# Seismic Performance Evaluation of Steel Braces in Enhancing the Lateral Load Resistance of RCC Flat Slab Structures

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**Abstract:** *This research paper conducts a comprehensive investigation into the seismic performance of reinforced concrete flat slab structures, employing different configurations of steel bracing systems. The seismic behavior of flat slab buildings with 5, 7, and 9 stories is scrutinized through Equivalent Lateral Force (ELF) analysis and Response Spectrum Analysis (RSA). The study delves into the efficacy of various bracing configurations, encompassing X-bracing, eccentric bracing, and knee bracing, in augmenting the lateral load resistance of these structures. Additionally, the research evaluates the influence of bracing systems on crucial structural response parameters such as displacement, drift ratio, base shear, and fundamental natural period.*

**Keywords**: *steel bracing, seismic performance, flat slab structures, comparative study*

## 1. Introduction

Reinforced concrete flat slab structures are known for their architectural adaptability and space efficiency, yet they face susceptibility to lateral loads during seismic events. Introducing steel bracing systems has emerged as a promising strategy to bolster the seismic resilience of these structures. This study seeks to compare the seismic response of flat slab structures across varying heights, while examining different configurations of steel bracing systems. It assesses the predictive capabilities of Equivalent Lateral Force (ELF) analysis and Response Spectrum Analysis (RSA) in anticipating structural behavior, and explores how different bracing setups impact the overall seismic performance.

## 2. Literature Review

In a study by Md. Shahzar (2021), the seismic response of a G+24 multistory structure employing shear walls and bracings is investigated. Utilizing static analysis with ETABS software, the research aims to contrast the seismic behavior across different frame models.

Shivnarayan Malviya (2020) explores the adoption of advanced sections in buildings, particularly for large spans. The research synthesizes findings from various studies on different section types like flat slabs, waffle slabs, and ribbed sections. The study also examines the incorporation of secondary beams in flat slab structures to enhance load transfer efficiency. Concluding that flat slabs are viable for multistory buildings and waffle/ribbed slabs for high-rises due to their superior resistance to bending moments.

Dr. K NARESH (2019) investigates a G+14 commercial multistoried structure employing flat slabs and conventional slabs. Parameters such as base shear, story drift, stiffness, and displacements in seismic zones II and V of India are evaluated. The study finds that flat slabs with shear walls exhibit better displacement resistance, with story drift increasing as the number of stories rises.

Milan Karki (2019) delves into the advantages of flat slab RC structures, analyzing G+5, G+8, and G+11 models using Equivalent Static Method and Response Spectrum analysis with IS 1893. Results suggest that flat slabs with shear walls and perimeter beams demonstrate satisfactory seismic performance.

Ashwini Ghorpade (July 2018) examines a three-layered RC flat slab building using SAP2000 software, comparing seismic response with and without shear walls and drop panels. The study concludes that flat slabs with shear walls exhibit superior seismic resistance compared to those without.

Md. Mahmud Hasan Mamun (2018) conducts a comparative study on three design models using nonlinear static analysis with ETABS, finding that flat slab structures with perimeter beams display enhanced seismic performance compared to conventional beam-column frame structures.

Rathod Chiranjeevi (Oct 2016) investigates the seismic behavior of various RC structures, including flat slabs, using pushover analysis. The study concludes that flat slab models exhibit larger base shear and displacement values compared to conventional slab structures.

Anuj Bansal and Dakshayani S (Jan 2016) compare the performance of multi-story buildings with flat slabs and grid slabs, considering base shear, story drift, and maximum displacement under seismic forces. The analysis reveals that flat slab structures tend to exhibit larger displacement and base shear values.

## 3.Modelling

- **General**

**3.1** Three different story levels are considered: G+5, G+7, and G+9. Additionally, a conventional building with a beam-column system is modeled for comparison. Four types of steel braces—Diagonal, X-bracing—are applied at various locations, including corner bays, middle bays, alternate bays, and all peripheral bays. Furthermore, combinations of two different bracing types are examined. The impact of these bracing configurations on flat slab buildings is thoroughly analyzed.

### 3.2 Modelling Data

#### 3.2.1Plan and Configuration

A simple square shaped plan is taken for study. Number of bays are four and the bay size is 5m. Typical storey height is taken 3m and three different storey levels i.e. G+5,G+7, G+9 stories are modelled for study purpose.

This chapter provides model geometry information, including items such as story levels, point coordinates, and element connectivity.

