Comparative Seismic Analysis of High-Rise Buildings Using Recycled and Conventional Steel in the Context of 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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Section: 24C

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DECLARATION

It is hereby declared that this thesis/project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedicated

to

"The brave souls of 1971 and the martyrs of 24th and July–August movements — your blood wrote our history"

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ABSTRACT

This study examines the seismic and economic feasibility of using recycled steel as a substitute for conventional steel in the construction of high-rise buildings across all four seismic zones in Bangladesh. Recycled steel has become a promising solution as the building industry becomes increasingly concerned about environmental sustainability and resource efficiency. It has the ability to lower the cost of building and lessen its impact on the environment while yet achieving structural performance standards.

The study utilizes ETABS 2022 software to model and evaluate a 10-story building, aiming to determine the feasibility of this technique. The analysis examines three representative lateral load-resisting systems—moment-resisting frames, shear walls, and bracing systems subjected to seismic loading conditions as delineated in BNBC 2020 for seismic zones 1 to 4. Researchers determined the mechanical properties of recycled steel through experiments with varying carbon content (0.25%, 0.27%, and 0.30%) and heating the steel evenly to 760°C.

Along with evaluating the structural performance, a cost-benefit analysis was conducted comparing recycled and regular steel, taking into account factors such as the ease of obtaining materials, design requirements, and long-term maintenance costs. The study aims to determine if recycled steel meets the necessary standards of strength, ductility, and reliability to be considered a viable alternative in structural design, particularly in regions prone to earthquakes.

The results of this study are anticipated to yield significant insights for civil engineers, architects, and urban planners in pursuit of sustainable solutions for resilient infrastructure development in Bangladesh. The results may also be used to modify local building regulations and promote the use of environmentally friendly products in everyday life.

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CHAPTER 1
INTRODUCTION

1.1 Background and Motivations

The construction sector in Bangladesh is experiencing significant growth, particularly in metropolitan centers, where demand for multi-story residential and commercial structures is gradually increasing. This is especially true in commercial and residential buildings. The vertical growth of infrastructure becomes a realistic solution as population density in cities decreases and increases. On the other hand, Bangladesh is located in an area that is moderately to highly sensitive to seismic activity throughout the region. According to BNBC 2020, the nation is divided into four distinct seismic zones, each with a different level of seismic strength. As a result, maintaining the seismic safety of high-rise structures is a matter that needs to be addressed immediately.

Concurrently, the issue of sustainability in construction materials has emerged as a global concern due to the growing scarcity of resources and environmental destruction. Steel is one of the most critical components in contemporary reinforced concrete construction; nevertheless, conventional steel manufacturing is primarily dependent on imported materials, resulting in increased costs and environmental impact. The utilization of recycled steel that is generated from local scrap sources is an efficient alternative. Not only does this cut costs, but it also encourages environmentally responsible activities by reusing products that contain waste.

There is a dearth of full-scale application data, particularly under seismic loading, which causes engineers and stakeholders to be hesitant about using recycled steel, despite encouraging results in mechanical property testing. The question of whether recycled steel can meet the structural requirements of earthquake-prone locations without compromising safety is becoming an increasingly popular topic of investigation.

1.2 Research Objectives and Overview

Despite the growing interest in the exploitation of recycled materials in the construction industry, there has been a limited amount of research conducted on the performance of recycled steel in actual building models under seismic loading circumstances. This is despite the emergence of a growing market for recycled materials. The vast majority of studies conducted in the past have focused solely on the mechanical properties of recycled steel through laboratory investigations. Despite this, these findings have not been utilized in simulating genuine building environments, nor have they been examined for their effectiveness in various seismic zones.

Furthermore, there has been no extensive research in Bangladesh that compares the performance of recycled steel with conventional steel while utilizing the national building code. This gap highlights the need for a detailed investigation.

Our Objectives:

- To use recycled steel with different carbon contents (0.25%, 0.27%, 0.30%) treated at 760°C.
- To compare the performance of recycled steel with conventional steel.
- To evaluate structural behavior under earthquake loading.
- To measure story displacement, story drift, and steel requirement.
- To examine whether recycled steel meets BNBC 2020 seismic performance standards.
- To observe if the use of recycled steel can reduce environmental impact and promote sustainable circular construction.
- To conduct a cost comparison between recycled steel and conventional steel.

1.3 Organization of the thesis

Chapter 1: Introduction

Provides background and motivation for the study, outlines the problem statement, and presents the overall structure of the thesis.

Chapter 2: Literature Review

Reviews previous studies related to recycled steel, seismic performance, and structural analysis in the context of high-rise construction.

Chapter 3: Methodology

Describes the modelling process using ETABS, the selection of material properties, and the approach to dynamic analysis as per BNBC 2020.

Chapter 4: Results and Discussion

It presents the results of the seismic performance analysis and compares recycled and conventional steel across different seismic zones.

Chapter 5: Conclusion and Recommendations

Summarizes the main findings of the study and provides suggestions for future research and practical implementation.

Chapter 6: References

Lists all sources cited throughout the thesis.

CHAPTER 2
Literature Review

2.1 Introduction

Significant focus has been directed toward the reuse of materials readily available in the local area, in response to the growing demand for environmentally responsible building techniques. Steel is an essential component of reinforced concrete constructions, and when it is created from scrap, it presents a potential for both cost savings and environmental sustainability. This chapter presents a review of the most recent and pertinent literature on the mechanical characteristics and structural performance of recycled steel. The focus of this review is on the application of recycled steel in seismic zones.

The purpose of this review is to draw attention to the existing research, highlighting both its strengths and weaknesses, identifying the gaps that still exist in this subject, and thereby justifying the need for the current study. In this study, a particular focus is placed on the impact that carbon content and final rolling temperature have on the properties of recycled steel, as well as the correlation between these factors and the structural safety of high-rise buildings located in earthquake-prone regions, such as Bangladesh.

2.2 Content

A comprehensive study was conducted by Abbas et al. (2023) on reinforcing steel rebars made from local scrap at various finishing rolling temperatures (FRT). The research focused on five different FRTs with temperatures ranging from 640°C to 800°C, as well as three different carbon content levels: 0.25%, 0.27%, and 0.30%. Several mechanical parameters, including yield strength, tensile strength, ductility, toughness, and hardness, were evaluated through the experimental program in accordance with the requirements established by ASTM A605.

Increasing the FRT was discovered to often result in a decrease in yield and tensile strength, while simultaneously increasing ductility and toughness. On the other hand, the carbon concentration exhibited a favorable relationship with both the strength and hardness of the material, while simultaneously limiting its ductility. Microstructural

insights were also offered by the study, which demonstrated that greater FRT leads to larger austenite grains, which in turn influence the ultimate mechanical behavior of the steel during the manufacturing process.

However, the study did not investigate the seismic performance of these materials in actual structural systems or model them under cyclic loads. Neither of these topics was addressed. Additionally, the performance under heat settings, which is essential during fire exposure, was not taken into consideration. Consequently, the mechanical data, although useful as a reference, do not provide an adequate answer to the question of whether these rebars can be utilized safely in high-rise buildings located in seismic zones.

By incorporating mechanical discoveries into structural modelling and seismic analysis, the current research builds upon the foundation laid by previous research. According to BNBC 2020, recycled steel that has been heat-treated at 760 degrees Celsius and categorized according to its carbon content is modelled in a ten-story building and then examined throughout all four seismic zones in Bangladesh using ETABS 2022 models. This approach ensures that both mechanical and dynamic performance are tested under realistic loading conditions, thereby eliminating the fundamental limitation present in past work.

2.3 Summary

The research material that was examined in this chapter provides evidence that recycled steel has the potential to be used in structural applications. On the other hand, it also highlights considerable shortcomings, particularly in the analysis of full-scale performance under seismic conditions. Although prior research has demonstrated that FRT and carbon content have an effect on the strength and ductility of materials, the lack of zone-wise seismic analysis makes it difficult to determine how these factors should be applied in actual construction activities. Through the implementation of a model-based evaluation method that makes use of actual seismic loading conditions and national design codes, the purpose of this thesis is to close that divide. The purpose of these results is to determine whether recycled steel can serve as a feasible and secure alternative to traditional reinforcement in earthquake-prone regions, such as Bangladesh.

CHAPTER 3
Methodology

3.1 Introduction

This chapter provides an extensive elucidation of the scientific methodology employed to evaluate the seismic performance of high-rise structures constructed using both recycled and traditional steel. The approach consists of a step-by-step process that encompasses structural design, modeling, and analysis of a ten-story reinforced concrete (RC) structure situated in various seismic zones, as defined by BNBC 2020. Bangladesh is divided into four zones, each exhibiting distinct levels of earthquake risk. The primary objective is to compare recycled steel with conventional steel side by side, with the recycled steel sorted by carbon content (0.25%, 0.27%, and 0.30%) and heated to 760°C, to assess their performance under dynamic seismic stresses.

The ETABS 2022 software was used for all structural modeling and analysis operations to ensure the simulation was realistic and reliable. The RC building was built to meet BNBC 2020 standards, ensuring it can handle the lateral and gravity loads common in Bangladesh. We got experimental figures for the mechanical properties of recycled steel, like Elastic Modulus, Yield Strength, and Ultimate Tensile Strength, from reliable published sources. Using the correct safety factors and assumptions in accordance with the AISC design criteria, these numbers were further refined for accuracy. This makes sure that the model is both safe and conservative.

To simulate how the structure would respond to earthquakes for each type of material and zone, dynamic analysis —specifically, response spectrum analysis —was employed. To ensure the comparison was fair and accurate, all models had the same load applications and boundary conditions. The study aims to confirm that recycled steel, when adequately processed and classified, can offer structural reliability comparable to traditional steel, thereby endorsing its use in sustainable seismic design practices in developing nations such as Bangladesh.

3.2 Methodology Overview

The research methodology followed a structured sequence of steps:

1. **Literature Review**: Identification of the research gap and relevance of recycled steel for seismic zones in Bangladesh.
2. **Material Selection**: Recycled steel categorized into three groups (0.25%, 0.27%, and 0.30% carbon), heat-treated at 760°C, and conventional steel as baseline.
3. **Property Assignment**: Mechanical properties such as Elastic Modulus, Yield Strength, and Ultimate Tensile Strength were derived from published experimental data. Expected design values were calculated by applying conservative assumptions in accordance with AISC provisions.

