International Journal of Research Publication and Reviews, Vol 6, no 1, pp 4291-4296 January 2025

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Improving Seismic Resilience: The Impact of Inclined Steel Bracket at RCC Beam-Column Interfaces

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ABST RACT

This study explores the use of inclined steel brackets at RCC beam-column interfaces to enhance seismic resilience. Analytical models developed in ETABS assess their impact on ductility, energy dissipation, and seismic performance. The research examines a single portal frame and a 15-storey building, evaluated per IS 456:2000, IS 13920:2016, and IS 1893:2016 standards. Configurations include: (1) RCC frame without ductile detailing, (2) RCC frame with ductile detailing, (3) RCC frame with diagonal steel brackets, and (4) RCC frame with both ductile detailing and brackets.

Results indicate that inclined brackets significantly reduce lateral displacement and enhance energy dissipation, with inclination angle playing a key role. The RCC frame with both ductile detailing and brackets performs best, minimizing inter-story drift and base shear. Economic analysis highlights long- term cost benefits. Future research should optimize bracket design, explore smart materials, and validate findings through dynamic testing for practical implementation.

Keywords: Seismic resilience, RCC frame, inclined steel brackets, ductile detailing, seismic performance, IS 1893: 2016, IS 456: 2000, IS 13920: 2016

Introduction

General

As urbanization accelerates worldwide, high-rise structures have become integral to modern cityscapes, addressing the dual needs of population growth and efficient land use. These structures, while architecturally innovative and functional, are inherently vulnerable to seismic forces due to their height, complexity, and structural systems. In earthquake-prone regions, the safety and resilience of these buildings are paramount to safeguarding lives and minimizing economic losses. One critical area of concern in high-rise buildings is the performance of reinforced concrete (RCC) beam-column joints during seismic events. These joints are pivotal in maintaining the structural integrity of the entire frame, as they transfer loads between beams and columns. Under earthquake-induced stresses, these joints often become the most vulnerable points, prone to damage such as joint shear failure, cracking, and plastic hinging. Inclined steel brackets have emerged as a promising solution to address these challenges. Positioned at RCC beam-column interfaces, these brackets provide additional stiffness, strength, and ductility, mitigating joint vulnerabilities under seismic loads. By redistributing stresses and enhancing energy dissipation, inclined brackets can significantly improve the overall seismic performance of high-rise buildings. This research explores the potential of these brackets, focusing on their design, implementation, and effectiveness in improving the seismic resilience of urban structures.

Objectives

01	**Improve seismic resilience of RCC structures**
02	Analyze inclined steel brackets at beam-column joints
03	Compare seismic performance of different RCC frame configurations

Literature Review

Jagadish J. S (2013):

This study investigated the influence of various bracing systems on multi-storey steel constructions. Models of G+15 steel buildings with the same configuration were analyzed using STAADPRO, incorporating bracing systems such as Single-Diagonal, X-bracing, Double X-bracing, K-bracing, and V- bracing. The findings revealed that while bracings effectively reduce displacement, the displacement in K and V-bracing systems was higher due to the irregularity of the structure. Storey drift in braced structures was observed to either increase or decrease depending on the type of bracing system compared to unbraced buildings of the same configuration.

Metre, Sachin (2017):

This research concluded that bracing systems significantly improve lateral deflection resistance and are particularly effective in earthquake-prone areas. Among various types, X-bracing was found to be the most effective in reducing lateral displacement and drifts, as it spans the entire wall surface and accommodates openings for windows and doors. In comparison to inverted V-bracing and Single-Diagonal bracing, X-bracing models exhibited higher shear forces, improving their performance under lateral loads.

Zasiah Tafheem (2013):

A six-storey steel building was analyzed under earthquake and wind loads, along with dead and live loads. Using HSS sections, the study evaluated concentric (X-bracing) and eccentric (V-bracing) systems. Results showed that bracing systems reduced lateral movements compared to unbraced buildings. Concentric X-bracing was particularly effective in minimizing lateral displacement, significantly enhancing structural rigidity and reducing inter-storey drift, thereby limiting floor-to-floor relative motion.

Thakre, Gayatri (2016):

This study highlighted the effectiveness of bracing systems in resisting wind-induced displacement. Inverted V-bracing reduced displacement more effectively than other configurations. It was observed that bracings increased the horizontal shear force at the footing while decreasing the base moment. Among the systems, diagonal bracing exhibited higher axial force, and the base shear increased due to bracing indeterminacy, which contributed to the overall stiffening of the structure to resist horizontal displacement.

K.K. Sangle (2012):

A linear time-history analysis was conducted on a high-rise steel building with various bracing patterns under the Northridge earthquake. The study examined natural frequencies, fundamental time periods, mode shapes, inter-storey drift, and base shear for braced and unbraced models. Findings confirmed that bracings significantly impact structural behavior under seismic loads, with diagonal bracing proving to be both effective and cost-efficient.

Manish S. Takey (2015):

This study analyzed a G+9 steel moment-resisting frame under linear static conditions in seismic zone III, with and without bracing systems, using ETABS software. Results demonstrated that braced buildings exhibited reduced storey drift compared to unbraced models, indicating improved structural responsiveness. The reduction in displacement varied depending on the type and size of the bracing system, highlighting their importance in enhancing stability.

