

Seismic Performance Evaluation of RC Buildings Using Buckling Restrained Braces: A Comparative Study

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Abstract—The increasing demand for high-rise structures in seismic regions necessitates efficient lateral load-resisting systems to ensure structural safety and serviceability. Conventional reinforced concrete (RC) moment-resisting frames exhibit significant lateral deformations under seismic excitation, leading to potential structural damage. Buckling Restrained Braces (BRBs) have emerged as an effective solution due to their superior energy dissipation capacity and stable hysteretic behaviour under cyclic loading.

This study investigates the seismic performance of a multi-storey RC building with and without BRB systems using the response spectrum method in accordance with IS 1893:2016 provisions. A G+25 storey building model is developed and analysed using ETABS software. Key structural parameters such as storey displacement, storey drift, storey shear, overturning moment, time period, and frequency are evaluated.

The results demonstrate that the incorporation of BRBs significantly enhances the seismic performance by reducing lateral displacement, inter-storey drift, and base shear demand. The braced structures exhibit improved stiffness and controlled deformation compared to the unbraced frame. The findings confirm that BRB systems are highly effective in mitigating seismic response and can be efficiently utilized in both new construction and retrofitting applications.

Index Terms—Buckling Restrained Braces; Seismic Analysis; RC Frame; Response Spectrum Method; Storey Drift; ETABS Drift; ETABS

I. INTRODUCTION

Rapid urbanization and population growth have led to an increasing demand for tall buildings, especially in seismically active regions. However, past earthquake events have demonstrated that conventional reinforced concrete (RC) structures are highly vulnerable to lateral loads due to insufficient stiffness and energy dissipation capacity. Structural failures during earthquakes are primarily attributed to excessive inter-storey drift and inadequate lateral load-resisting mechanisms.

To address these challenges, various seismic control systems such as shear walls, dampers, and bracing systems have been introduced. Among these, Buckling Restrained Braces (BRBs) have gained significant attention due to their ability to provide stable and symmetric behavior in both tension and compression without buckling. Unlike conventional braces, BRBs consist of a steel core encased within a restraining mechanism that prevents global buckling, thereby enabling full utilization of material strength. BRBs were first developed in Japan and have since been widely adopted in seismic design due to their excellent ductility and energy dissipation characteristics [1]. Studies have shown that BRB systems significantly reduce storey displacement and inter-storey drift, enhancing the overall seismic performance of structures [2–4]. Furthermore, BRBs improve structural stiffness while maintaining architectural flexibility, making them suitable for both new constructions and retrofitting of existing buildings [5].

In this context, the present study focuses on evaluating the effectiveness of BRBs in improving the seismic response of RC frame structures. A comparative analysis is carried out between a conventional unbraced RC building and a BRB-integrated structure using linear dynamic analysis. The response spectrum method is adopted as per IS 1893:2016 guidelines to simulate seismic loading conditions.

The building model considered in this study is a multi-storey RC frame analyzed using ETABS software, where parameters such as storey displacement, drift, shear, and overturning moment are evaluated. The primary objective is to quantify the improvement in seismic performance achieved through the incorporation of BRBs.

II. LITERATURE REVIEW

The seismic performance of reinforced concrete (RC) structures has been a major area of research due to the vulnerability of conventional moment-resisting frames under strong ground motion. Several studies have focused on enhancing structural response using advanced bracing systems, among which Buckling Restrained Braces (BRBs) have emerged as one of the most effective solutions.

Early developments of BRB systems demonstrated their ability to overcome the limitations of conventional braces, particularly buckling under compressive forces. Unlike traditional bracing systems, BRBs exhibit stable hysteretic behavior and symmetric strength in both tension and compression, leading to improved energy dissipation capacity [1,2]. This characteristic makes BRBs highly suitable for seismic-resistant design in high-rise structures.

Extensive analytical and experimental studies have been conducted to evaluate the effectiveness of BRBs. highlights that the incorporation of bracing systems significantly reduces lateral displacement and inter-storey drift in RC buildings. Similarly, research by Black et al. [3] and Sabelli et al. [4] confirmed that BRB systems provide enhanced ductility and stiffness, thereby improving the seismic resilience of structures.

Recent studies have focused on the application of BRBs in multi-storey buildings using numerical modeling tools such as ETABS and SAP2000. Patel and Patel (2025) investigated the seismic behavior of

G+14 RC structures with different bracing configurations and reported a reduction of more than 60% in storey displacement when BRBs were used [5]. Likewise, Catalan et al. (2025) demonstrated that BRB systems significantly improve performance under response spectrum analysis by reducing base shear and drift demands [6].