Table 3.1: Recycled Steel Properties at 760°C

Steel Type	Elastic Modulus (E) lb/in²	Minimum Yield strength (Fy) lb/in²	Minimum Tensile strength (Fu) lb/in²	Expected Yield strength (Fye) lb/in²	Effective Tensile strength (Fue) lb/in²
0.25% carbon at 760°C	29007548	55470	86130	61640	95700
0.27% carbon at 760°C	29007548	56130	88770	62370	98630
0.30% carbon at 760°C	29007548	57440	91370	63820	101530

4. **Modelling in ETABS: A ten-storied RCC building was modelled** using ETABS 2022. Design parameters were chosen based on BNBC 2020 guidelines. Reinforcement sections were dimensioned based on gravity and lateral load requirements.

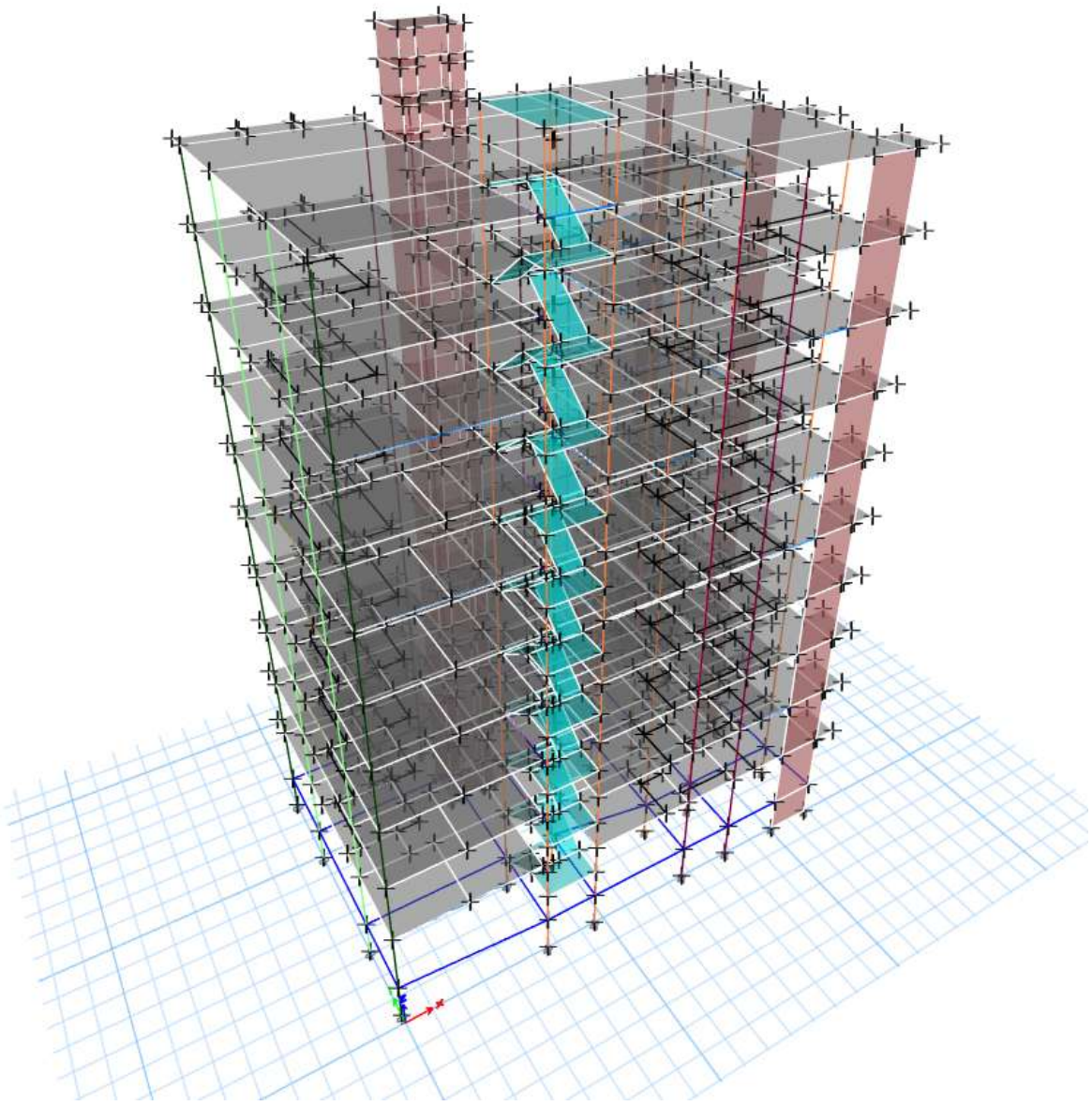


Figure 3.1 3D Model of 10-Storied RCC Building in ETABS

5. **Seismic Zone Consideration**: Four separate models were created for Zone 1, Zone 2, Zone 3, and Zone 4. Each zone considered both EX and EY directional earthquake loads.
6. **Analysis Type**: Dynamic response spectrum analysis was used to evaluate the seismic behavior of the structures.
7. **Result Extraction**: Story displacement, story drift, and required reinforcement areas were extracted and compared.

3.3 Summary

This chapter outlines the approach used to evaluate the performance of recycled steel under seismic conditions. It encompasses material classification, ETABS modelling, and the implementation of BNBC 2020 regulations throughout four seismic zones. The procedures ensure consistency and provide a systematic approach, from data selection to outcome analysis. The subsequent chapter provides a comprehensive elucidation and examination of the results of these analyses.

CHAPTER 4
Results and Discussion

4.1 Introduction

This chapter summarizes the seismic study of a 10-story reinforced concrete building model with recycled and conventional steel under BNBC 2020 seismic conditions. This study investigates the structural behavior of structures composed of recycled steel with carbon contents of 0.25%, 0.27%, and 0.30%, and heat-treated at 760°C. All four seismic zones of Bangladesh were used to evaluate the model's lateral displacement and inter-story drift.

With the rise of urbanization in Bangladesh, sustainable and cost-effective construction approaches are crucial. Correctly processed and categorized recycled steel is an environmentally benign and economically effective alternative to conventional reinforcement materials. However, a simulation and a comparative study are needed to assess its structural performance, particularly under dynamic loading, such as seismic excitation. This study utilizes ETABS 2022 to analyze seismic zone dynamic response spectra and fill this gap.

Measurements of structural reaction include Maximum Story Displacement and Maximum Story Drift. These characteristics are crucial to a building's seismic performance. Story displacement measures the horizontal movement of each floor level relative to the base, while story drift measures the relative displacement between floors. Extreme values in any metric can compromise structural integrity, cause non-structural damage, and lead to collapse.

This chapter compares recycled and conventional steel to determine if recycled steel can resist seismic pressures equally. The results were comparable, as all simulations employed the same loading and boundary conditions. This study investigates the application of moment-resisting frames, shear walls, and bracing for resisting lateral loads.

To help comprehend seismic zone trends, this chapter offers tabular numerical data and graphical representations. EX and EY values represent displacement and drift

along the X and Y axes for each zone. These results show if recycled steel reacts differently to earthquake intensity.

This chapter seeks to investigate if recycled steel is suitable for high-rise buildings in earthquake-prone Bangladesh. The purpose is to give engineers, academics, and politicians data to promote recycled steel as a safe, sustainable construction material.

4.2 Specific Aim 1: Seismic Performance Evaluation

This section presents the maximum story displacement and maximum story drift values for both regular and recycled steel in all four seismic zones. These two measurements are crucial for determining how a structure will behave and its utility during earthquakes. Displacement shows how much the top of a building moves, while drift shows how much the floors move in relation to one another. This is significant for both non-structural damage and human comfort.

For clarity, the results are shown in both tables and graphs. The comparison analysis enables a direct performance assessment of recycled steel and conventional steel at varying degrees of seismic activity.

Table 4.1: Maximum Story Displacement (inch)

Seismic Zone	Conventional Steel 0.25% C		Recycle Steel					
			0.25% C Steel		0.27% C Steel		0.30% C Steel	
	EX	EY	EX	EY	EX	EY	EX	EY
Zone 1	0.7452	0.7398	0.7452	0.7398	0.7452	0.7398	0.7452	0.7398
Zone 2	1.0509	1.0432	1.0509	1.0432	1.0509	1.0432	1.0509	1.0432
Zone 3	2.0493	2.0343	2.0493	2.0343	2.0493	2.0343	2.0493	2.0343
Zone 4	2.6349	2.6156	2.6349	2.6156	2.6349	2.6156	2.6349	2.6156

4.2.1 Maximum Story Displacement: Table 4.1 shows the highest story displacement values for all earthquake zones. The results reveal a consistent pattern in how the steel grades behave when displaced, regardless of whether they are new or recycled. This includes steel grades with carbon content of 0.25%, 0.27%, and 0.30% that were treated at 760°C. Although the characteristics of the materials differ, the lateral displacement values for each zone are nearly identical. This consistency indicates that using recycled steel does not weaken the building's lateral stiffness or its ability to deform globally. Displacement is a crucial factor in determining a structure's flexibility and the comfort it provides to people during seismic activity. The observed performance shows that using recycled steel as a reliable substitute for traditional materials is possible.

