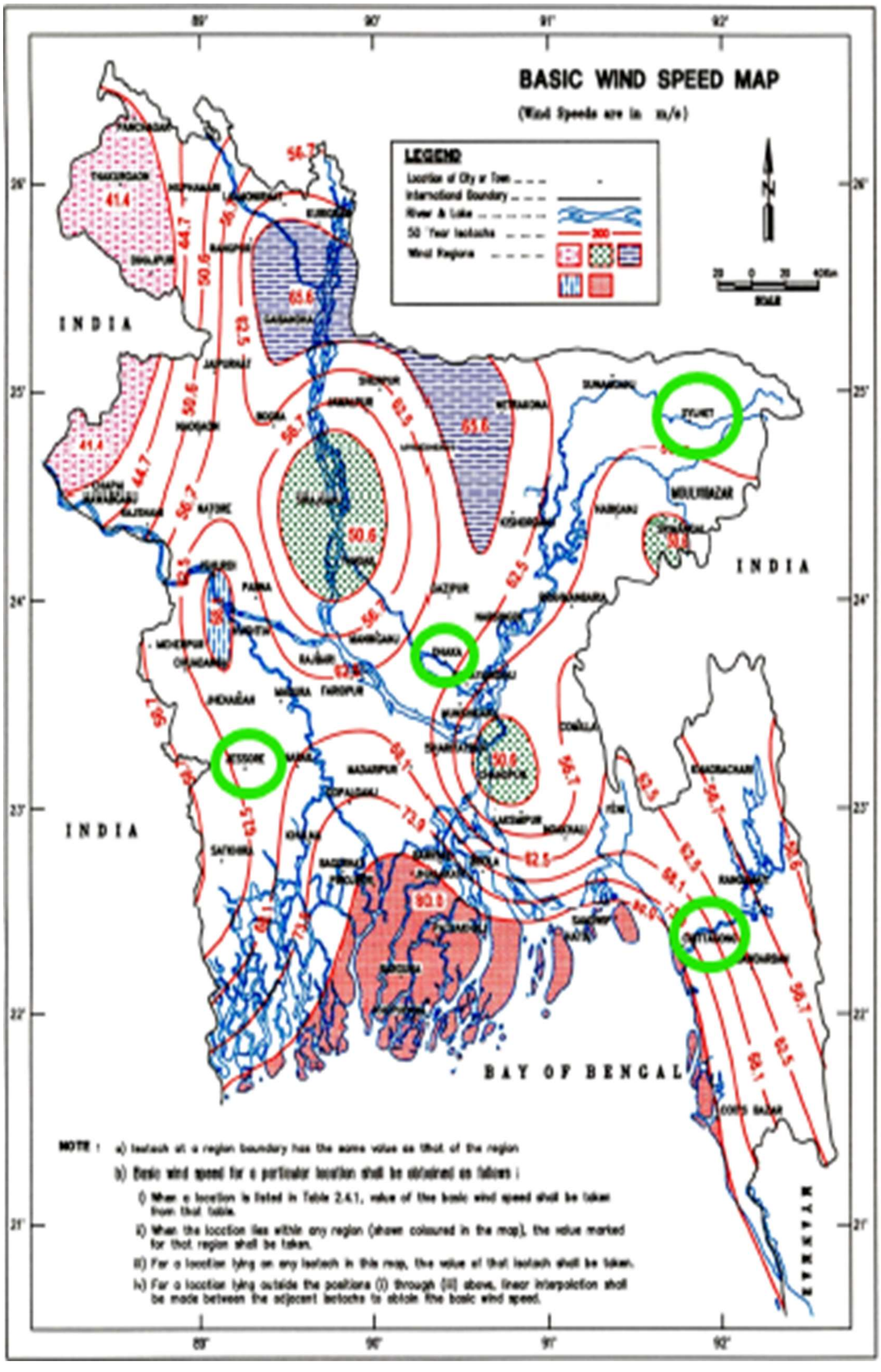


Figure 3-4. Basic Wind speed map in different zone

3.4.4 Earthquake Loads

As per specifications of BNBC2020, Part-6, Chapter-2, section-2.5, Equivalent Static Force Method applied to calculate the earthquake force of this structure.

- Soil Site Classifications (Sec: 2.5.3.2, Eq: 6.2.32, Table:6.2.13)
- Seismic Zone (Table:6.2.15)
- Importance Factor (Table:6.2.17)
- Seismic Design Category of Building (Table:6.2.18)
- Response Reduction Factor, Deflection Amplification Factor and Height Limitations for Different Structural Systems (Table:6.2.19)

Design Base Shear, V=Sa W……………………………………….