The influence of bracing configuration has also been widely studied. Gottem et al. (2023) analyzed different bracing patterns such as inverted V, X-pattern, and zig-zag configurations under varying seismic zones. Their findings indicated that X and inverted V configurations provide superior performance in terms of displacement control and stiffness enhancement [7]. Similar conclusions were reported by Kumar et al. [8], who emphasized that the selection of bracing configuration plays a crucial role in optimizing structural behavior.

In addition to configuration, the location of bracing within the structure significantly affects seismic response. Studies have shown that placing braces at corners or along the perimeter enhances lateral stiffness more effectively compared to central placement [9]. This is because edge bracing improves torsional resistance and ensures uniform load distribution throughout the structure.

Furthermore, research on performance-based seismic design has highlighted the importance of BRBs in reducing damage concentration in primary structural members. Ravi Kant et al. (2022) demonstrated that BRBs not only reduce storey shear and displacement but also improve overall structural stability by concentrating inelastic deformation within the brace elements [10]. This controlled energy dissipation mechanism is a key advantage of BRB systems over conventional bracing techniques.

Recent advancements have also explored the durability and material optimization of BRBs. Studies by Kim et al. (2023) emphasized the need for corrosion-resistant materials in BRB systems to ensure long-term performance, especially in aggressive environmental conditions [11]. These developments indicate a shift toward sustainable and resilient structural design.

Research Gap

Despite extensive research on BRB systems, the following gaps are identified: Most studies focus either on configuration comparison or performance

evaluation, but limited work integrates both aspects within a single framework.

The influence of bracing placement (corner, middle, adjacent bays) is not comprehensively studied in combination with different configurations.

Many studies emphasize global parameters, while detailed comparison of multiple response parameters (displacement, drift, shear, overturning moment, time period) is limited.

There is a lack of studies based on Indian seismic codes (IS 1893:2016) for high-rise RC structures incorporating BRBs.

Objective of Present Study

Based on the identified gaps, the present study aims to:

Evaluate the seismic performance of RC buildings with and without BRBs

- Analyze key structural parameters such as:
- Storey displacement
- Storey drift
- Storey shear
- Overturning moment
- Time period and frequency

Assess the effectiveness of BRB systems using response spectrum analysis (IS 1893:2016)

Provide a comparative understanding of structural behavior under seismic loading

III. METHODOLOGY

3.1 General Framework

The present study evaluates the seismic performance of a multi-storey reinforced concrete (RC) building with and without Buckling Restrained Braces (BRBs) using linear dynamic analysis. A comparative approach is adopted to quantify the effectiveness of BRB systems in reducing seismic demand parameters.

The methodology consists of:

- Structural modeling of a high-rise RC building
- Application of seismic loads as per Indian standards
- Linear dynamic analysis using the response spectrum method
- Extraction and comparison of key response parameters

All analyses are carried out using ETABS 2022, a widely recognized structural analysis software for high-rise buildings.

3.2 Seismic Analysis Approach

Seismic analysis of structures can be performed using static or dynamic methods depending on building characteristics such as height, irregularity, and importance. For high-rise structures, dynamic analysis is essential due to the significant contribution of higher modes.

In this study, the Response Spectrum Method (RSM) is adopted, as it provides a realistic estimation of peak structural response under earthquake excitation while maintaining computational efficiency. The method involves:

Determination of natural modes of vibration

Calculation of modal responses using a predefined response spectrum

Combination of modal responses to obtain total structural response

The response spectrum used in this study is based on IS 1893 (Part 1): 2016, which defines spectral acceleration as a function of structural time period and soil conditions.

3.3 Design Seismic Coefficient

The design horizontal seismic coefficient governs the lateral force acting on the structure and is expressed as:

$$A_h = \frac{Z}{2} \cdot \frac{S_a}{g} \cdot \frac{I}{R}$$

Where:

Z= Seismic zone factor

I= Importance factor

R= Response reduction factor

S_a/g= Spectral acceleration coefficient

This formulation accounts for seismic intensity, structural importance, ductility, and dynamic characteristics of the building.

3.4 Fundamental Time Period

The natural time period of the structure plays a crucial role in determining seismic forces. For RC frame structures, it can be estimated using empirical relationships:

$$T = 0.075h^{0.75}$$

where h is the height of the building in meters.

The time period influences spectral acceleration and thus directly affects base shear and displacement response.

3.5 Seismic Base Shear

The total design lateral force, known as base shear, is calculated as:

$$V_b = A_h \cdot W$$

Where:

- V_b = Base shear
- A_h = Design horizontal seismic coefficient
- W = Seismic weight of the structure

The base shear is distributed along the height of the building based on mass and mode shape participation.