Story Response - Maximum Story Displacement

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EX	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

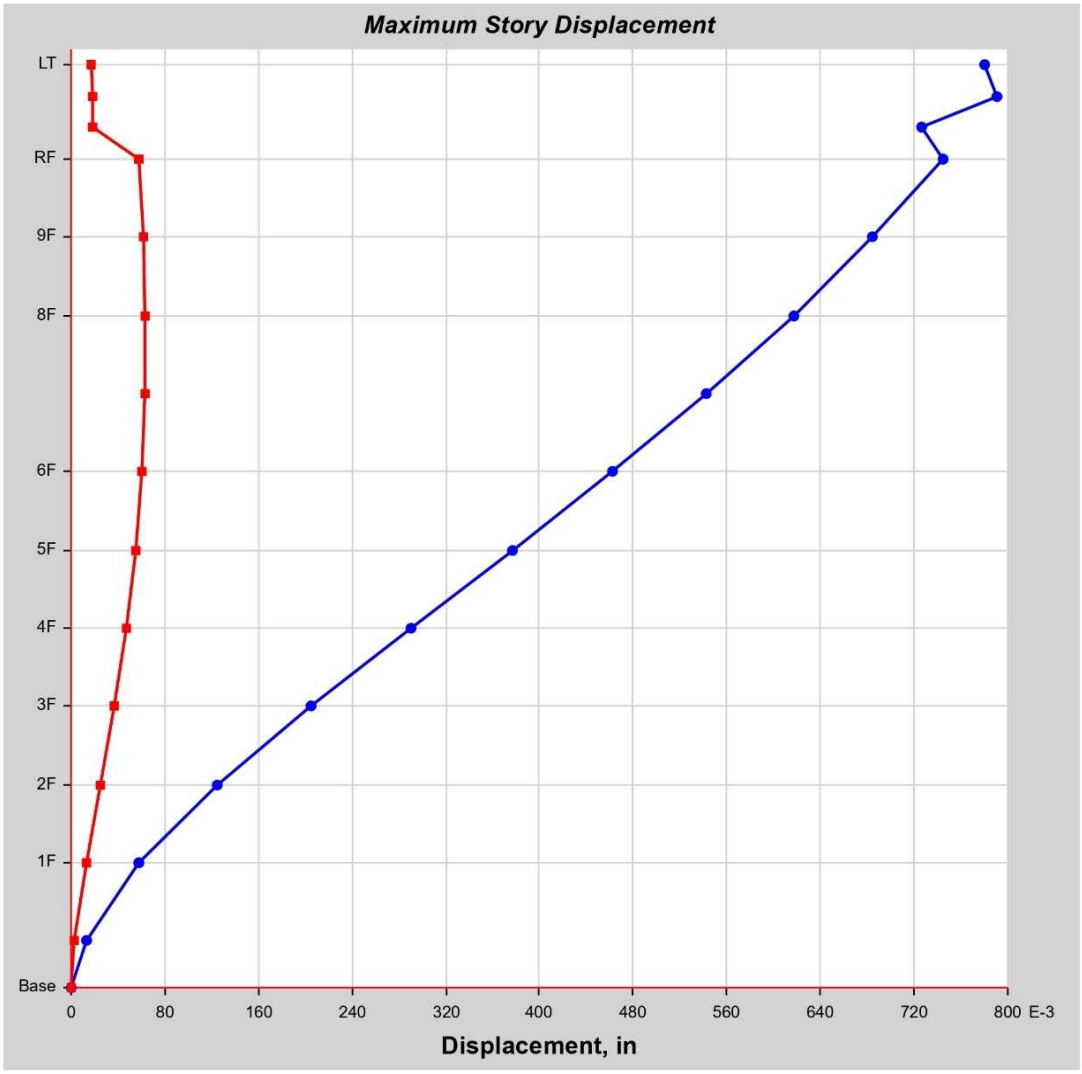


Figure 4.1 Maximum Story Displacement for Zone 1 (EX)

Story Response - Maximum Story Displacement

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EY	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

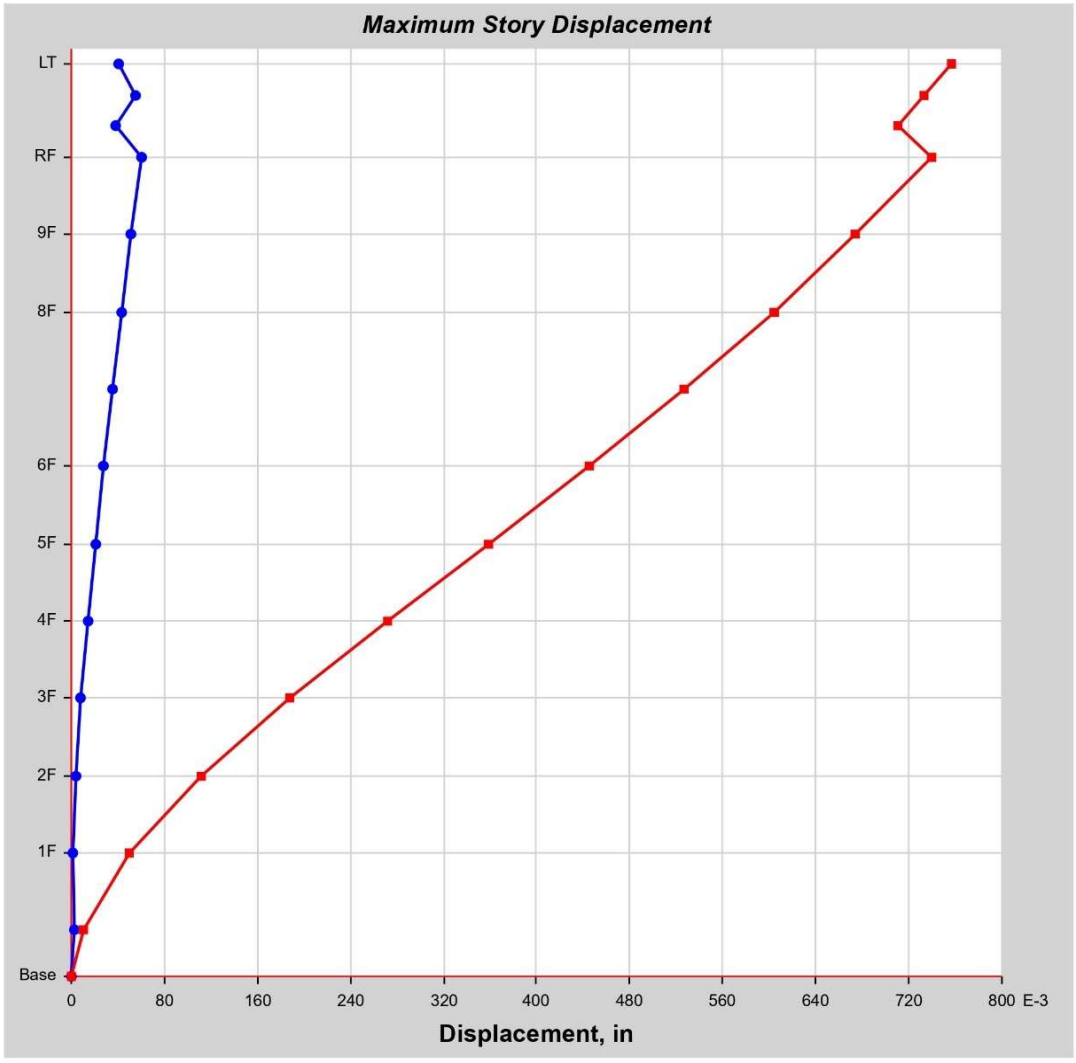


Figure 4.2 Maximum Story Displacement for Zone 1 (EY)

Story Response - Maximum Story Displacement

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EX	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

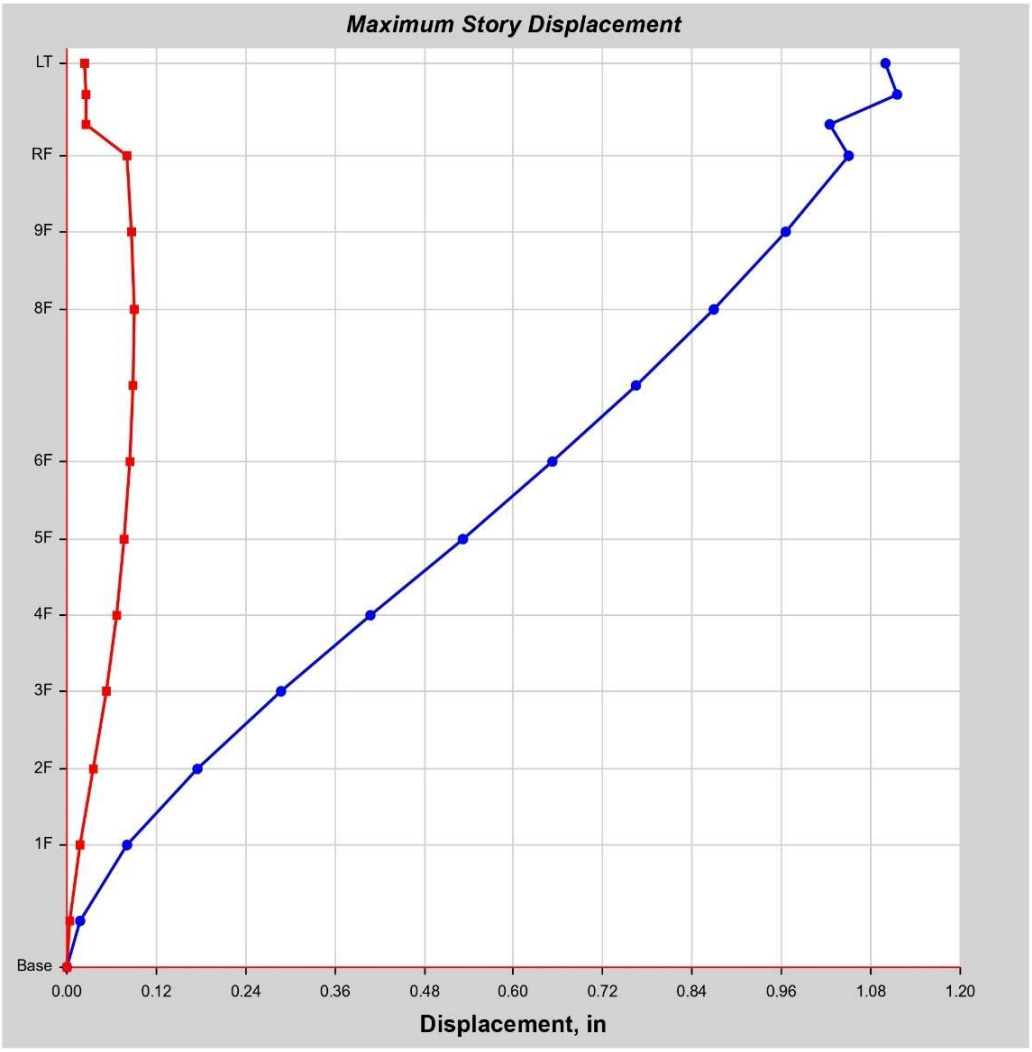


Figure 4.3 Maximum Story Displacement for Zone 2 (EX)

Story Response - Maximum Story Displacement

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EY	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

