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Performance-Based Seismic Analysis of Flat Slab Buildings with Lateral Resistance

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Abstract: Flat slab structural systems are increasingly adopted in modern multistorey buildings due to their architectural flexibility, reduced construction time, and economical formwork. However, the absence of beams leads to reduced lateral stiffness, making flat slab structures vulnerable under seismic loading. This study presents a detailed survey and analytical investigation on the seismic behavior of flat slab buildings, emphasizing the role of lateral load resisting systems such as shear walls and bracing. A nonlinear static pushover analysis approach is adopted to evaluate structural performance under seismic actions. The study reviews existing literature, identifies research gaps, and proposes a systematic methodology using ETABS for modelling , hinge assignment, and performance evaluation. Key seismic response parameters such as base shear, roof displacement, storey drift, and hinge formation patterns are analyzed. The findings highlight the effectiveness of lateral load resisting systems in enhancing the seismic performance of flat slab structures and provide insights for future research directions.
Keywords: Flat slab structures, seismic performance, pushover analysis, shear walls, ETABS, nonlinear analysis.

I. INTRODUCTION

Flat slab structural systems consist of reinforced concrete slabs directly supported by columns without the use of beams. These systems offer several advantages such as reduced floor height, flexibility in architectural planning, ease of formwork, and faster construction. Due to these benefits, flat slabs are widely used in commercial buildings, parking structures, and residential complexes. Despite their advantages, flat slab structures exhibit inherent weaknesses under seismic loading. The absence of beams results in lower lateral stiffness and ductility, making them more susceptible to excessive lateral displacements, punching shear failure at slab–column connections, and progressive collapse during earthquakes. Past seismic events have demonstrated the poor seismic performance of flat slab buildings when not supplemented with adequate lateral load resisting systems.

To address these concerns, lateral load resisting systems such as shear walls, braced frames, and core walls are commonly introduced in flat slab buildings. These systems significantly enhance stiffness, strength, and energy dissipation capacity. However, linear elastic analysis methods are often inadequate to capture the true nonlinear behavior of structures during strong ground motions.

Nonlinear static pushover analysis has emerged as an effective tool for assessing seismic performance by simulating progressive damage and plastic hinge formation. This study focuses on understanding the seismic behavior of flat slab structures through nonlinear pushover analysis and evaluating the effectiveness of different lateral load resisting systems. The motivation, objectives, and analytical framework of the study are established based on identified research gaps.

II. LITERATURE REVIEW

An Extensive research has been conducted to evaluate the seismic performance of flat slab structures. Early studies highlighted the vulnerability of flat slab systems due to limited lateral stiffness and poor energy dissipation capacity. Researchers reported that flat slab buildings without lateral resisting elements exhibit excessive storey drift and premature punching shear failures under seismic loading.

Several studies have emphasized the importance of incorporating shear walls in flat slab buildings. The presence of shear walls significantly improves lateral load capacity, reduces storey drift, and delays the formation of plastic hinges. Comparative studies between bare flat slab systems and those with shear walls demonstrated substantial improvement in seismic performance levels.

Nonlinear pushover analysis has been widely used to evaluate structural capacity and performance levels. Researchers have employed pushover curves, capacity spectra, and hinge formation patterns to assess damage distribution and collapse mechanisms. Studies comparing different configurations revealed that centrally located shear walls provide better seismic performance compared to peripheral walls.

Bracing systems have also been explored as an alternative lateral resisting mechanism. While bracing improves stiffness, its effectiveness is influenced by configuration, material properties, and connection detailing. Previous research primarily focused on linear analysis, leaving limited studies addressing nonlinear behavior and performance-based evaluation of flat slab systems.

From the literature, it is evident that there is a need for comprehensive nonlinear seismic analysis of flat slab structures with different lateral load resisting systems. This study aims to bridge this gap by conducting a systematic pushover analysis and comparing seismic response parameters.

III. PROPOSED METHODOLOGY

The proposed methodology involves a step-by-step analytical approach to evaluate the seismic performance of flat slab structures using nonlinear pushover analysis.

A. Structural Modeling

Multistorey flat slab building models are developed using ETABS software. Different structural configurations are considered, including:

1) Flat slab without lateral load resisting system
2) Flat slab with shear walls
3) Flat slab with bracing systems

Material properties are defined as per relevant Indian Standard codes. Slab, column, and shear wall dimensions are selected based on practical design considerations.

B. Load Calculation and Assignment

Dead loads, live loads, and seismic loads are calculated and applied according to IS 875 and IS 1893 provisions. Gravity load combinations and seismic load combinations are defined for analysis.

C. Nonlinear Hinge Assignment

Nonlinear hinge properties are assigned to structural elements based on FEMA and ATC guidelines. Plastic hinges are defined for columns and shear walls to capture nonlinear behavior during seismic loading.

D. Pushover Analysis Procedure

A nonlinear static pushover analysis is performed by applying lateral loads incrementally until target displacement or structural instability is reached. Capacity curves representing base shear versus roof displacement are obtained.

E. Performance Evaluation

Seismic performance is evaluated using key response parameters:

1) Base shear capacity
2) Roof displacement
3) Storey drift
4) Capacity curves
5) Hinge formation patterns

Performance levels such as Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP) are identified and compared for different models.

