Seismic Strengthening of RCC Flat Slab Structures Using Steel Braces

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Abstract

RCC flat slab structures are commonly used in the construction industry due to their architectural flexibility and efficient space utilization. However, these structures may be vulnerable to seismic forces, necessitating the implementation of effective seismic strengthening measures. This research paper aims to investigate the application of steel braces as a viable solution for enhancing the seismic performance of RCC flat slab buildings. The study includes a comprehensive analysis using both linear static and linear dynamic approaches to assess the effectiveness of steel braces in reducing the structural response and improving the overall seismic behavior. Various types of steel bracing configurations are examined, considering different bay locations and design parameters. The findings highlight the potential of steel braces as an alternative lateral load-resisting system for flat slab structures, offering improved seismic strength and architectural versatility.

Keywords: *RCC, Slab, Steel, Seismic*

1. Introduction

1.1 Background

RCC flat slab structures have gained popularity in modern construction due to their architectural appeal and flexibility. However, the absence of traditional vertical elements such as columns and shear walls may compromise their seismic performance. Therefore, there is a need to explore innovative seismic strengthening techniques for flat slab buildings.

1.2 Motivation

The vulnerability of flat slab structures to seismic forces and the desire to ensure the safety and resilience of buildings in high-seismicity regions have motivated researchers and engineers to investigate effective retrofitting strategies. Steel braces have emerged as a potential solution due to their strength, ductility, and ease of installation.

1.3 Research Objectives

The primary objectives of this research are:

- To evaluate the effectiveness of steel braces in enhancing the seismic performance of RCC flat slab structures.
- To investigate the behavior and response of flat slab buildings under seismic loads through linear static and linear dynamic analyses.
- To compare the performance of braced and unbraced flat slab models in terms of storey displacement, drift ratio, base shear, and fundamental natural time period.
- To explore the influence of different steel bracing configurations on the seismic response of flat slab structures.

To assess the architectural implications, cost considerations, and economic feasibility of implementing steel braces in flat slab buildings.

2. Literature Review

2.1 Seismic Performance of RCC Flat Slab Structures

The literature review provides an overview of the seismic behavior of RCC flat slab structures, highlighting their strengths and weaknesses in resisting lateral loads. It discusses the challenges associated with flat slab design and the importance of seismic strengthening measures.

2.2 Lateral Load-Resisting Systems

Different lateral load-resisting systems used in building structures are reviewed, including shear walls, moment frames, and bracing systems. The advantages and limitations of each system are discussed, emphasizing the unique characteristics of steel braces.

2.3 Steel Bracing Systems

The literature review focuses on steel bracing systems, exploring their role in improving the seismic performance of various building types. The behavior, design principles, and installation considerations of steel braces are examined.

2.4 Previous Studies on Steel Bracing in Flat Slab Structures

A review of previous research studies and case studies related to the application of steel braces in flat slab structures is presented. The findings from these studies inform the research methodology and contribute to the current understanding of the topic.

3. Methodology

3.1 Analysis Approach

The methodology section describes the analytical approach employed in this research, which includes both linear static and linear dynamic analyses. The selection of appropriate analysis methods is justified, considering the objectives of the study and the characteristics of flat slab structures.

3.2 Structural Modeling and Design Parameters

The process of structural modeling for flat slab buildings is explained, including the consideration of relevant design parameters such as material properties, geometric configurations, and boundary conditions. The modeling techniques ensure the accuracy and reliability of the analysis results.

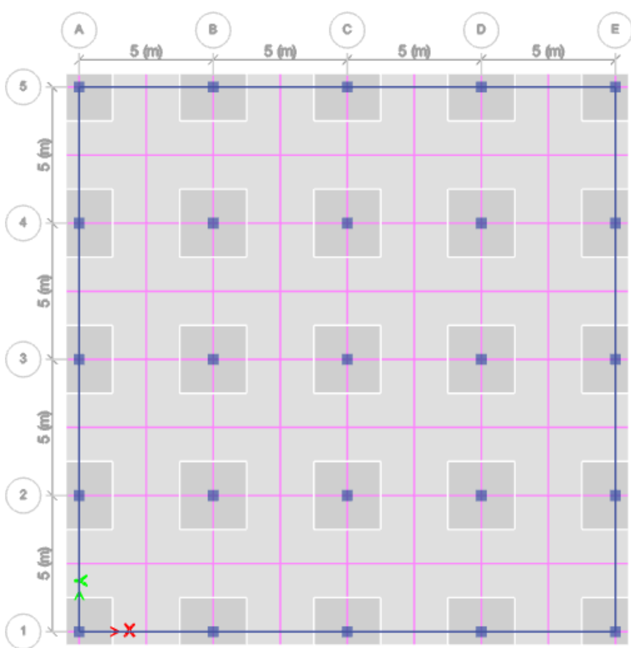

Figure 1 Geometric Plan of Flat Slab building with Concealed Beam and Drop Panels