Methodology

1. Literature Review
2. Material and section selection
3. Load calculation (using IS 875 part-2)
4. Modeling (In ETABS evaluating various parameters)
5. Analysis of different models (SEISMIC)
6. Result interpretation

Structural Modelling and Analysis General

This section presents the structural modeling and analysis of the studied frames to evaluate the impact of inclined steel brackets on seismic resilience. The models were developed using ETABS software, adhering to the provisions of **IS 456:2000, IS 1893:2016, and IS 13920:2016** to ensure compliance with seismic design requirements.

Details of Structural Models

Two primary cases were modeled and analyzed:

- **Single-Storey Portal Frame**
- **Multi-Storey RCC Frame (15-storey buildings)**

Each model was analyzed under different configurations:

1. **Bare RCC Frame (Without Ductile Detailing)**
2. **RCC Frame with Ductile Detailing**

3. **RCC Frame with Inclined Steel Brackets at Beam-Column Interfaces**
4. **RCC Frame with Both Ductile Detailing and Inclined Steel Brackets**

The models were designed considering actual structural behavior and seismic load distribution.

Plan of Model

- **Single-Storey Portal Frame:** The frame consists of two columns and a beam with defined support conditions, representing a fundamental seismic load-resisting system.
- **Multi-Storey RCC Frame:**
  - Plan dimensions: **30m × 20m**
  - Number of bays: **5 bays (each 6m) in X-direction and 4 bays (each 5m) in Y-direction**
  - Storey height: **3.5m per storey**
  - Structural grid designed as per IS code recommendations.

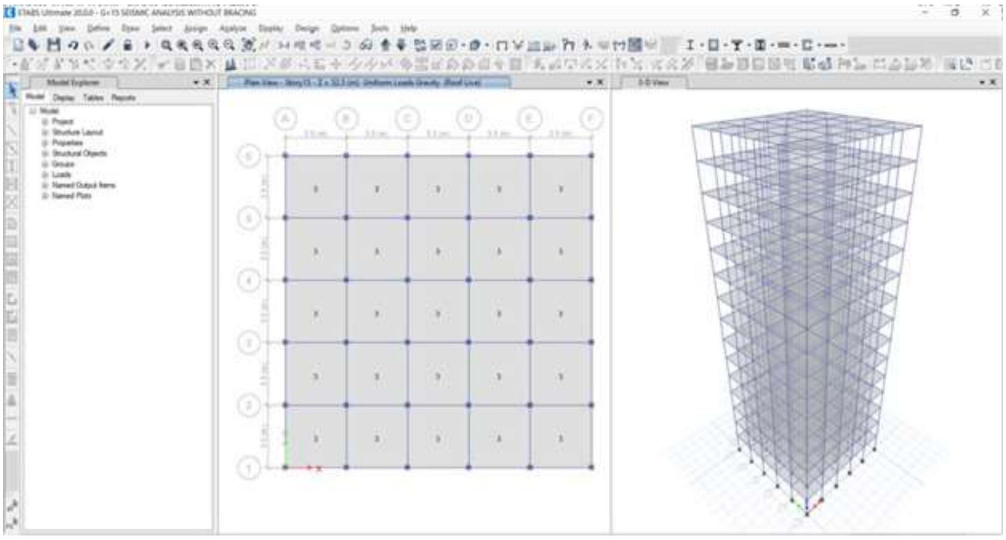

Figure 1: Plan View of Multi-Storey RCC Frame Material Properties

The following material properties were assigned based on IS code provisions:

Material	Property	Value
Concrete	Grade	M35
Steel Rebar	Grade	Fe415
Steel Bracing	Section	ISMB200
Concrete	Density	25 kN/m³
Concrete	Poisson’s Ratio	0.2
Concrete	Modulus of Elasticity (E)	5000√fck

Loadings on Structure

The models were subjected to the following loads as per IS 875 and IS 1893:

Dead Load (DL) (As per IS 875 Part 1)

Component	Load (kN/m²)
Slab Self-weight	5.0

Floor Finish	1.5

Live Load (LL) (As per IS 875 Part 2)

Building Type	Load (kN/m²)
Residential	3.0
Commercial	4.0

Seismic Load (As per IS 1893:2016)

Parameter	Value
Seismic Zone	IV
Zone Factor (Z)	0.24
Importance Factor (I)	1.2
Response Reduction Factor (R)	5.0
Soil Type	Medium (Type II)

Design Sections

The structural members were designed as per IS 456:2000 and IS 13920:2016:

Structural Element	Dimension (mm)
Beams	300 × 500
Columns	600 × 600
Slab Thickness	200
Bracing Sections	ISMB200

4.7 Preliminary Data

4.7.1 Single-Storey Frame Data

Parameter	Value
Span	6m
Column Height	3.5m
Beam Size	300 × 500mm
Bracket Angle	45° and 60°