### 3.1.1 A Story Data

**Table 3.1.1 -a Story Data**

| Name | Height mm | Elevation mm | Master Story | Similar To | Splice Story |
|---|---|---|---|---|---|
| Story5 | 3000 | 18000 | Yes | None | No |
| Story6 | 3000 | 15000 | Yes | None | No |
| Story4 | 3000 | 12000 | Yes | None | No |
| Story3 | 3000 | 9000 | No | Story4 | No |
| Story2 | 3000 | 6000 | No | Story4 | No |
| Story1 | 3000 | 3000 | No | Story4 | No |
| Base | 0 | 0 | No | None | No |

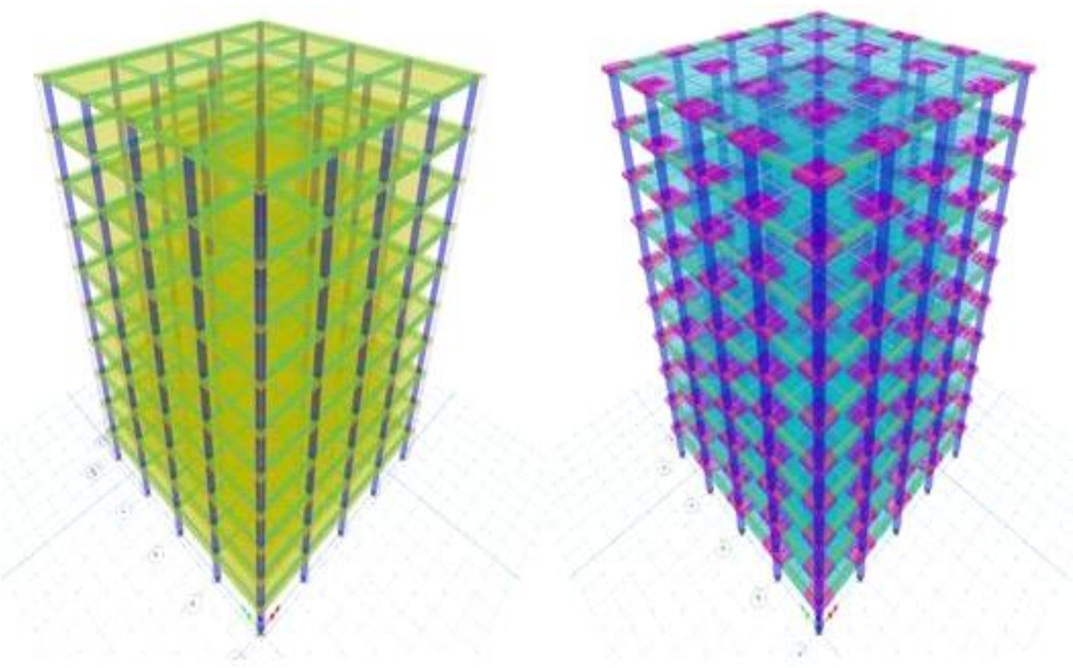

Figure 3: 11 Conventional and Flat Slab Building Model (3D), G+9 Storey

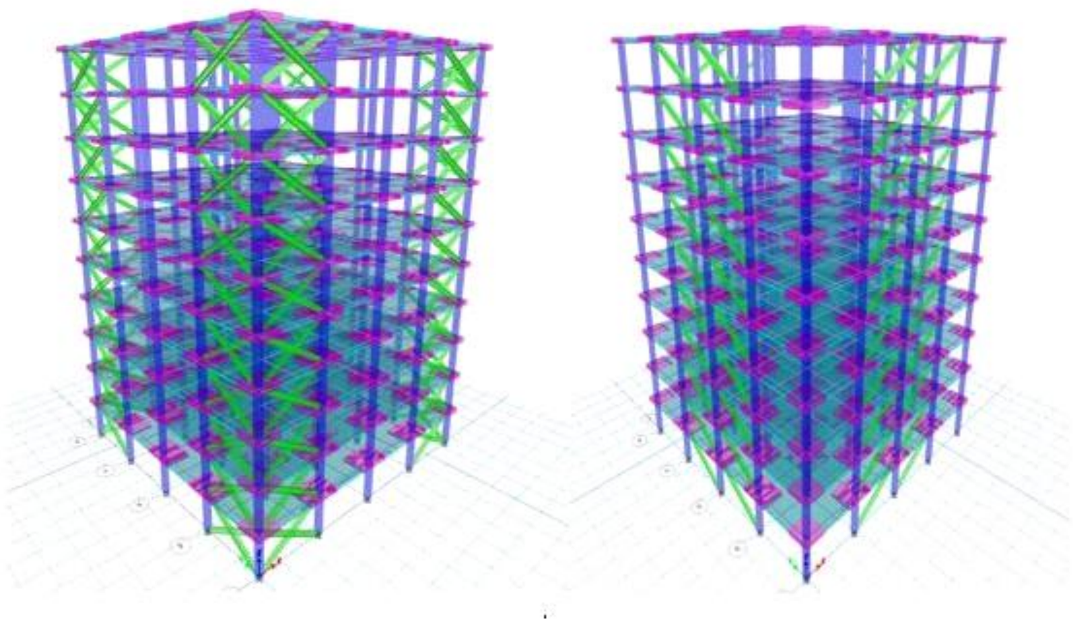

Figure 3: 12 X at Corner Bays and Diagonal at middle bays braced model (3D), G+9 Storey

## 4. Analysis

### 4.1 Equivalent Static Analysis

According to the Indian Seismic Code IS:1893 2016, the design base shear (VB) for the entire building is calculated first. This base shear is then distributed to each floor level based on its corresponding center of mass. Finally, the design seismic force at each floor level is allocated to individual lateral load resisting elements through structural analysis, taking into account the floor diaphragm action.

The following calculations represent the automatically generated lateral seismic loads for the load pattern eq x, as computed by ETABS.

Direction and Eccentricity:

- Direction: Multiple
- Eccentricity Ratio: 5% for all diaphragms

Structural Period:

- Period Calculation Method: Program Calculated

Factors and Coefficients:

- Seismic Zone Factor, Z [IS Table 2]: Z = 0.36
- Response Reduction Factor, R [IS Table 7]: R = 3
- Importance Factor, I [IS Table 6]: I = 1.2
- Site Type [IS Table 1]: II

Seismic Response:

- Spectral Acceleration Coefficient, Sa/g [IS 6.4.5]: Sa/g = 2.5, Sa/g = 2.5

The following calculations represent the automatically generated lateral seismic loads for the load pattern eq y, as computed by ETABS, in accordance with IS1893 2002.

Direction and Eccentricity:

- Direction: Multiple
- Eccentricity Ratio: 5% for all diaphragms

Structural Period:

- Period Calculation Method: Program Calculated

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- Seismic Zone Factor, Z [IS Table 2]: Z = 0.36
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Seismic Response:

- Spectral Acceleration Coefficient, Sa/g [IS 6.4.5]: Sa/g = 2.5, Sa/g = 2.5

These calculations are based on the provisions and coefficients specified in the IS1893 2002 code, and have been generated using the ETABS software.