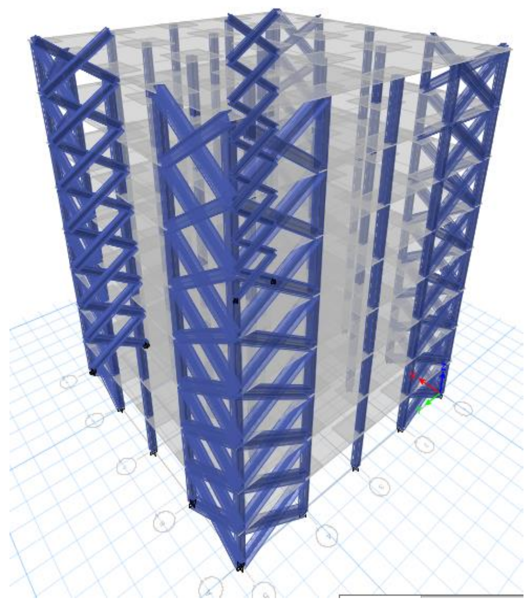

Figure 2 Diagonal, X Type Bracings at Corner Bays Respectively

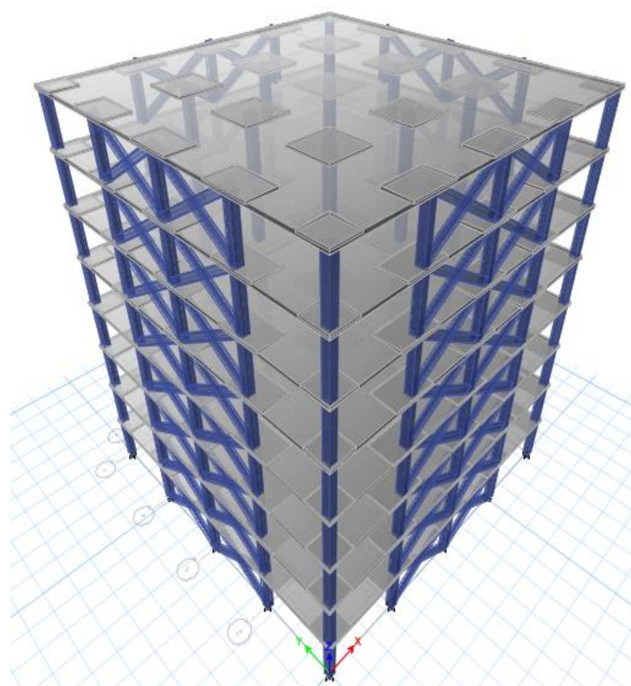

Figure 3 Diagonal, X Type Bracings at Middle Bays Respectively.

Some of the images of building models after completion of modelling steps on ETABS are presented as,

Engineering Universe for scientific Research and management
ISSN (Online): 2319-3069
Vol. XV Issue VI
June 2023

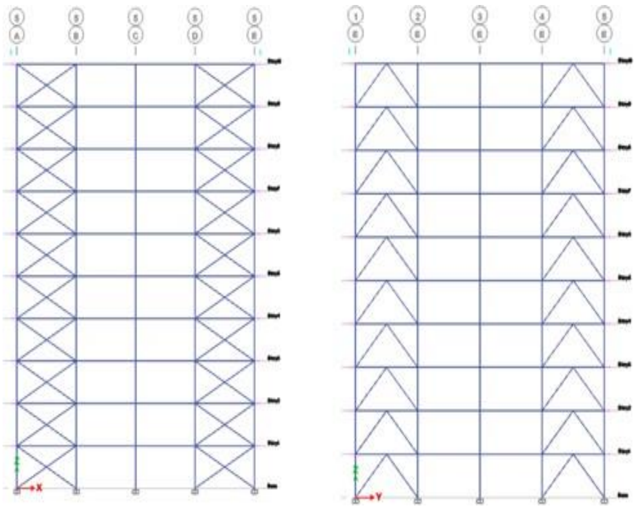

Figure 4 X and Chevron Brace at Corner Bays after modelling on ETABS

3.3 Loadings and Boundary Conditions

The methodology section further details the loadings and boundary conditions applied in the analysis. It discusses the selection of seismic loadings based on relevant design codes and standards. The boundary conditions, including fixed supports and constraints, are defined to simulate realistic structural behavior.
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,

3.4 Considered Steel Bracing Configurations

The different configurations of steel braces considered in the study are outlined, taking into account the placement of braces in corner bays, middle bays, alternate bays, and peripheral bays. The rationale behind the selection of these configurations is discussed, considering their potential impact on the overall structural response.