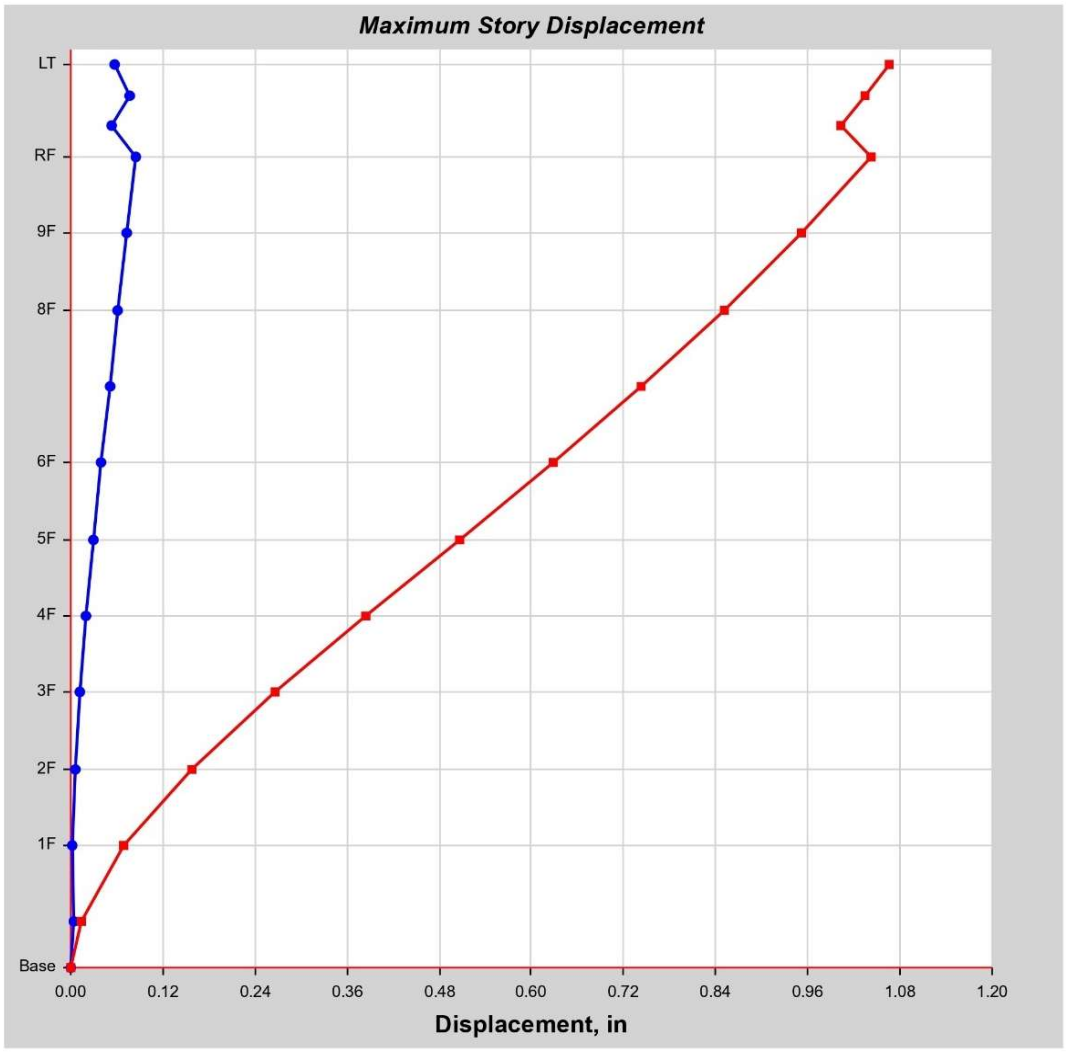


Figure 4.4 Maximum Story Displacement for Zone 2 (EY)

Story Response - Maximum Story Displacement

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EX	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

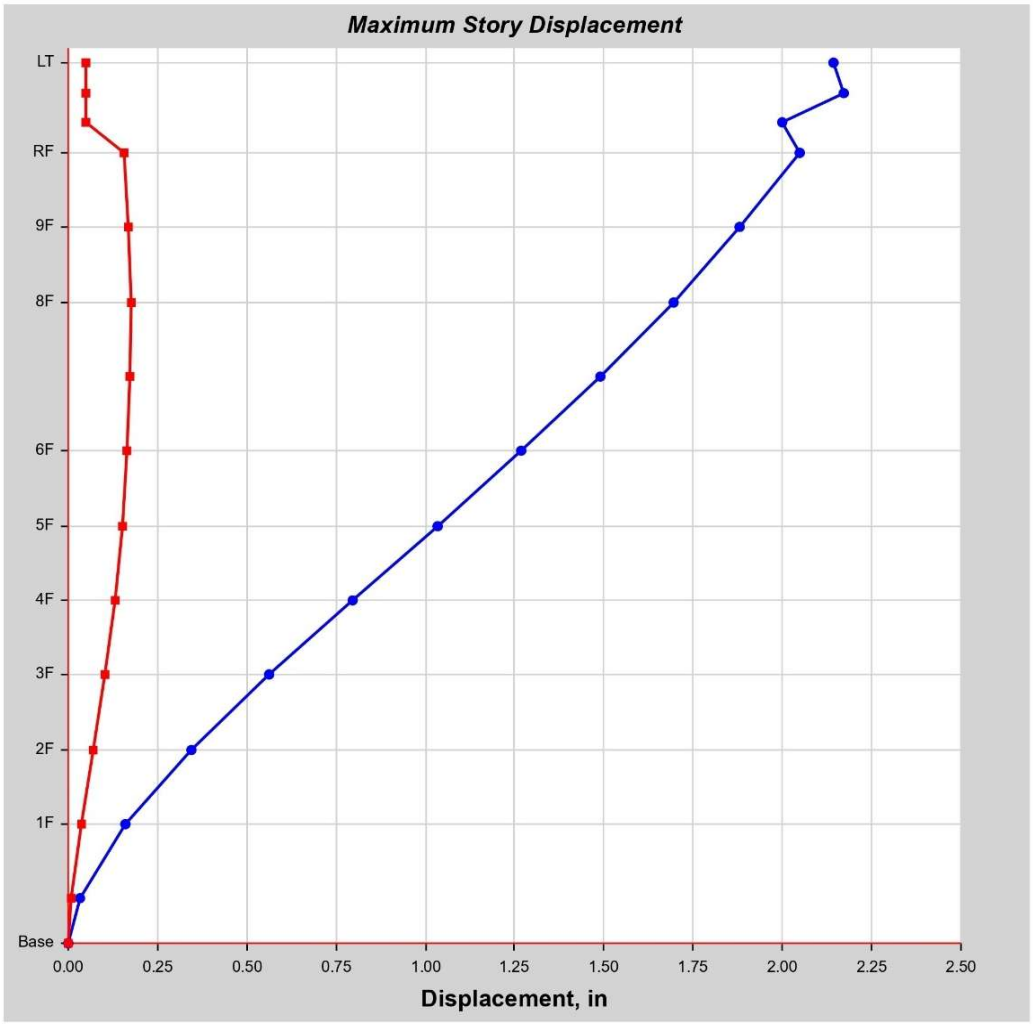


Figure 4.5 Maximum Story Displacement for Zone 3 (EX)

Story Response - Maximum Story Displacement

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EY	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

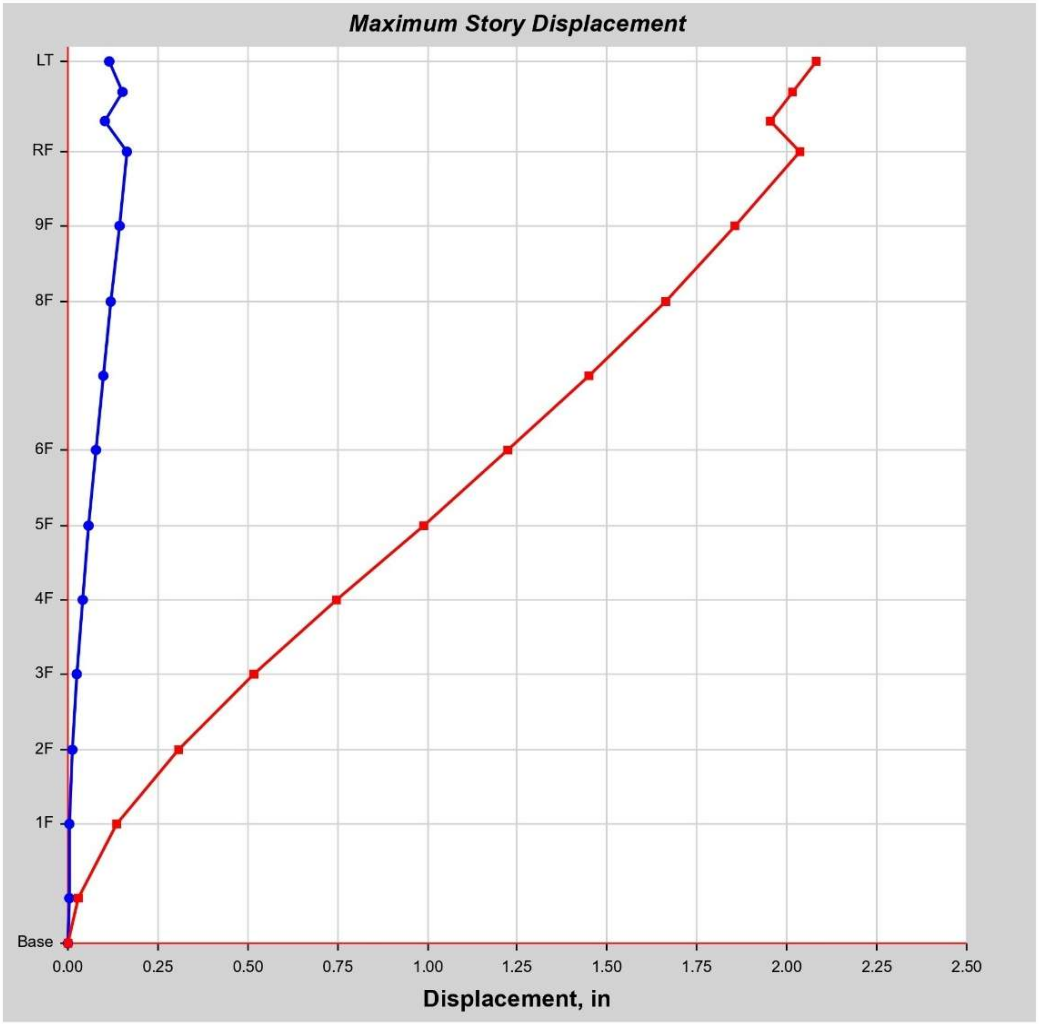


Figure 4.6 Maximum Story Displacement for Zone 3 (EY)