### 4.2 Response Spectrum Analysis

Response Spectrum Analysis serves as a crucial technique for assessing the dynamic behavior of structures under seismic forces. It aids in determining the maximum response of a structure across different periods of ground motion. This analysis involves utilizing a response spectrum to represent the structure's acceleration, velocity, or displacement response concerning its natural period.

The procedure commences with the choice of a ground motion record or a design spectrum that reflects the seismic conditions at the site. Subsequently, the selected ground motion undergoes transformation into a response spectrum, typically achieved through Fourier transform or comparable methodologies. The resultant response spectrum illustrates the peak response amplitudes across a range of vibration periods.

## 5.CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusions

The research outcomes and discussions yielded several noteworthy conclusions:

- Implementing steel braces on flat slab buildings resulted in an overall decrease in structural response and an augmentation in structural stiffness, thereby enhancing the seismic performance.
- The incorporation of steel braces notably mitigated storey displacement and drift ratio in flat slab buildings, primarily attributed to the increased stiffness imparted by the braces. Among the various brace types, X and Chevron braces exhibited the most significant reduction in displacement and drift ratio when positioned at corner and alternate bays, while X braces were most effective for middle and peripheral bays.
- The presence of braces led to heightened base shear in the structure due to enhanced stiffness, with X and Chevron braces showing a particularly pronounced effect in increasing base shear values, indicative of improved resistance to lateral forces.
- After the application of braces, there was a decrease in the fundamental natural time period of flat slab structures, with X and Chevron braces demonstrating the most substantial reduction. This reduction signifies heightened structural stiffness and improved dynamic behavior.
- Different bracing configurations showcased reductions in displacement, drift ratio, and time period of the structure, with Configuration-3A exhibiting the highest reduction and Configuration-2C displaying the least among the studied configurations.
- The integration of steel braces offers an alternative solution for the lateral load-resisting system in flat slab buildings, thereby enhancing seismic performance and structural behavior.