3.6 Structural Modeling

A three-dimensional model of a high-rise RC building is developed using ETABS software. The structure is assumed to be fixed at the base, and all structural components such as beams, columns, and slabs are modeled using appropriate section properties.

Key modeling considerations include:

- Rigid diaphragm assumption at each floor level
- Lumped mass representation at storey levels
- Linear elastic material behavior
- Inclusion of gravity and seismic load combinations

The building is analyzed under two primary conditions:

- Without bracing (bare frame)
- With BRB system (braced frame)

This enables direct comparison of structural performance under identical loading conditions.

3.7 Performance Parameters

To evaluate seismic performance, the following parameters are considered:

- Storey Displacement → Overall lateral movement
- Storey Drift → Inter-storey deformation (critical for damage assessment)
- Storey Shear → Distribution of lateral forces
- Overturning Moment → Global stability indicator
- Time Period & Frequency → Dynamic characteristics

These parameters provide a comprehensive understanding of both global and local structural behavior under seismic loading.

IV. STRUCTURAL MODELING AND BUILDING DETAILS

4.1 Description of Building Model

A three-dimensional analytical model of a multi-storey reinforced concrete (RC) building is developed using ETABS 2022 to evaluate seismic performance under different structural configurations. The building considered in this study is a G+25 storey structure located in a high seismic zone and designed according to Indian Standard provisions.

The structure is modeled as a regular plan building with uniform mass and stiffness distribution along the height. All structural elements, including beams, columns, and slabs, are modeled using frame and shell elements. The base of the structure is assumed to be fixed, representing realistic foundation conditions.

The modeling approach enables accurate simulation of structural behavior under seismic loading and allows comparison between bare frame and BRB-integrated systems.

4.2 Geometric and Material Properties

The essential details of the building model used for analysis are summarized below.

Table 1: Structural Properties of the Building

Parameter	Value
Number of storeys	G+25
Total building height	76 m
Storey height (ground)	4.0 m
Storey height (typical)	3.0 m
Slab thickness	150 mm
Beam size	300 × 500 mm
Column size	600 × 600 mm
Grade of concrete	M30
Grade of steel	Fe500

These parameters are adopted to represent a typical high-rise RC building commonly used in urban construction.

4.3 Seismic and Loading Parameters

The seismic analysis is carried out in accordance with IS 1893 (Part 1): 2016. The building is assumed to be located in a severe seismic region with medium soil conditions.

Table 2: Seismic Parameters

Parameter	Value
Seismic zone	Zone V
Zone factor (Z)	0.16
Importance factor (I)	1.0
Response reduction factor (R)	5
Soil type	Medium (Type II)

In addition to seismic loads, gravity loads are applied as per standard design practice:

- Live load: 4 kN/m²
- Floor finish load: 1 kN/m²

These loads are considered in combination with seismic forces during analysis.

4.4 Modeling Assumptions

To ensure consistency and accuracy in analysis, the following assumptions are made:

- The structure is considered linearly elastic
- Floor slabs act as rigid diaphragms
- Mass is lumped at floor levels
- Damping ratio is assumed as 5% of critical damping
- Effects of soil-structure interaction are neglected

Structural irregularities are not considered

These assumptions are consistent with standard practices for linear dynamic analysis of high-rise buildings.

4.5 Bracing Configurations Considered

Although this paper primarily focuses on the overall effectiveness of BRBs, the modeling includes braced systems to compare against the bare frame structure.

The building is analyzed under:

- Unbraced condition (moment-resisting frame)
- BRB-integrated condition

The BRB system is modeled as axial members capable of resisting both tensile and compressive forces without buckling. This ensures realistic simulation of their behavior under cyclic seismic loading.

The comparison between these two conditions forms the basis for evaluating the improvement in seismic performance.

V. RESULTS AND DISCUSSION

5.1 General Observations

The seismic response of the RC building is evaluated for two primary cases:

- Bare Frame (Without Bracing)
- BRB-Integrated Frame

The results are compared in terms of displacement, drift, shear, overturning moment, and dynamic properties. The analysis clearly indicates that the inclusion of BRBs significantly enhances the structural performance under seismic loading.

The unbraced structure exhibits higher flexibility, resulting in larger lateral deformations, whereas the braced system demonstrates increased stiffness and controlled response.

5.2 Storey Displacement

Storey displacement is one of the most critical indicators of seismic performance, representing the lateral movement of each floor level.

From the analysis results:

- The maximum displacement occurs at the top storey in both cases
- The bare frame shows significantly higher displacement
- The BRB system reduces displacement considerably across all storeys

For example, the unbraced structure shows a top storey displacement of approximately 190 mm, indicating high flexibility and potential vulnerability under seismic loading.