Story Response - Maximum Story Displacement

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EX	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

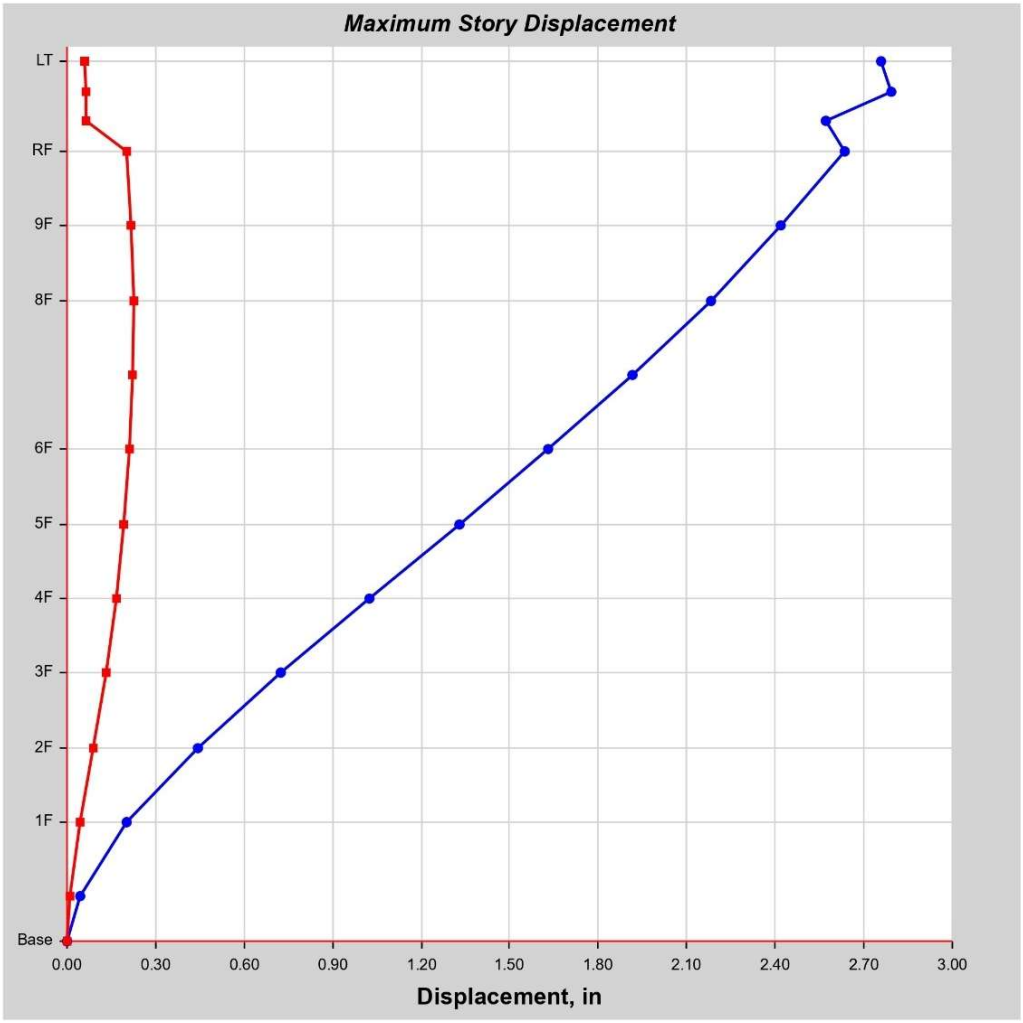


Figure 4.7 Maximum Story Displacement for Zone 4 (EX)

Story Response - Maximum Story Displacement

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EY	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

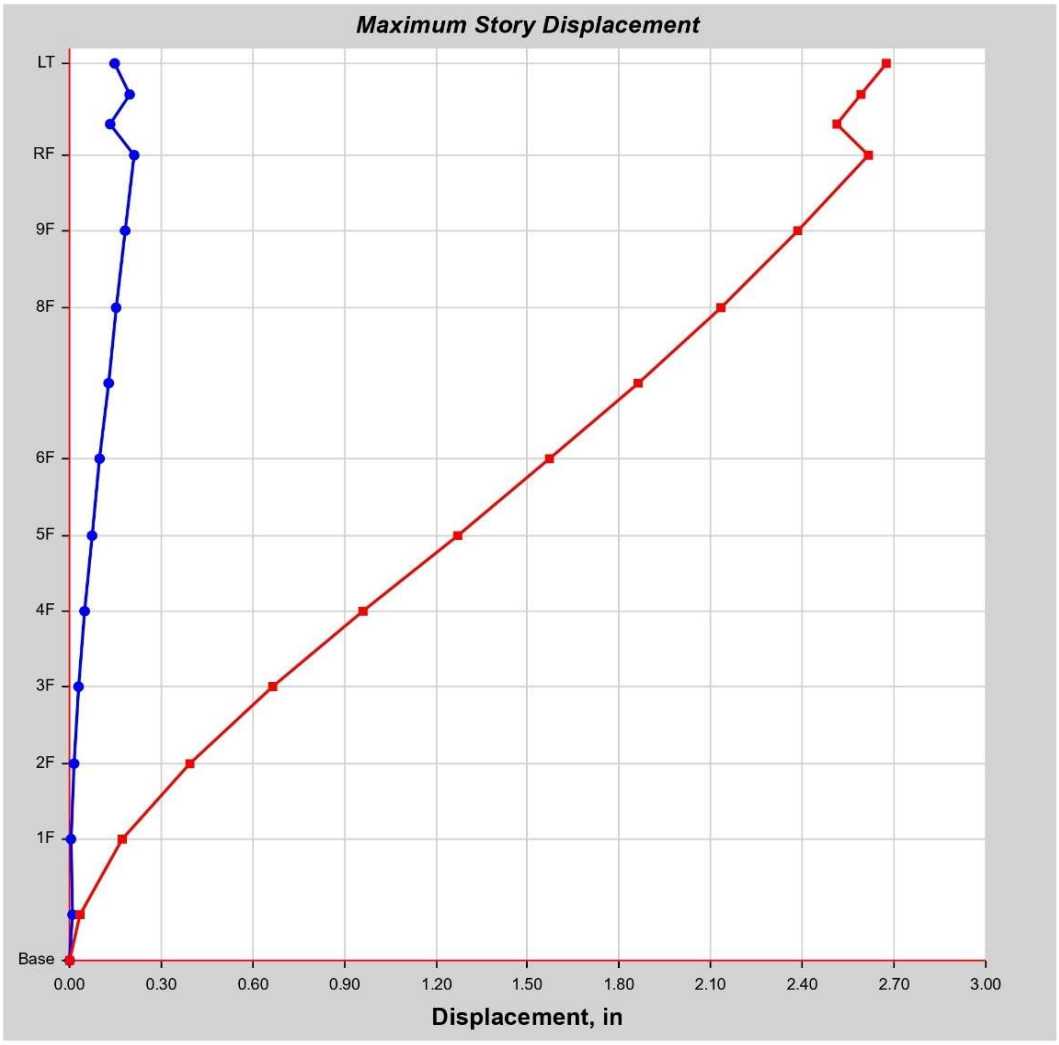


Figure 4.8 Maximum Story Displacement for Zone 4 (EY)

Table 4.2: Maximum Story Drift (inch)

Seismic Zone	Conventional Steel 0.25% C		Recycle Steel					
			0.25% C Steel		0.27% C Steel		0.30% C steel	
	EX	EY	EX	EY	EX	EY	EX	EY
Zone 1	0.0265	0.0227	0.0265	0.0227	0.0265	0.0227	0.0265	0.0227
Zone 2	0.0374	0.0321	0.0374	0.0321	0.0374	0.0321	0.0374	0.0321
Zone 3	0.0730	0.0625	0.0730	0.0625	0.0730	0.0625	0.0730	0.0625
Zone 4	0.0938	0.0804	0.0938	0.0804	0.0938	0.0804	0.0938	0,0804

4.2.2 Maximum Story Drift: Table 4.2 illustrates the maximum story drift values. Similar to displacement, the drift values remain consistent across the different steel grades. This indicates that recycled steel does not adversely affect the drift performance of the structure, which is critical for serviceability and safety during seismic events.

Story Response - Maximum Story Drifts

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EX	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

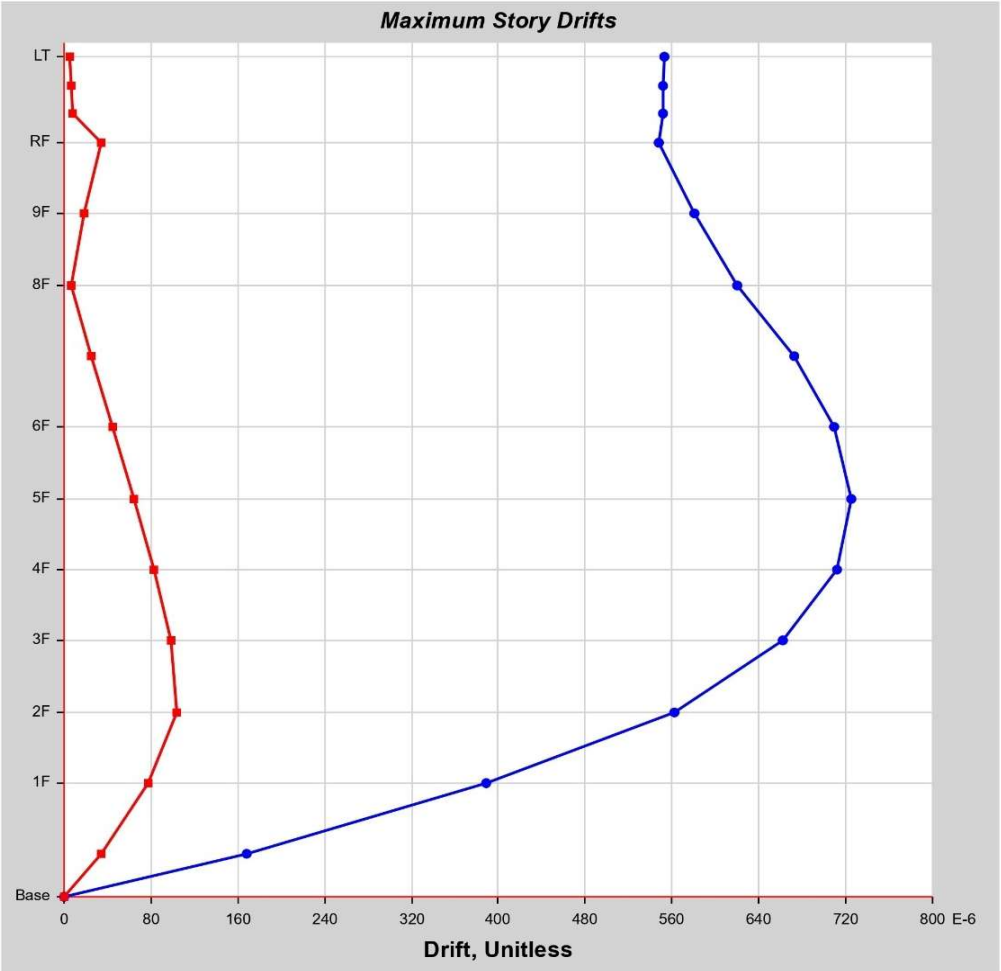


Figure 4.9 Maximum Story Drift for Zone 1 (EX)