4.7.2 Multi-Storey Frame Data

Parameter	15-Storey Building
Total Height	52.5m
Bay Size	6m × 5m
Slab Thickness	200mm
Bracing System	At critical junctions

Figures and Diagrams

- **Figure 1:** Plan View of Multi-Storey RCC Frame
- **Figure 2:** Seismic Load Application on Multi-Storey RCC Frame

- **Figure 3:** Structural Model of Single-Storey Portal Frame in ETABS
- **Figure 4:** Bracing System Layout in Multi-Storey Frame

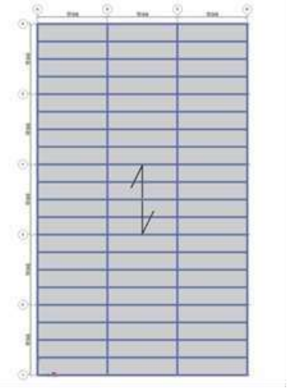

Fig.1-2Dview Model

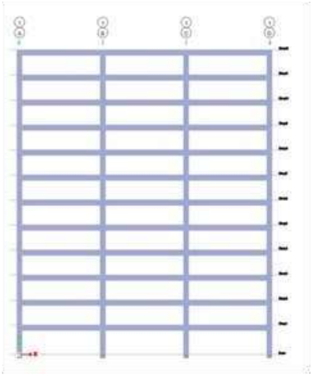

Fig.2-Elevationof Model

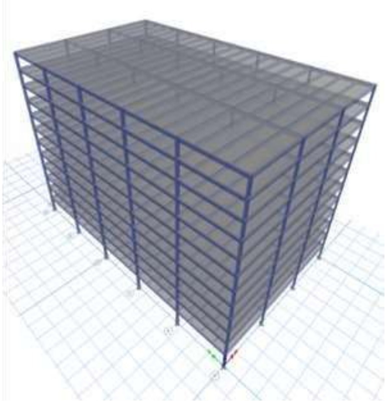

Fig.3–3DView

Fig.4-2Dviewof Model

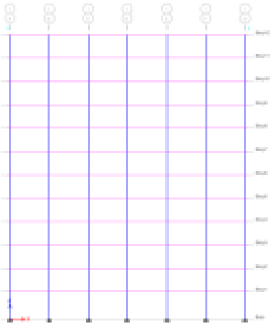

Fig.5-Elevation of Model

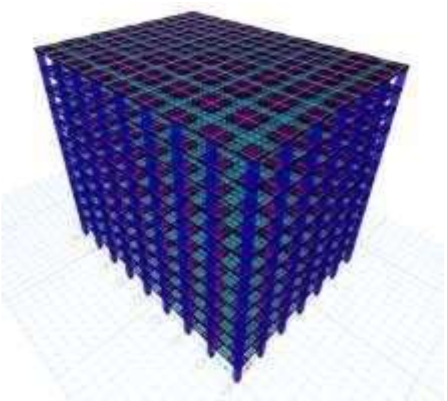

Fig.6–3DView

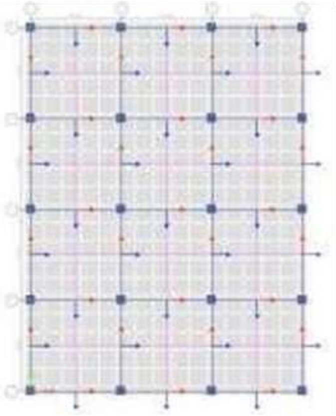

Fig.7 - 2DViewof Model

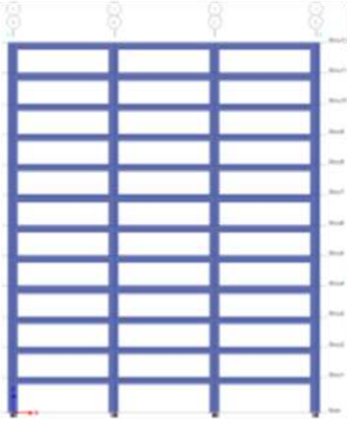

Fig.8-Elevation of Model

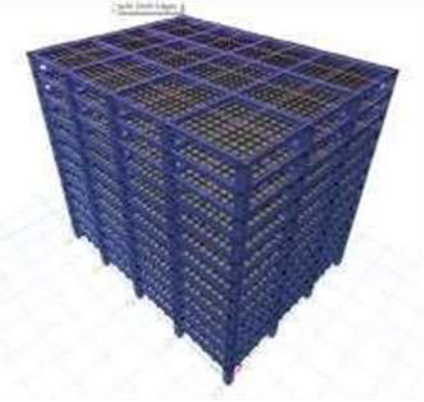

Fig.9 –3DView

Conclusion

This study evaluates the effectiveness of inclined steel brackets in enhancing the seismic resilience of RCC beam-column interfaces through ETABS modeling and analysis of **a** G+15 commercial building**.**

Four structural configurations were analyzed:

- RCC Frame without Ductile Detailing (Baseline model)

- RCC Frame with Ductile Detailing (Improved seismic performance)
- RCC Frame with Inclined Brackets (Structural enhancement with steel elements)
- Ductile RCC Frame with Inclined Brackets (Best performance model)