W= Total seismic weight of the building defined in

Sa= Lateral seismic force coefficient calculated

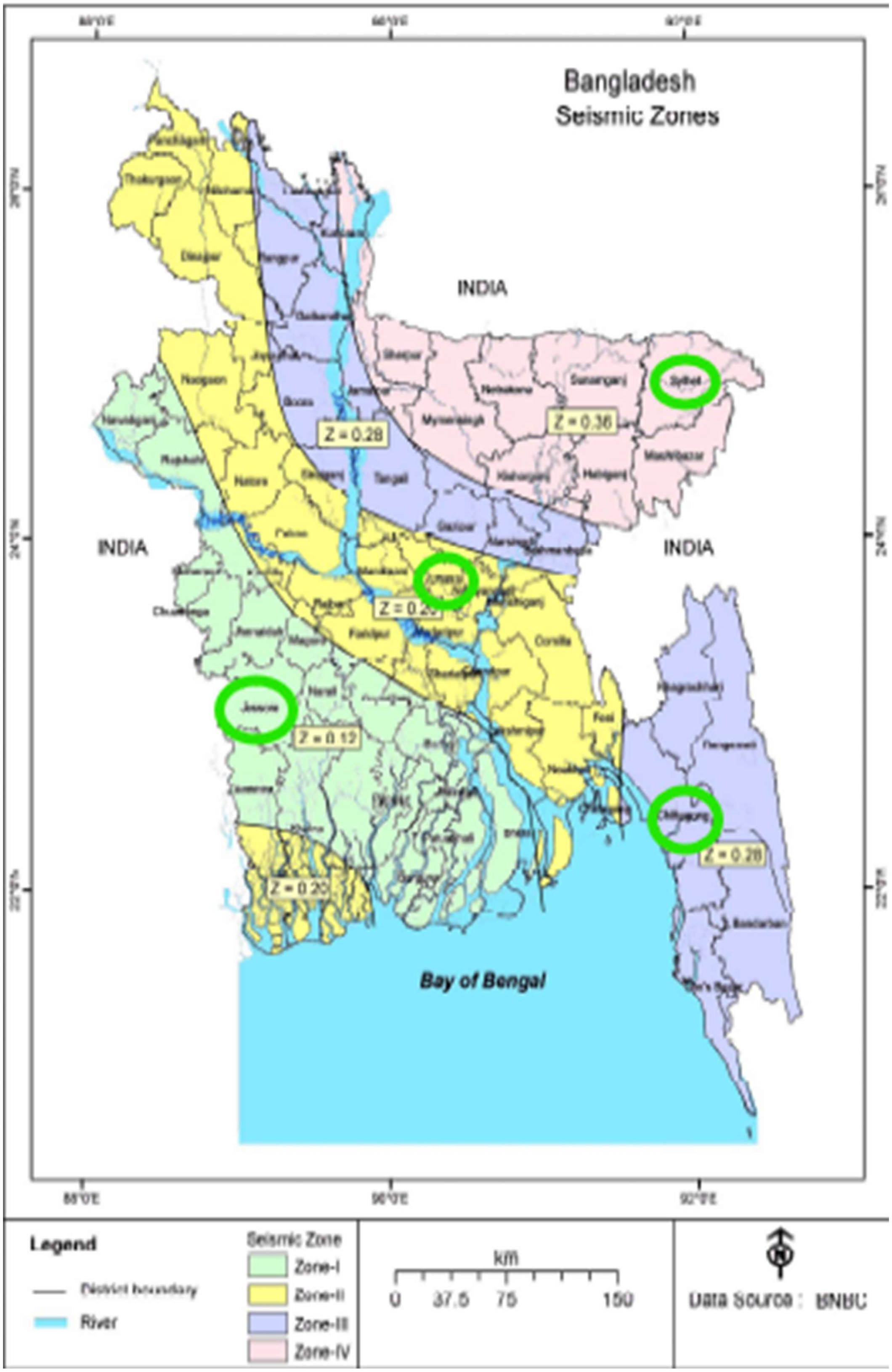


Figure 3-5. Seismic Zone in Bangladesh

3.5 Design Parameters

The design parameters for wind and seismic loads are summarized in Table 5. Site class SD and occupancy category II are used for all regions, with wind exposure category A chosen since all the buildings are in urban areas. The other parameters change by region.

Table 3-4. Design Parameters

Location	**Jessore**	**Dhaka**	**Chittagong**	**Sylhet**
Seismic Zone	Zone 1	Zone 2	Zone 3	Zone 4
Seismic Zone Coefficient	0.12	0.20	0.28	0.36
Site Class	SD	SD	SD	SD
Seismic Design Category	D	D	D	D
Occupancy Category	II	II	II	II
Importance Factor (Seismic Load)	1.00	1.00	1.00	1.00
0.2 sec Spectral Acceleration, Ss	0.3	0.5	0.7	0.9
1 sec Spectral Acceleration, S1	0.12	0.2	0.28	0.36
Site Coefficient, Fa	1.35	1.35	1.35	1.35
Site Coefficient, Fv	2.7	2.7	2.7	2.7

Basic Wind Speed	64.1 m/s	65.7 m/s	80 m/s	61.1 m/s
Exposure Category	A	A	A	A
Importance Factor (Wind Load)	1.00	1.00	1.00	1.00

3.6 Seismic Design Parameters

The seismic design parameters for SMRF and Dual System are presented in Table 5. SMRF has a response reduction factor of 8, indicating high ductility and energy dissipation, while dual systems have a factor of 6.5 due to their complex interactions and lower energy dissipation.

Table 3-5. Seismic Design Parameters

Framing System	**SMRF**	**IMRF**	**Dual System (IMRF with Special Shear Wall)**
Response Reduction Factor	8	5	6.5
System Overstrength Factor	3	3	2.5
Deflection Amplification Factor	5.5	4.5	5

3.7 Load Combinations

The load combinations used for the finite element analysis in ETABS software, with appropriate safety factors, are based on BNBC (2020) guideline and are presented in, where, D= Dead Load, L= Live Load, W= Wind Load and E= Earthquake Load.

Table 3-6. Load Combinations

No	Load Combinations
1.	1.4(D + F)
2.	1.2(D + F + T) + 1.6(L + H) + 0.5(Lr or R)
3.	1.2D + 1.6(Lr or R) + (L or 0.8W)
4.	1.2D + 1.6W + L + 0.5(Lr or R)
5.	1.2D + 1.0E + 1.0L
6.	0.9D + 1.6W + 1.6H
7.	0.9D + 1.0E + 1.6H

3.8 Codes and Standards

- Bangladesh National Building Code (BNBC-2020).
- American concrete Institute (ACI 318-08)
- American Society of Civil Engineers (ASCE 7-05)
- American Institute of Steel Construction (AISC 360-05)

CHAPTER 4

Analysis and Discussion

4.1 Introduction

This study investigates the lateral performance of different structural framing systems under wind loading, focusing on key response parameters such as story displacement, story drift, and structural stiffness. Intermediate Moment Resisting Frame (IMRF), Special Moment Resisting Frame (SMRF), and Dual Systems are evaluated in both principal directions across varying seismic zones. The analysis aims to assess the effectiveness of each framing system in controlling lateral deformation and enhancing structural stiffness, thereby ensuring serviceability and structural safety under wind-induced loads.