Story Response - Maximum Story Drifts

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EY	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

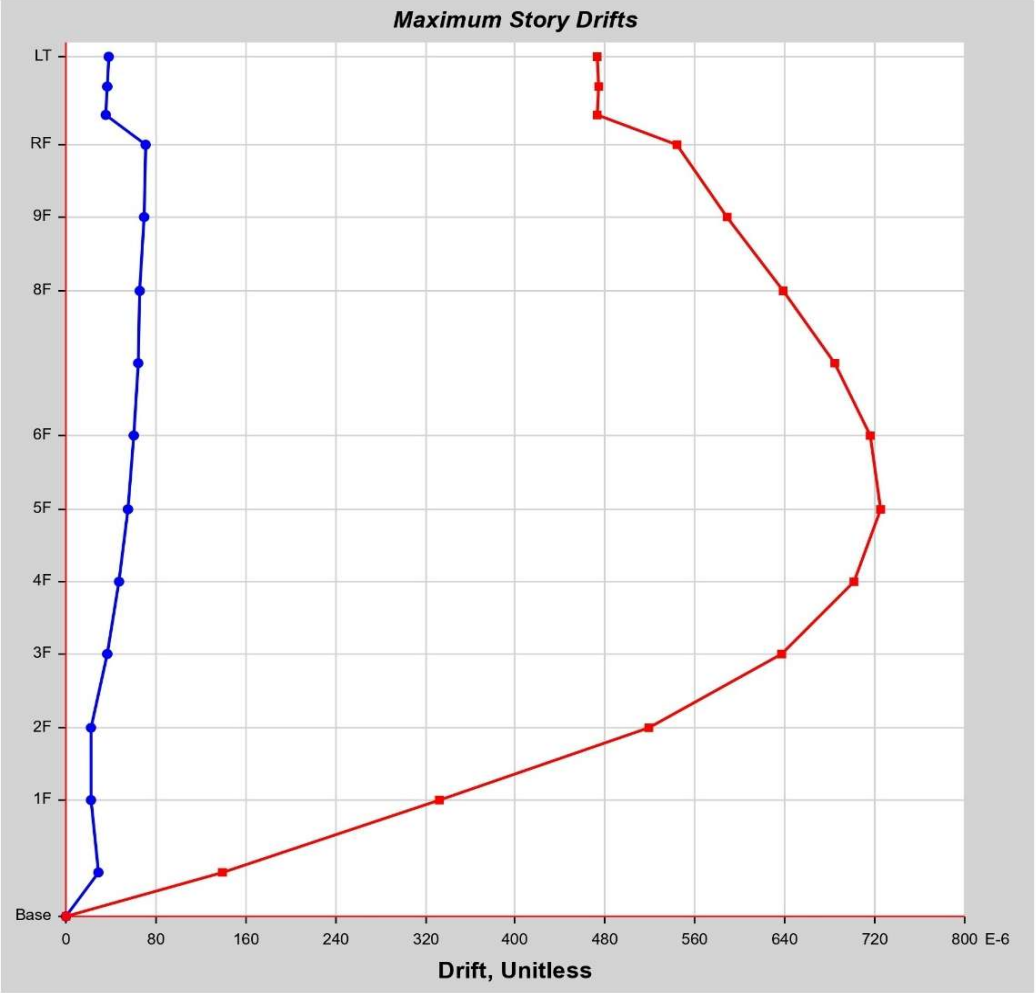


Figure 4.10 Maximum Story Drift for Zone (EY)

Story Response - Maximum Story Drifts

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EX	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

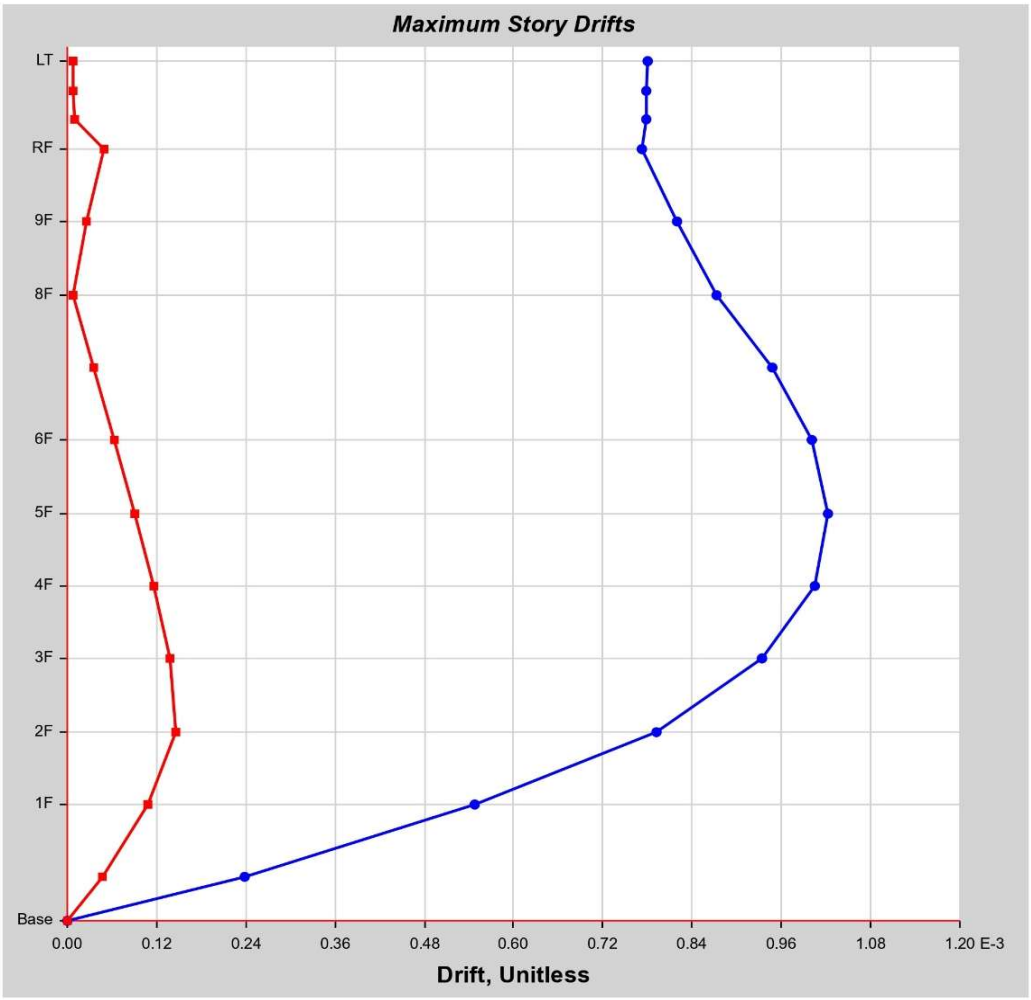


Figure 4.11 Maximum Story Drift for Zone 2 (EX)

Story Response - Maximum Story Drifts

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EY	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

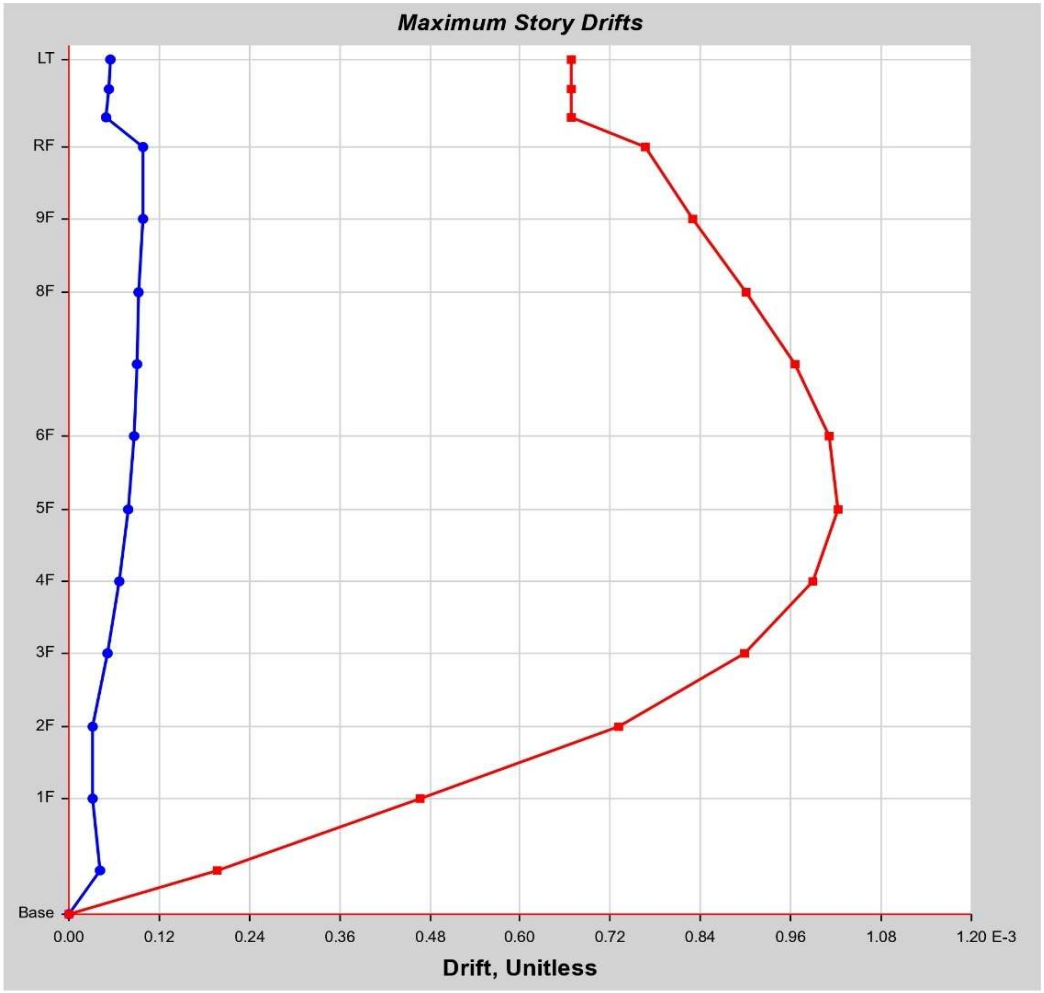


Figure 4.12 Maximum Story Drift for Zone 2 (EY)