### 5.2 Recommendations based on the study findings:

• Delve into the impact of various irregular plan configurations, shapes, sizes, and differing numbers of stories on the behavior of braced flat slab structures to comprehensively assess their response to different design parameters.

• Explore the influence of soil-structure interaction on the performance of flat slab systems, as this aspect was not addressed in the current study but can significantly affect seismic response.

• Investigate the nonlinear static and nonlinear dynamic behavior of braced flat slab structures to gain insights into their performance under more realistic and complex loading conditions, providing a more comprehensive understanding of their seismic resilience.

• Conduct cost analyses to compare the economic feasibility of utilizing steel braces versus other lateral load-resisting systems such as shear walls or lift core walls, helping stakeholders make informed decisions regarding structural design and construction strategies.

## 6. References

• Milan Karki, Rajan Suwal, "Comparative Study of Flat Slab Structures", IOE Graduate Conference, volume-6, 2019-summer.

• Ema Coelho, Psulo Candeis et.al," Assesment of the seismic behaviour of RC flat slab building structures", World conference on Earthquake Engineering-2004.

• Sanjay P N, "Behavior of Flat Slab RCC Structure Under Earthquake Loading", International Journal of Engineering Research & Technology. Vol. 3 May- 2014.

• R. P. Apostolska, "Seismic Performance of Flat Slab Building Structural Systems"World conference for earthquake engineering-2008.

• Lan N Robertson," Analysis of flat slab structures subjected to combined lateral andgravity loads", ACI Structural Journal, November-December 1997.

• Sharad P. desai, Swapnil B. Cholekar," Seismic behaviour of flat slab structure withand without masonary infill", IJERT-2013

• Navyashree K, Sahana T.S," Use of flat slabs in multi-story commercial building situated in high seismic zone", International Journal of Research in Engineering and Technology, Volume 03, Aug-2014.

• Bhavesh Rajesh Saahni," Comparision of flat slab and conventional slab" IRJET- 2015.

- Dr. M Rame, Techi Tata, "Study of seismic behavior of buildings with flat slab",International Research Journal of Engineering and Technology, Volume-03, Sep- 2016.

- Kalyan Chowdary, "Comparative Study of Seismic Performance of high rise 30 Story Building with beam slab, flat slab and alternate flat beam slab systems in zone 5", 2014.

- K. S. Sable," Comparative Study of Seismic Behavior of Multistory Flat slab and Conventional Reinforced Concrete Framed Structures", 2012.

- Abhishek Lakshman Dhangar, "A comparative study of seismic response of flat slab structure and conventional structure", 2015.

- G.S. Necevska-Cvetanovska, "Seismic Performance of Flat Slab Building Structural Systems", 14th world conference on Earthquake Engineering, 2008.

- R. Mundhan Khan, "Seismic parameters comparison of flat slab and grid slab wasdone for multistory building." International Research Journal of Engineering Technology, 2015

- Woo-Seung Shin, Jinkoo Kim, "Seismic Retrofit of Flat Plate Structure", Civil Engineering and Architecture 1(1): Page 7-19, 2013.

- Ashok K. Jain, "Seismic performance of RC frames with steel braces", Journal ofstructural engineering ASCE -1985.

- M.R. Maheri, A Sahebi," Use of steel bracings in reinforced concrete frames", Shiraz University, Engineering Structures, Vol 19 No.12, 1997.

- S.M.Razak, T.C. Kong, "A review of influence of Various Types of Structural Bracings to the Structural performance of Buildings", Department of Civil EngineeringTechnology-2018.

- Dr. Chandan Kumar et al." Effect of steel Bracings on RC Framed Structure", International Journal of mechanics and solids, Volume-9, 2018.

- Pratik Patel, Sandip Patel et al." Comparative study of different bracing systems in RCC Building Using STAAD. ProV8i", International Research Journal of Engineering and Technology, Volume-06, 2019.

- Harshitha M.K et al." Analysis of RC framed structure with structural system braces using Etabs", International Research Journal of Engineering and Technology, Volume -05, 2018.

- IS 1893: 2016, Criteria for Earthquake Resistant Design of Structures.

- IS 456: 200 Plain and Reinforced concrete code of practice.
- Seismic Retrofitting Guidelines of India-2016.
- Earthquake Resistance Design of Structure- Pankaj Agrawal, Manish Shrikhande.
- Milan Karki, Dr Rajan Suwal "Comparative Study of Flat Slab Structures ''
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