4.2 Storey Displacement

The variation of story displacement along the height of the building under wind loading in the X- and Y-directions for different seismic zones and framing systems. Story displacement increases with height in all cases, reflecting the cumulative effect of lateral wind forces on the structure. From the figure 4-1 & 4-2 depicting story displacement due to wind load in the X and Y direction, a gradual and nearly linear increase in displacement is observed from the base to the top of the structure for all seismic zones and framing systems. The maximum displacement occurs at the roof level, indicating that the structure behaves as a typical laterally loaded system.

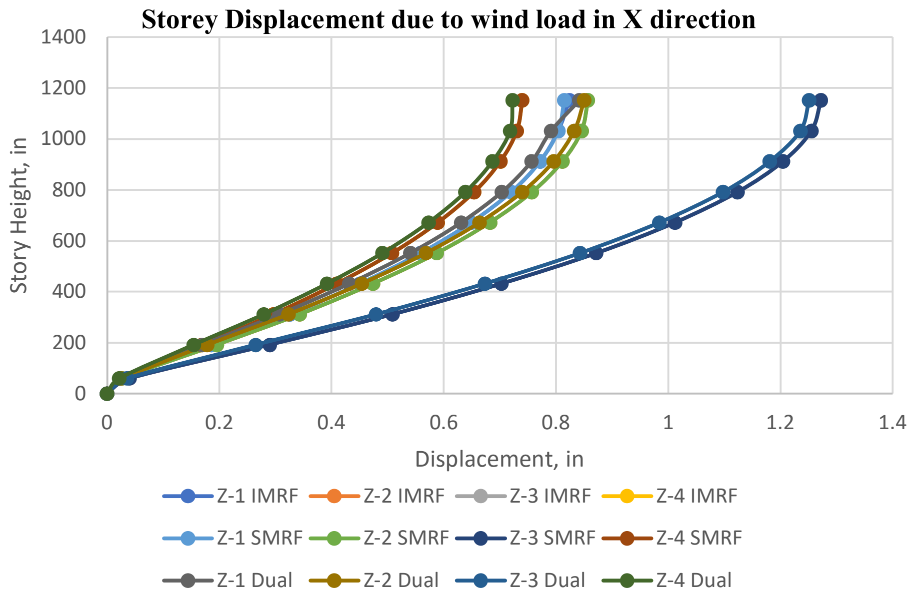


Figure 4-1. Story Displacement due to wind(X) loads in different seismic zone

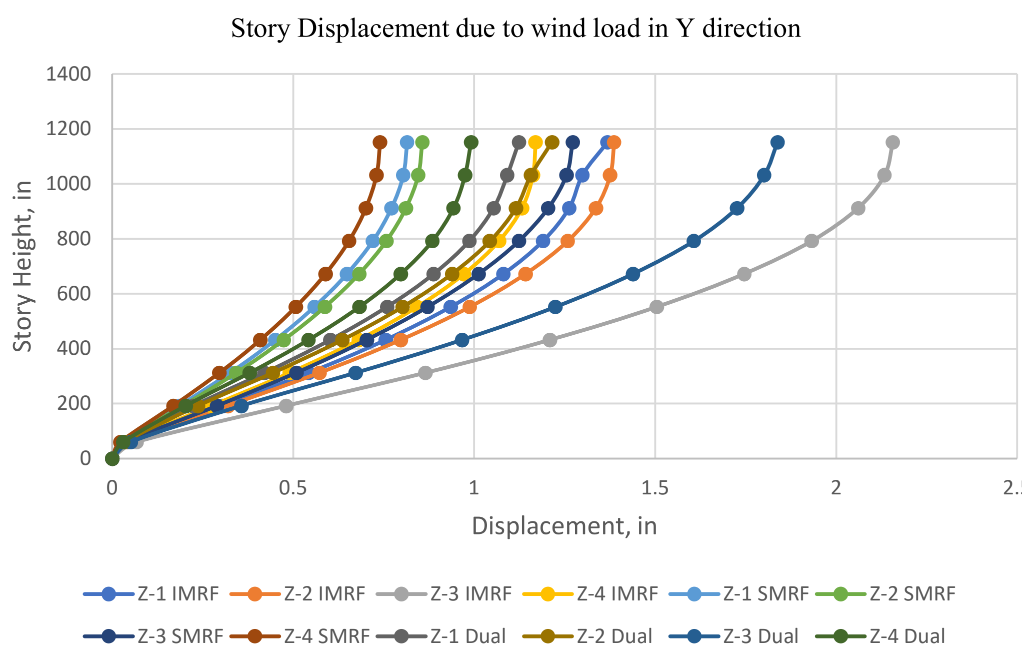


Figure 4-2. Story Displacement due to wind(Y) loads in different seismic zone

From the figure 4-3 showing maximum story displacement in the X-direction, it is evident that the SMRF system exhibits the highest displacement values, followed closely by the IMRF system, while the Dual System shows comparatively lower displacements across all seismic zones. Among the locations considered, Chittagong consistently records the maximum displacement, with values of approximately 1.26 in for both IMRF and SMRF systems and 1.24 in for the Dual System. This indicates a greater wind response in higher seismic zones. In contrast**,** Sylhet shows the lowest displacement values, ranging from 0.72 in to 0.73 in, depending on the framing system. Jessore and Dhaka exhibit moderate displacement values, generally between 0.79 in and 0.85 in. The reduced displacement in the Dual System suggests enhanced lateral stiffness due to the combined action of moment-resisting frames and shear walls or bracing elements.