Story Response - Maximum Story Drifts

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EX	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

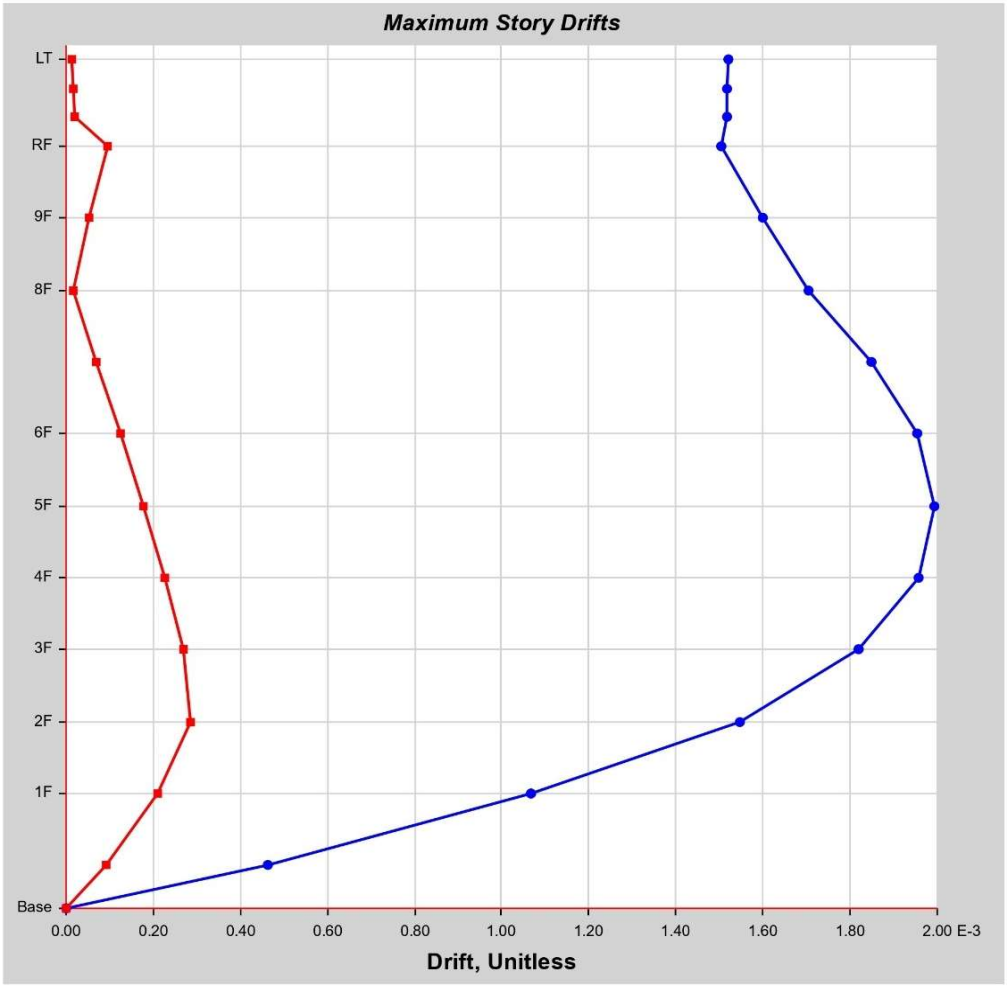


Figure 4.13 Maximum Story Drift for Zone 3 (EX)

Story Response - Maximum Story Drifts

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EY	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

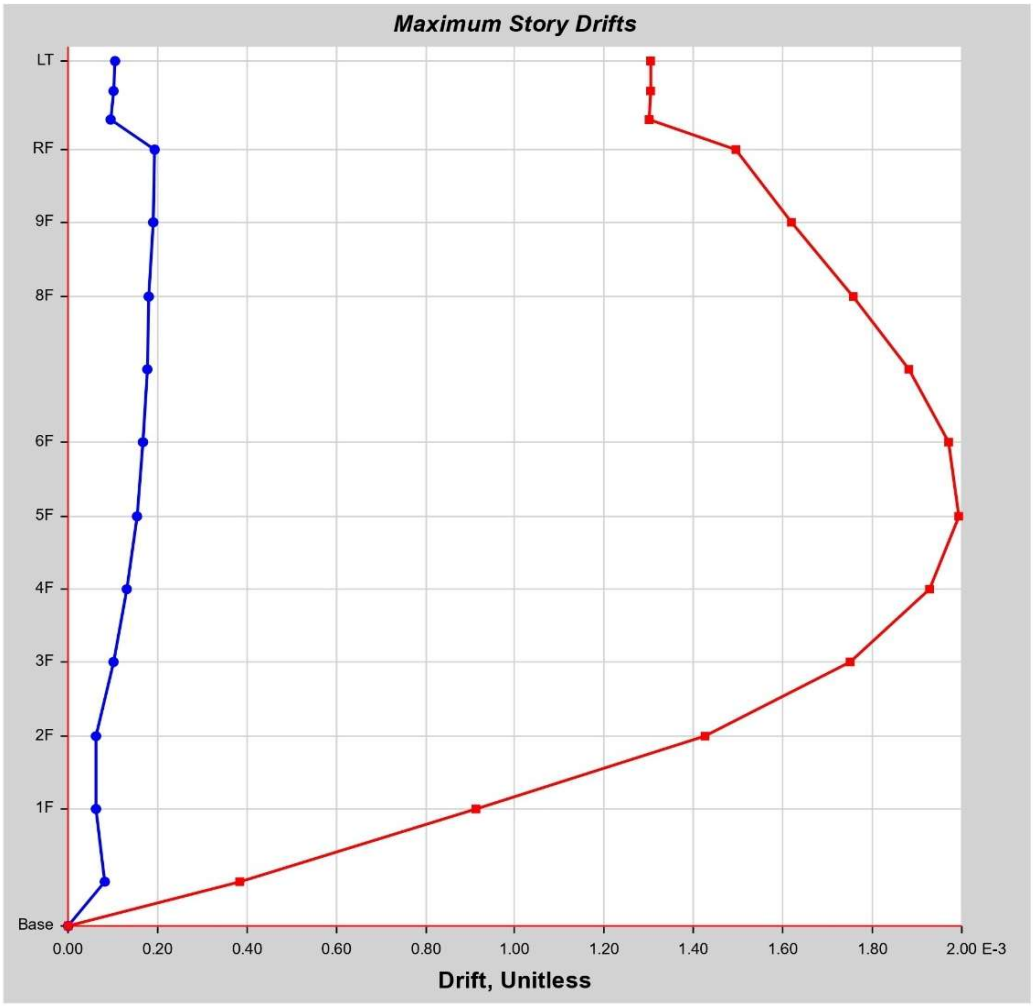


Figure 4.14 Maximum Story Drift for Zone 3 (EY)

Story Response - Maximum Story Drifts

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EX	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

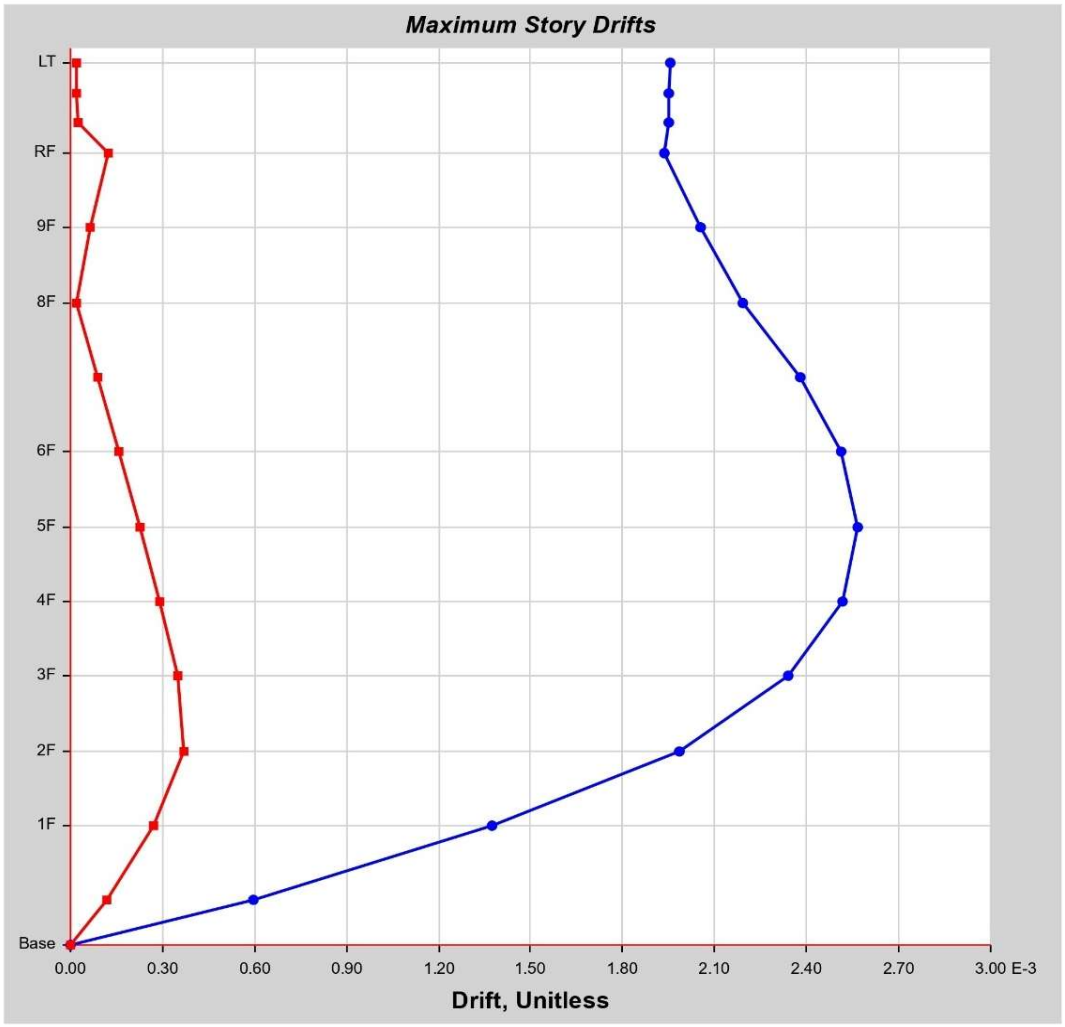


Figure 4.15 Maximum Story Drift for Zone 4 (EX)