4. Results and Discussion

The results and discussion section presents the findings obtained from the analysis of braced and unbraced flat slab structures. It includes a comparative evaluation of the seismic performance in terms of storey displacement, drift ratio, base shear, and fundamental natural time period.

4.1 Analysis Results of Unbraced Flat Slab Structures

The analysis results of unbraced flat slab structures are presented, highlighting the response characteristics and vulnerabilities of these structures under seismic loads. The obtained values of storey displacement, drift ratio, and base shear provide a baseline for comparison with the braced models. Maximum Storey displacement.

Bare vs Corner Bays Braced models

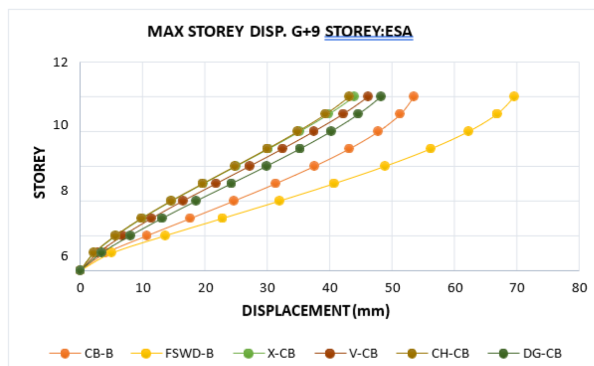

Figure 5 Max. Storey Displacement, Corner Bays Bracings, G+9 Storey due to ESA

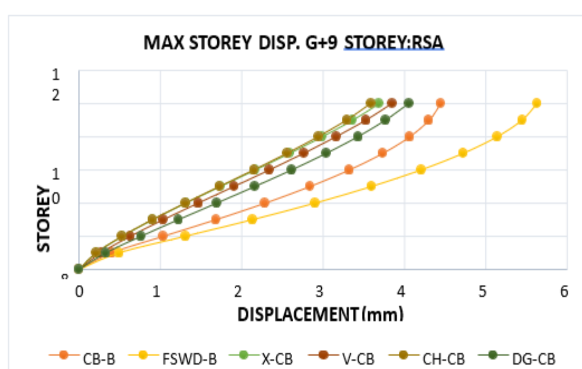

Figure 6 Max. Storey Displacement, Corner Bays Bracings, G+9 Storey due to RSA

Figures 4:1 and 4:2 compare the maximum storey displacement of a G+9 storey building using equivalent static analysis and response spectrum analysis. The plots show that the bare model of the flat slab building has higher storey displacement values compared to the conventional building. Introducing steel braces in the corner bays significantly reduces storey displacement. Diagonal, X, V, and Chevron braces reduce storey displacement by 30-43%, 37-59%, 33-50%, and 38-59% respectively in equivalent static analysis. The reduction ranges from 28-43%, 35-60%, 31-52%, and 36-60% in response spectrum analysis. X and Chevron braces are more effective than V and Diagonal braces at the corner location. Similar results were observed for G+5 and G+7 storey buildings.

4.2 Comparison of Seismic Performance:

Braced vs. Unbraced Models This subsection compares the seismic performance of braced and unbraced flat slab models. It discusses the reduction in storey displacement and drift ratio achieved through the application of steel braces. The influence of different bracing configurations, including corner bays, middle bays, alternate bays, and peripheral bays, is analyzed and their respective effects on the structural response are discussed.

4.3 Architectural Considerations and Aesthetics

The impact of steel braces on the architectural aspects of flat slab structures is examined. The paper explores how the addition of steel braces can offer architectural versatility and improve the overall aesthetic appeal of the building while ensuring enhanced seismic performance.

5. Conclusion and Future Work

The paper concludes by summarizing the key findings and implications of the research. It emphasizes the effectiveness of steel braces in seismic strengthening of RCC flat slab structures and highlights their potential as an alternative lateral load-resisting system. Recommendations for future research directions are provided, including the consideration of different plan configurations, soil-structure interaction, nonlinear analysis, and cost comparisons with other bracing options. The findings and discussions led to the following significant conclusions:
Application of steel braces on flat slab buildings resulted in an overall reduction in structural response and an increase in structural stiffness. The addition of braces enhanced the structural integrity and improved the seismic performance.
The installation of steel braces effectively reduced the storey displacement and drift ratio of flat slab buildings. This reduction can be attributed to the increased stiffness imparted by the braces. Among the different brace types, X and Chevron braces exhibited the most significant reduction in displacement and drift ratio when placed at corner bays and alternate bays. For middle and peripheral bays, X braces proved to be the most effective.

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