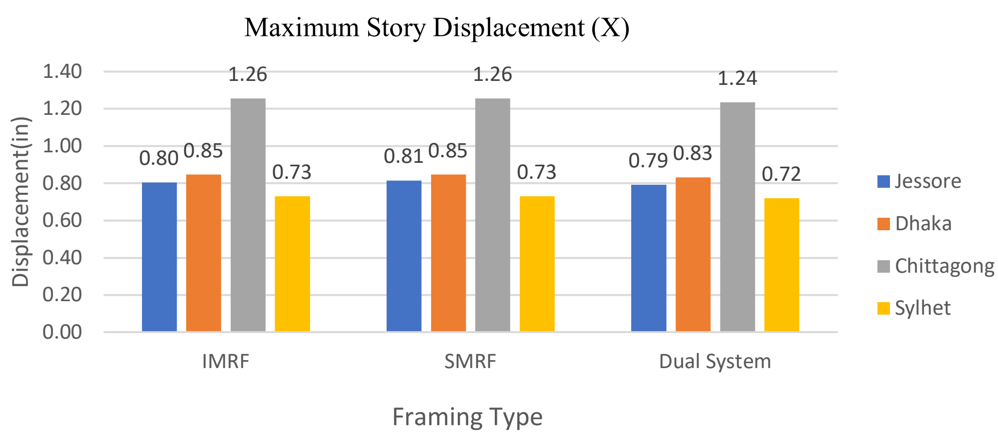


Figure 4-3. Maximum Story displacement in X direction

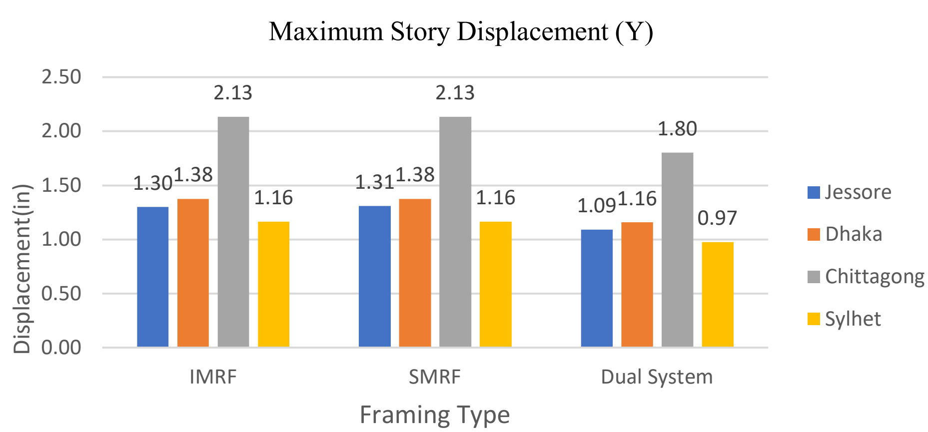
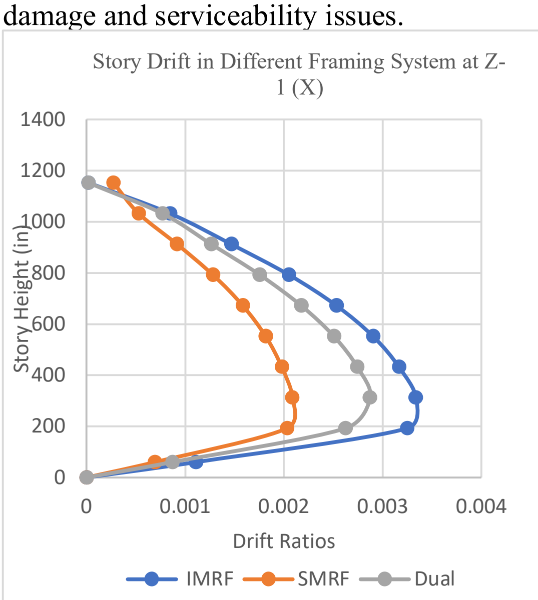


Figure 4-4. Maximum Story displacement in Y direction

From the figure 4-3 showing the maximum story displacement in the Y-direction is observed to be significantly higher than that in the X-direction for all framing systems and seismic zones. The highest displacement value of approximately 2.13 in occurs in Chittagong for both IMRF and SMRF systems. The Dual System again demonstrates improved performance, reducing the maximum displacement to about 1.80 in in the same zone. For lower seismic zones, Sylhet records the minimum displacement, with values around 0.97 in to 1.16 in, while Jessore and Dhaka show intermediate behavior. The consistently higher displacement in the Y-direction indicates directional dependency of structural stiffness, likely due to differences in structural layout, member sizing, or bay spacing along the two principal axes.

4.3 Story Drift

The variation of maximum story drift in the X- and Y-directions for three different framing systems Intermediate Moment Resisting Frame (IMRF), Special Moment Resisting Frame (SMRF), and Dual System across four seismic zones (Z-1 to Z-4). Story drift is a critical performance parameter, as excessive drift can lead to structural damage and serviceability issues.