Interpretation:

- High displacement → low stiffness
- Reduction due to BRB → increased lateral rigidity
- BRBs act as efficient axial load-resisting members, limiting deformation

This confirms that BRBs effectively control global structural movement.

5.3 Storey Drift

Storey drift is a key parameter for assessing structural damage and serviceability.

Observations:

- Maximum drift occurs in mid-height storeys
- The bare frame exhibits higher drift values
- BRB inclusion leads to significant reduction in inter-storey drift
- Peak drift ≈ 0.0031 (unbraced)
- Drift values reduce noticeably in the braced system
- Interpretation:
- Drift reduction \rightarrow lower damage potential
- BRBs help in uniform distribution of lateral forces
- Reduced drift ensures compliance with code limits

5.4 Storey Shear

Storey shear represents the cumulative lateral force at each level.

Key observations:

- Shear increases from top to bottom (as expected)
- Maximum shear occurs at the base level
- BRB system shows better force distribution
- Base shear in unbraced frame reaches very high values

Interpretation:

- BRBs redistribute seismic forces more efficiently
- Reduction in shear demand on columns and beams
- Enhances overall structural safety

5.5 Overturning Moment

Overturning moment is a measure of global stability.

Observations:

- Maximum overturning moment occurs at the base
- Bare frame shows higher overturning effects
- BRBs reduce overturning moment significantly
- Interpretation:
- Lower overturning moment \rightarrow improved stability

- BRBs reduce lateral sway and rotational effects
- Critical for high-rise safety

5.6 Time Period and Frequency

Dynamic characteristics are significantly affected by structural stiffness.

Observations:

- Bare frame \rightarrow higher time period (flexible structure)
- BRB frame \rightarrow reduced time period (stiffer structure)
- Interpretation:
- Reduced time period \rightarrow lower displacement demand
- Increased frequency \rightarrow better seismic resistance
- BRBs enhance dynamic performance

5.7 Overall Performance Evaluation Based on all parameters:

Parameter	Bare Frame	BRB Frame	Improvement
Displacement	High	Reduced	✓ Significant
Drift	High	Reduced	✓ Critical improvement
Shear	High	Optimized	✓ Better distribution
Overturning Moment	High	Reduced	✓ Improved stability
Time Period	High	Reduced	✓ Increased stiffness

Unlike conventional braces, BRBs ensure that inelastic deformation is concentrated within the brace, protecting primary structural elements.

VI. CONCLUSION

This study evaluated the seismic performance of a multi-storey reinforced concrete (RC) building with and without Buckling Restrained Braces (BRBs) using response spectrum analysis as per IS 1893 (Part 1): 2016. A comprehensive comparison was carried out based on key structural parameters including storey displacement, storey drift, storey shear, overturning moment, and dynamic characteristics.

The analytical results clearly demonstrate that the incorporation of BRBs significantly enhances the seismic behavior of RC frame structures. The unbraced (bare frame) structure exhibited higher flexibility, leading to larger lateral displacements and inter-storey drift, which can result in structural and non-structural damage during seismic events. In contrast, the BRB-integrated structure showed a marked reduction in displacement and drift, indicating improved stiffness and better control over lateral deformations.

The maximum storey displacement observed in the unbraced structure reached approximately 190 mm at the top level, highlighting its vulnerability under seismic loading. The introduction of BRBs effectively reduced this value, confirming their role in enhancing lateral rigidity. Similarly, inter-storey drift values were significantly reduced, ensuring compliance with codal limits and minimizing damage potential.

In terms of force distribution, the BRB system improved the behavior of the structure by optimizing storey shear and reducing overturning moments. This indicates that BRBs contribute not only to stiffness enhancement but also to improved load transfer mechanisms and global stability. Furthermore, the dynamic response of the structure was positively influenced, with a reduction in natural time period and an increase in structural frequency, reflecting a stiffer and more resilient system.

Overall, the study confirms that BRBs are highly effective seismic-resistant elements that provide:

- Enhanced energy dissipation capacity
- Improved lateral stiffness
- Controlled deformation behavior
- Increased structural stability

These characteristics make BRBs a suitable choice for both new construction and seismic retrofitting of existing structures, particularly in high seismic zones.

Future Scope

While the present study focuses on linear dynamic analysis, further research can be extended in the following directions:

- Nonlinear time history analysis for more realistic seismic behavior
- Performance-based design approaches for BRB-integrated structures

- Optimization of bracing configurations and placement
- Study of soil-structure interaction effects
- Experimental validation of analytical results
- Integration of smart materials such as Shape Memory Alloys (SMA) with BRB systems

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