Story Response - Maximum Story Drifts

Summary Description

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EY	Top Story	LT
Output Type	Step Number 1	Bottom Story	Base

Plot

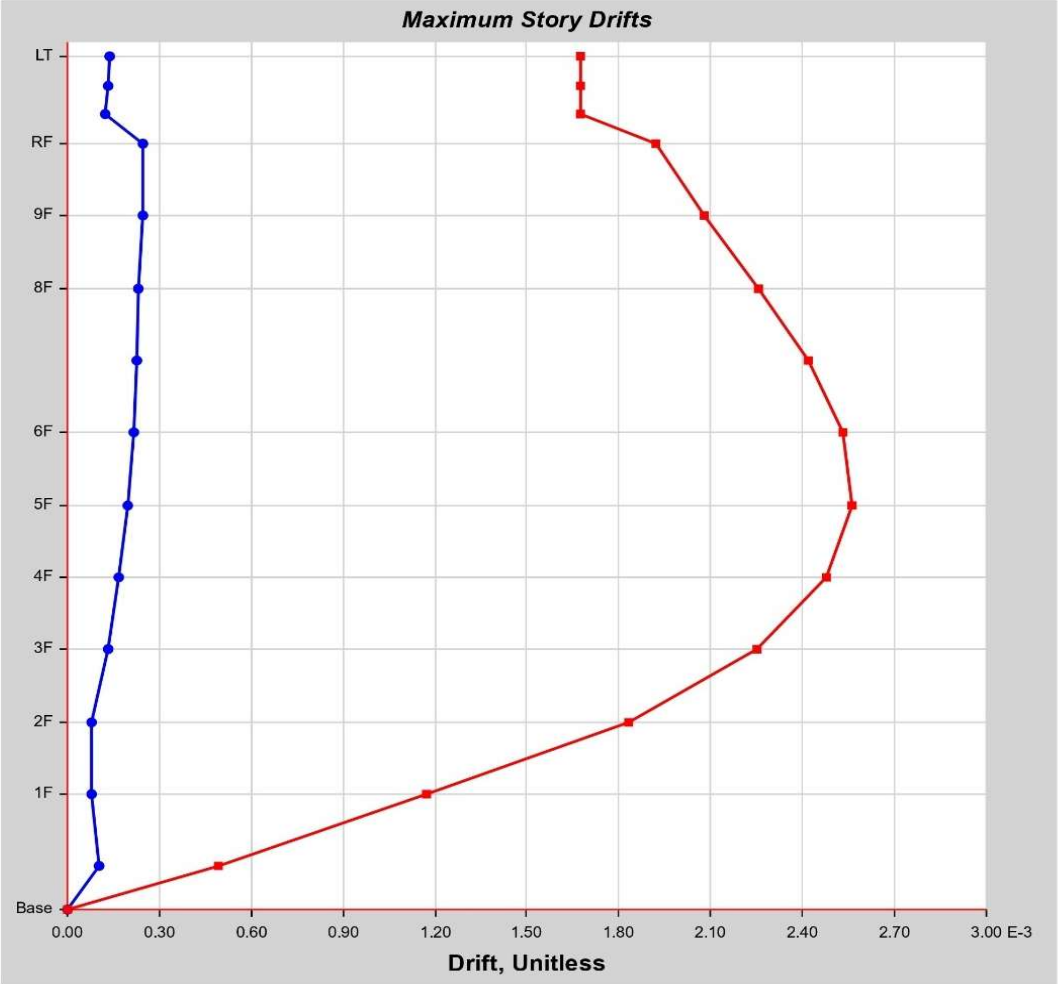


Figure 4.16 Maximum Story Drift for Zone 4 (EY)

From the table and graph above, we can see that in a specific zone, the values of maximum story displacement and maximum story drift are the same, whereas in other zones, the values vary. This indicates that recycled steel can be used in the structure. However, the required quantity of steel will depend on its quality—better quality may reduce the amount needed, while lower quality may increase it. The explanation is given below.

Table 4.3: Exterior Column steel area (inch square)

Conventional Steel	Recycle Steel		
0.25% Carbon	0.25% Carbon	0.27% Carbon	0.30% Carbon
3.56	4.47	4.43	4.37

Table 4.4: Interior Column steel area (inch square)

Conventional Steel	Recycle Steel		
0.25% Carbon	0.25% Carbon	0.27% Carbon	0.30% Carbon
9.19	11.53	11.38	11.12

4.2.3 Steel Area Requirements Tables 4.3 and 4.4 summarize the required steel areas for exterior and interior columns. While all recycled steel variants require slightly more reinforcement than conventional steel, the differences are not drastic. Among the recycled options, 0.25% carbon content steel demands the highest reinforcement area, followed closely by 0.27% and 0.30%. This indicates that selecting higher carbon content recycled steel may slightly reduce reinforcement requirements. Since the building contains many columns, we have shown the comparison using one exterior column and one interior column as samples.

Table 4.5 Cost Analysis

Type of Steel	Unit price (per Ton)	Cost (per sq inch)	Percentage Decrease For Recycle Steel
Conventional Steel	91,000.00	11.7	$\frac{11.7 - 9.3}{11.7} \times 100 = 20.5\%$
Recycle Steel	72,000.00	9.3	

12 mm BSRM Rod (per sq.inch) Calculation

Price of 1 ton = 91,000 Taka (1 ton = 1000 kg)

Weight per meter: Weight (kg/m) = $d^2 / 162 = 12^2 / 162 \approx 0.888$ kg/m

Total length in 1 ton: 1000 / 0.888 ≈ 1126 m

Cross-sectional area: Diameter = 12 mm = 0.472 inch and Radius = 0.236 inch

Total area in 1 ton: 1126 m × 39.37 (inch/m) × 0.175 ≈ 7,758 sq.inch

Price per sq.inch: 91,000 ÷ 7,758 ≈ 11.7 Taka/sq.inch

Final: 12 mm BSRM rod ≈ 11.7 Taka per sq.inch

Recycle steel (12mm) (per sq.inch) Calculation

Price: 1 ton = 72,000 Taka. For 12 mm rod → Cross-section = 0.175 sq.inch

1 ton length = 1126 m = 44,333 inch

Total area = 44,333 × 0.175 ≈ 7758 sq.inch (same as before)

Price per sq.inch = 72,000 ÷ 7758 ≈ 9.28 Taka

Final: Recycle steel (12mm) ≈ 9.3 Taka per sq.inch

The cost of recycled steel is 20.5% lower than that of conventional steel, making its use economically advantageous. In addition, it offers environmental benefits by reducing the demand for new steel production. Provided that its mechanical properties meet the required standards, recycled steel is considered acceptable and can be safely employed in various applications.

4.3 Summary

The purpose of this chapter was to offer a comparative analysis of recycled steel and conventional steel in seismic regions. According to the data, recycled steel exhibits performance comparable to that of conventional steel in terms of displacement and drift. When it comes to the utilization of environmentally sustainable materials, the slight increase in necessary steel areas might be considered a compromise. These findings lend support to the possibility of recycled steel serving as a viable alternative for structural applications in areas prone to seismic activity.

CHAPTER 5
Conclusions and Future Works

5.1 Conclusions

This study aimed to evaluate the seismic performance of high-rise buildings using recycled steel in comparison to conventional steel within the context of Bangladesh. The study involved modeling a ten-story reinforced concrete structure in ETABS 2022 and analyzing it under four seismic zones as defined by BNBC 2020. The recycled steel was sourced locally and classified according to its carbon content (0.25%, 0.27%, and 0.30%), then uniformly heat-treated at 760°C.

Key findings from the seismic analysis include:

1. Recycled steel models exhibited displacement and drift values similar to conventional steel in all four seismic zones.
2. The maximum story drift and displacement values remained within allowable limits, validating the structural adequacy of recycled steel.
3. Required reinforcement area for both interior and exterior columns was slightly higher in recycled steel, particularly with 0.25% carbon content.
4. Despite this increase, the trade-off is justified by the environmental and sustainability advantages of using recycled steel.

These findings support the hypothesis that recycled steel can be a viable alternative for structural applications in seismic zones, particularly in developing countries such as Bangladesh.

5.2 Limitations and Recommendations for Future Work

While the results of this study are promising, several limitations exist:

- The analysis was limited to a 10-storied moment-resisting frame and did not include other structural systems like shear walls or bracings.
- Only static and dynamic analyses under seismic loading were considered; other load combinations, such as wind or fire effects, were not addressed.
- Cost efficiency was not analyzed in terms of market price variations of steel.

Recommendations for future research include:

- Studying recycled steel performance in combination with other structural systems such as shear walls or braced frames.
- Exploring behavior under multiple load combinations and real-time earthquake data.
- Performing lifecycle cost analysis, including procurement, maintenance, and recycling.
- Extending the study to include real-world application and field validation of recycled steel in actual construction projects.

By addressing these aspects, future work can further validate and expand the applicability of recycled steel in modern construction practices, thereby promoting both structural safety and environmental responsibility.

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