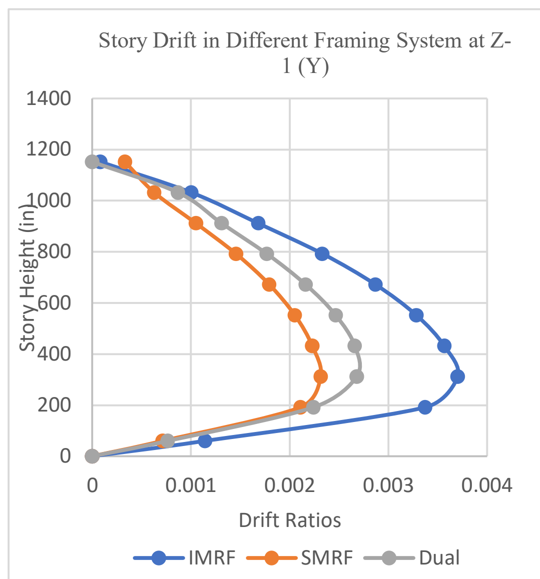


Figure 4-5. Story Drift in Seismic Zone-1

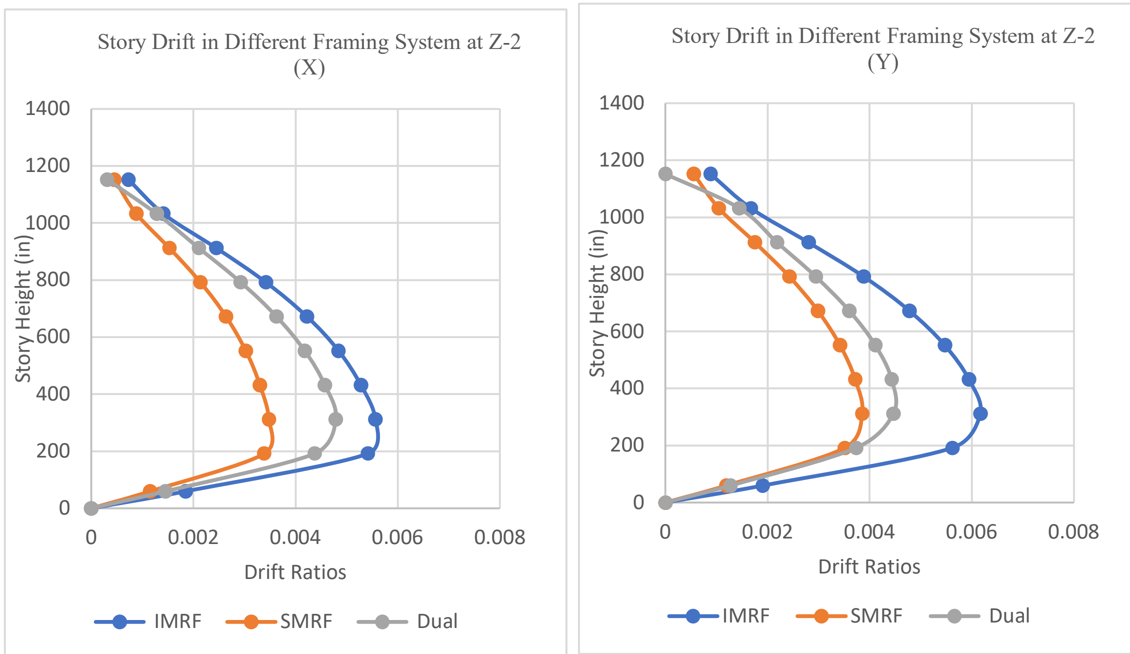


Figure 4-6. Story Drift in Seismic Zone-2

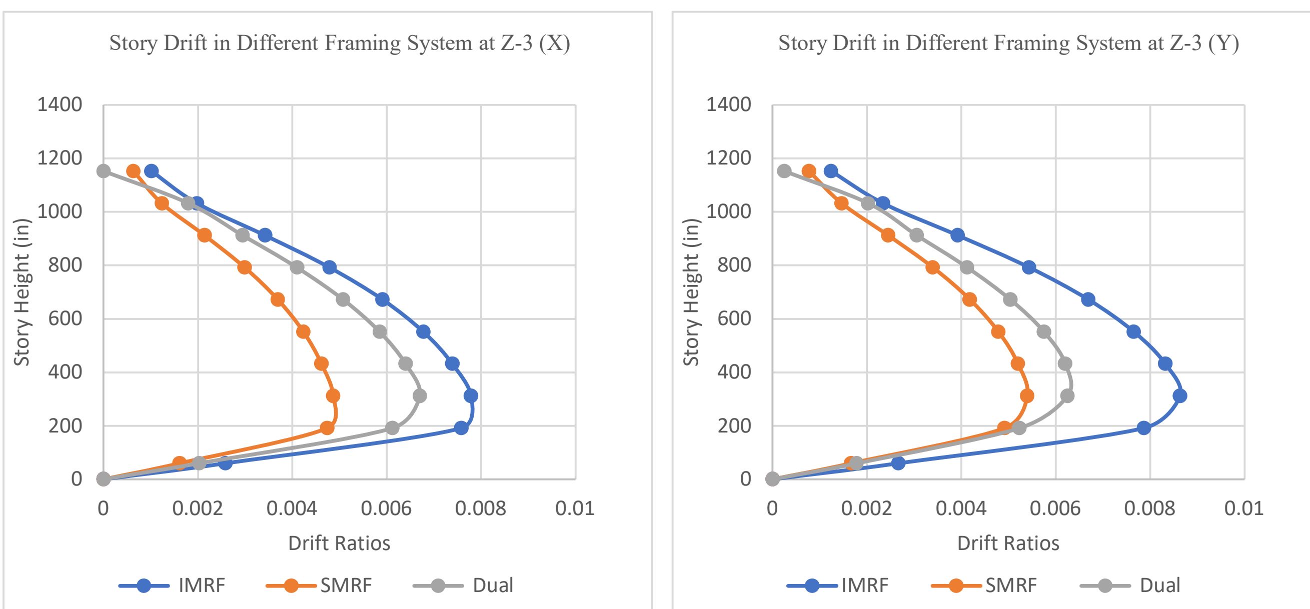


Figure 4-7. Story Drift in Seismic Zone-3

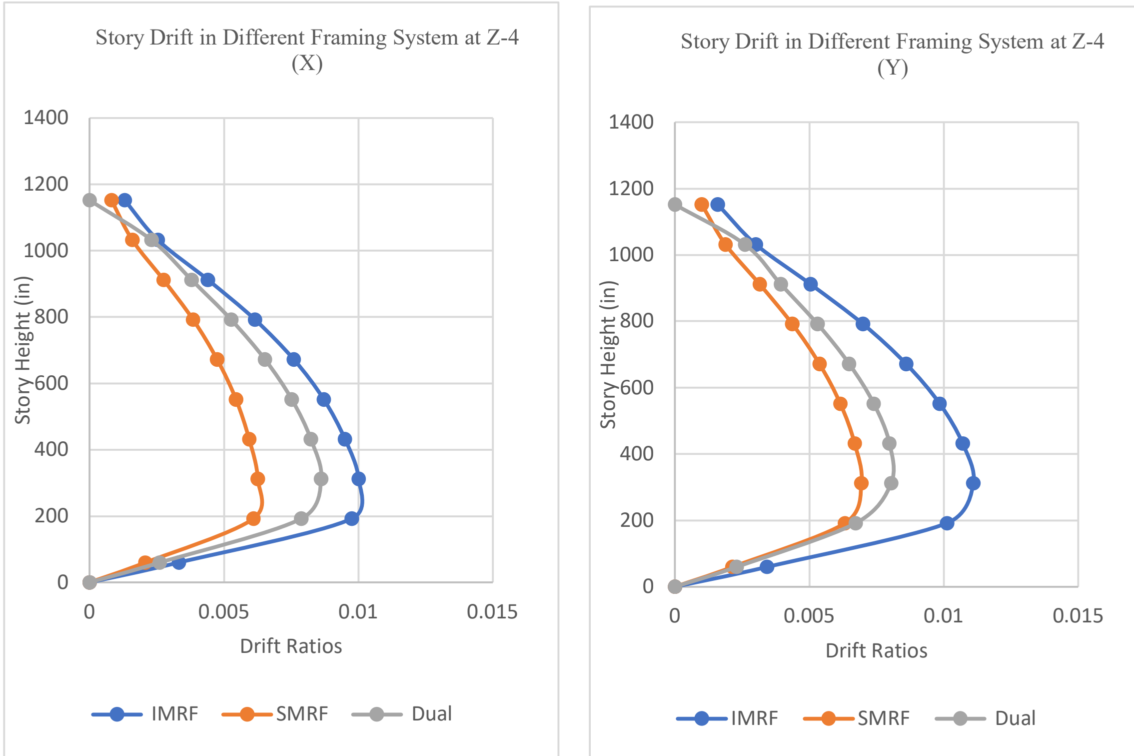
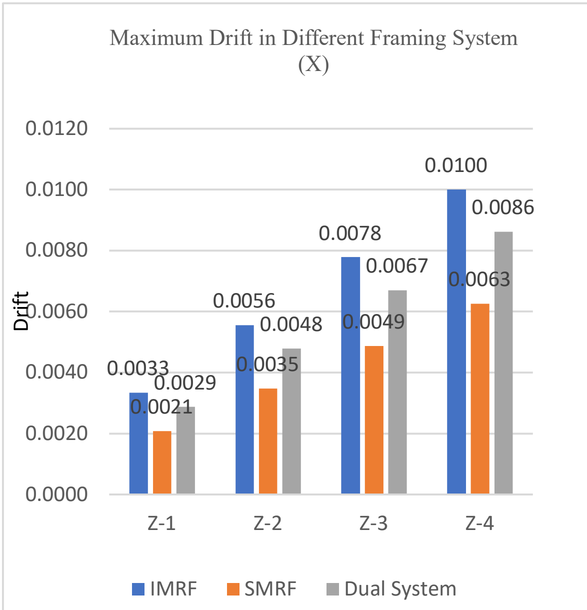


Figure 4-8. Story Drift in Seismic Zone-4

From the figure 4-9 representing maximum story drift in the X-direction, it is observed that story drift increases progressively with seismic zone for all framing systems. The IMRF system exhibits the highest drift values in all zones, while the SMRF system shows the lowest, indicating greater lateral stiffness. In Seismic Zone Z-1, the maximum drift values are approximately 0.0033 for IMRF, 0.0021 for SMRF, and 0.0029 for the Dual System. As the seismic zone increases to Z-4, these values rise to about 0.0100, 0.0063, and 0.0086, respectively. The Dual System consistently demonstrates reduced drift compared to IMRF due to the contribution of additional lateral load-resisting elements lateral load-resisting elements