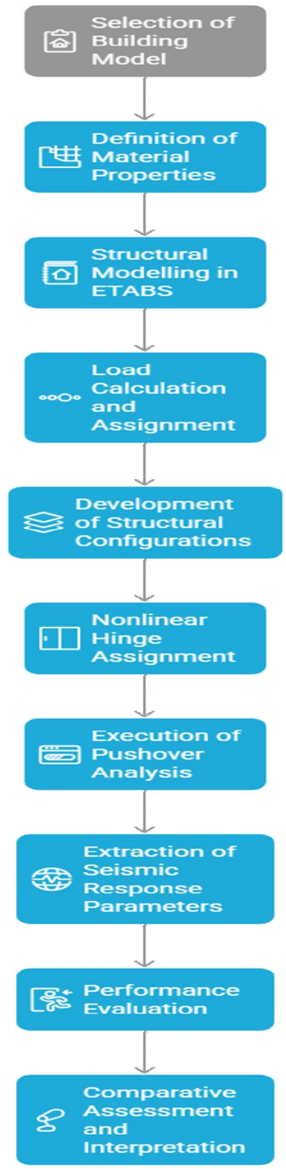

Fig. 1 Methodology Flowchart

IV. CONCLUSIONS

This study research provides a detailed survey and analytical assessment of flat slab structures subjected to seismic loading through nonlinear pushover analysis. The literature review identifies the inherent seismic deficiencies of flat slab systems and underscores the critical need for effective lateral load resisting mechanisms. The adopted methodology offers a robust framework for performance-based seismic evaluation.

The analytical results demonstrate that the inclusion of shear walls and bracing systems significantly enhances seismic performance by increasing base shear capacity, reducing roof displacement, limiting storey drift, and delaying plastic hinge development. Among the evaluated systems, shear walls exhibit superior stiffness and overall structural stability.

Furthermore, the comparative study of various structural configurations provides practical guidance for engineers in selecting appropriate lateral load resisting systems at the design stage. The outcomes reinforce the relevance of nonlinear pushover analysis in capturing damage progression and structural capacity, thereby supporting performance-based design approaches. Future investigations may extend this work through nonlinear time-history analysis, consideration of soil–structure interaction, and experimental validation to further improve the seismic resilience of flat slab buildings.

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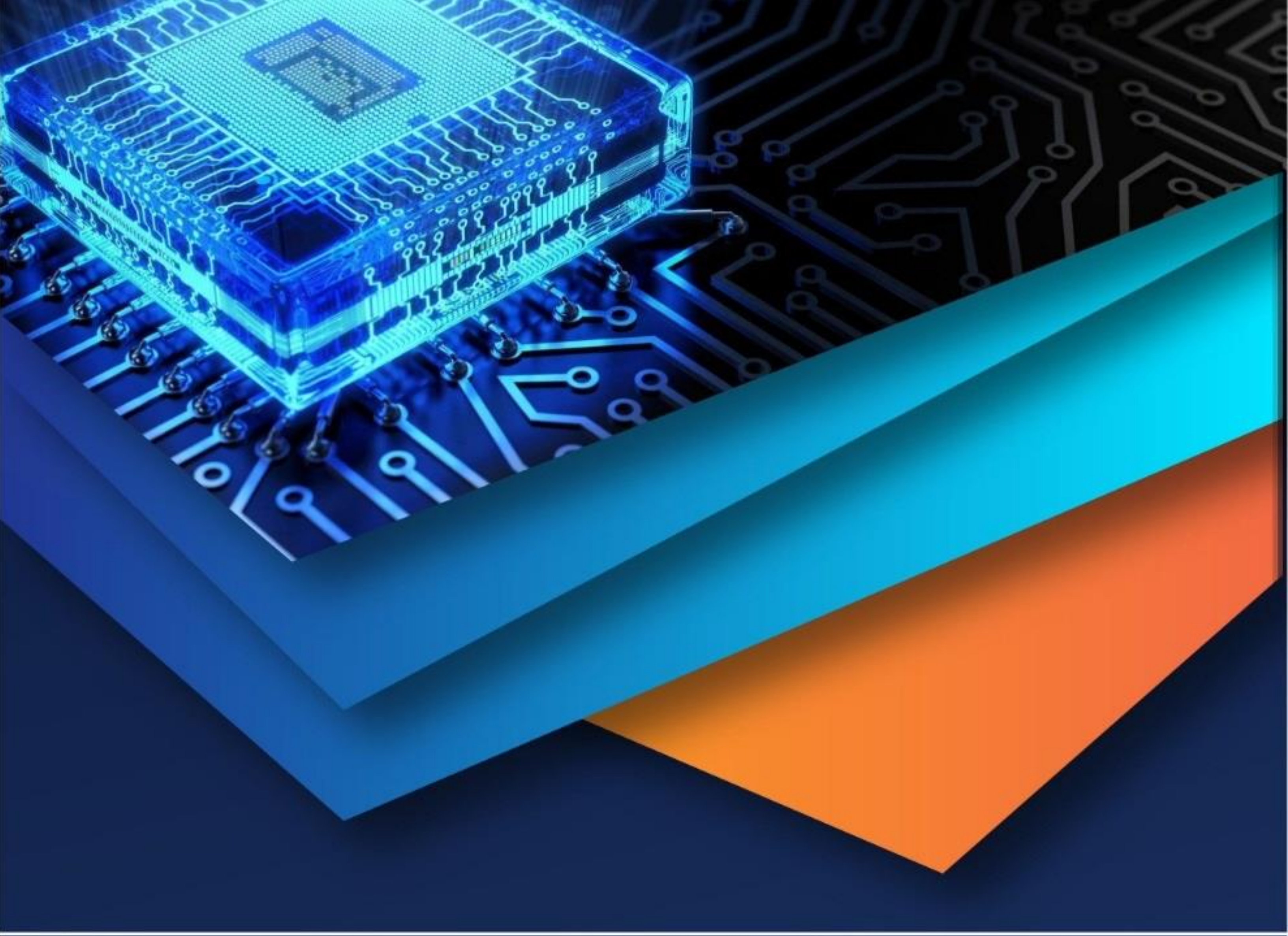

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