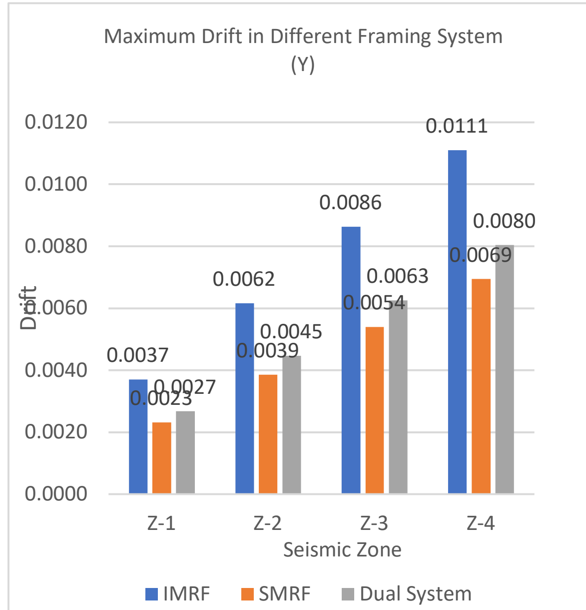


Figure 4-9. Maximum Story Drift in Different Zone

The figure 4-9 for maximum story drift in the Y-direction shows a similar increasing trend with seismic zone; however, the drift values are generally higher than those in the X-direction, indicating lower stiffness or higher flexibility along the Y-axis. In Zone Z-1, the drift values are approximately 0.0037 for IMRF, 0.0023 for SMRF, and 0.0027 for the Dual System. The maximum drift occurs in Zone Z-4, where IMRF reaches about 0.0111, followed by the Dual System at 0.0080, and SMRF at 0.0069. The increased drift in the Y-direction highlights the directional dependency of the structural response.

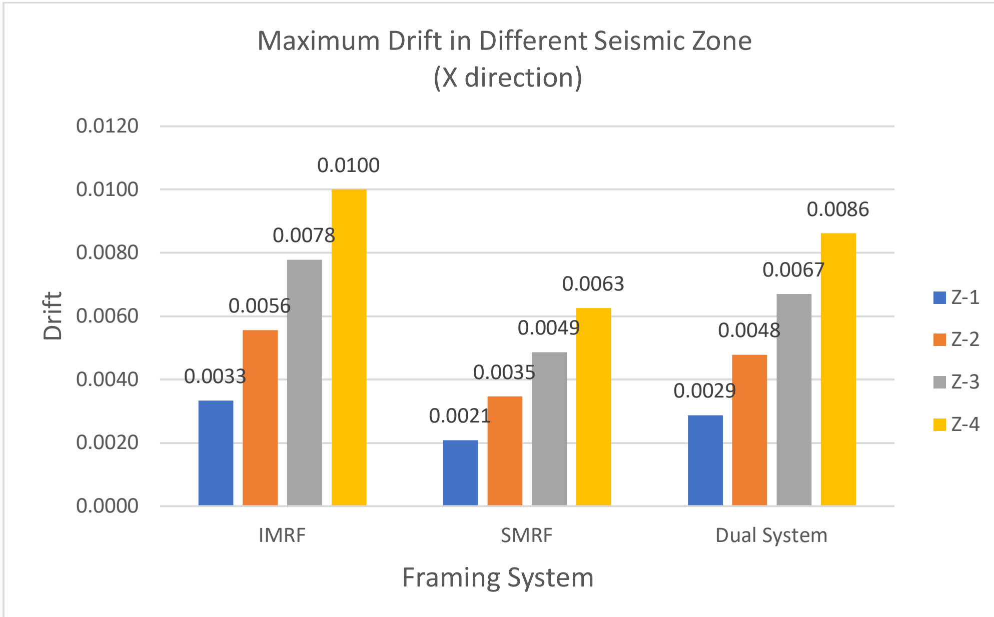


Figure 4-10. Maximum Story Drift in Different Zone X direction

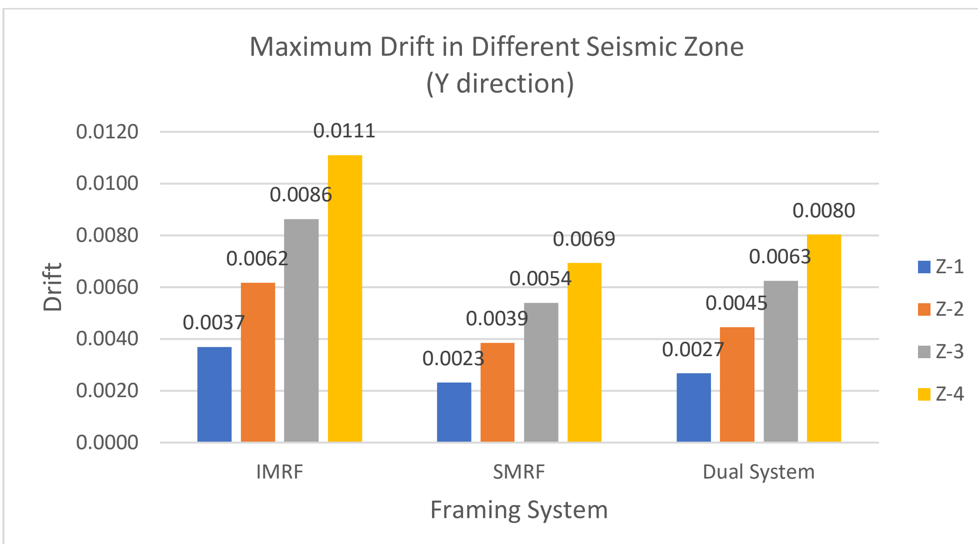


Figure 4-11. Maximum Story Drift in Different Zone Y direction

4.3 Story Stiffness

The figure compares the maximum lateral stiffness of the structure for IMRF, SMRF, and Dual framing systems in both X- and Y-directions. IMRF and SMRF show identical stiffness in the X-direction (46,023 kip/ft) and lower stiffness in the Y-direction (43,292 kip/ft), indicating reduced rigidity along that axis. The Dual System exhibits the highest stiffness in both directions, with values of 52,956 kip/ft in the X-direction and 58,256 kip/ft in the Y-direction. This increased stiffness explains the improved control of displacement and drift observed in the Dual System, demonstrating its superior lateral load-resisting performance compared to IMRF and SMRF systems.

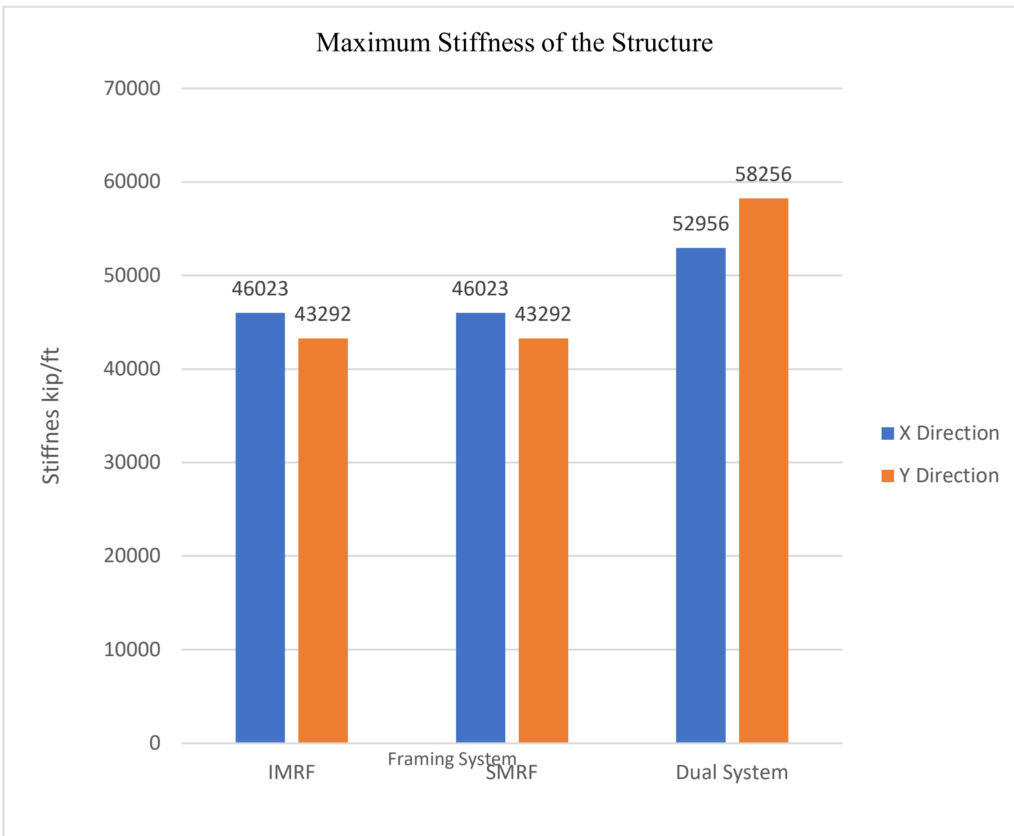


Figure 4-12. Storey Stiffness in Different framing system

CHAPTER 5
Conclusions and Future Works

5.1 Conclusions

This study evaluates the structural performance of SMRFs, IMRFs and Dual Systems in moderately tall residential buildings across four Bangladeshi cities - Jessore, Dhaka, Chittagong, and Sylhet, each representing different seismic zones. The research findings indicate that:

- Dual systems significantly reduce wind-induced displacements, achieving reductions compared to SMRFs, showing their effectiveness in high-wind regions like Jessore and Chittagong;
- Dual systems reduce earthquake-induced displacement in the Y direction but architectural constraints on shear wall placement led to an increase in the X direction. Therefore, a balanced approach to shear wall placement is important for maintaining effective seismic performance;
- SMRFs outperform dual systems in the X direction due to fewer shear walls, leading to larger story drifts. In the Y direction, dual systems reduce story drift. These findings emphasize the need for effective shear wall placement and careful planning to minimize story drift in both main directions;
- In Jessore (Zone 1), Dhaka (Zone 2), and Chittagong (Zone 3), dual systems reduce reinforcement requirements compared to SMRFs. However, in Sylhet (Zone 4), they require more reinforcement, showing the importance of selecting a lateral load-resisting system based on seismic conditions;
- Using a dual system reduces framing costs compared to SMRFs. Therefore, dual systems with IMRFs and special shear walls serve as an economical option for residential buildings up to 8 stories tall in Dhaka and Chittagong.
- In seismic zone 4, such as Sylhet, dual systems with IMRFs and special shear walls are less economical than SMRFs, requiring more reinforcement and leading to increase in costs.

5.2 Limitations

- This research was conduct using a medium-rise structural design concept**.**
- This study was conducted on a medium-rise (G+7) residential building.
- Architectural plan and Structure followed BNBC 2020 code.
- ETABS-2023 and autoCAD-2021 were used for analysis and modeling.

5.3 Recommendation for future works

The following recommendations can be made for future research work-

- The case study conducted in this research is for three districts of Bangladesh. However, the different Seismic zone coefficient and Wind varies for different parts of Bangladesh. Similar study can be performed for other parts of Bangladesh especially for different area and different seismic zones.
- Similar study can be performed for other types of buildings such as steel frames, ordinary moment resisting frames and masonry structures etc. located in different in places with different site conditions.
- To find the impact on design only the reinforcement requirement in point displacement, story drifts and longitudinal reinforcement are considered. This study can be extended of analysis Steel building.
- The current research was conducted on only one types of structural systems. Other structural systems listed in BNBC-2020, can be investigated further.
- Continuity of study on higher vertical structures in different seismic zones of Bangladesh.
- Future studies should consider taller or irregular building for more comprehensive analysis.
- Soil-structure interaction and different soil types should be incorporated for accuracy.

5.4 References

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