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Comparative Assessment of Seismic Response in G+20 & G+30 Soft-Storey Buildings with Flanged Shear Walls

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***Abstract*—Soft-storey reinforced concrete (RC) buildings are highly vulnerable to seismic forces due to stiffness irregularity at lower levels. This study evaluates the seismic behavior of G+20 and G+30 RC buildings with soft-storey conditions using advanced retrofitting techniques such as Buckling Restrained Braces (BRB), Shape Memory Alloy (SMA) systems, steel bracing, and Flag-shaped shear walls. Numerical modelling and response spectrum analysis were performed in ETABS 21 as per IS 1893:2016 provisions. Parameters such as storey displacement, inter-storey drift, stiffness, and time period were compared for normal and retrofitted models. Results indicate that retrofitting significantly improves seismic performance by reducing drift and displacement while enhancing stiffness and energy dissipation capacity. Among all techniques, Flag shear walls and BRB systems showed superior performance in controlling soft-storey effects.**

keywords: Soft-storey buildings, Seismic retrofitting, BRB, Shape Memory Alloy, Flag shear wall, Response spectrum analysis.

I. INTRODUCTION

Soft-storey buildings are structures having one floor with substantially lower stiffness compared to adjacent floors. Such irregularity leads to concentration of deformation and severe damage during earthquakes. Open ground floors used for parking or commercial purposes commonly create soft-storey conditions in urban buildings. Recent earthquakes have demonstrated the vulnerability of these structures due to excessive lateral displacement and inter-storey drift.

To improve seismic resistance, several retrofitting techniques are used such as shear walls, bracing systems, Buckling Restrained Braces (BRB), Shape Memory Alloys (SMA), and Flag-shaped shear walls. This study investigates the effectiveness of these techniques in improving the seismic performance of high-rise RC buildings.

II. METHODOLOGY

The study considered G+20 and G+30 RC framed buildings with soft-storey configurations at bottom, middle, and top levels. ETABS 21 software was used for modelling and analysis. Response spectrum analysis was performed according to IS 1893:2016. Different retrofitting techniques including BRB, SMA systems, steel bracing, and Flag shear walls were incorporated in the models.

The following engineering parameters were evaluated:

1. Storey displacement,
2. Inter-storey drift,
3. Storey stiffness,
4. Natural time period

Table I. Overview of Retrofitting Techniques

Technique	Main Function	Performance Improvement
BRB	Energy dissipation	High stiffness and ductility
SMA	Self-centering behavior	Reduced residual drift
Steel Bracing	Lateral resistance	Reduced displacement
Flag Shear Wall	Self-centering and stiffness	Maximum drift control

III. RESULTS AND DISCUSSION

The analytical results revealed that soft-storey structures without retrofitting experienced higher displacement and drift concentrations at irregular levels. Retrofitted models showed significant improvement in seismic response. BRB systems enhanced energy dissipation, while SMA systems reduced residual deformation due to self-centering behavior. Flag shear walls provided maximum stiffness enhancement and effectively controlled storey drift.

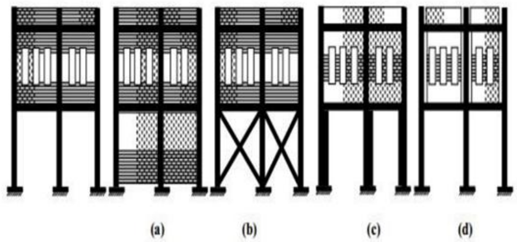

Figure 1: Methods of Preventing Soft-Story Irregularities

3.1 RCC SHEAR WALLS

RCC (Reinforced Cement Concrete) shear walls are crucial structural elements designed to resist lateral forces (like wind and seismic loads) in high-rise buildings and structures. They are vertically oriented slabs of concrete with embedded reinforcement and act as vertical cantilevers to provide stability against lateral displacements. RCC shear walls are particularly effective in soft story mitigation, which is vital in earthquake-prone areas to prevent building collapses due to unbalanced stiffness between floors.

3.1.1 KEY ASPECTS OF RCC SHEAR WALLS

• Materials: RCC shear walls use high-strength concrete and steel reinforcement to resist bending, shear, and lateral loads.
• Positioning: They are typically placed around elevator shafts, stairwells, and the building's perimeter.
• Design Standards: Codes like IS 13920 (India), ASCE 7 (USA), and Eurocode 8 (Europe) provide guidelines for shear wall design in seismic zones.

3.2 BRB

A Buckling Restrained Brace (BRB) is an advanced structural element used in seismic-resistant design to enhance the energy dissipation capacity of buildings while preventing buckling under compressive loads. Unlike conventional braces, which tend to buckle in compression and yield only in tension, a BRB is specifically designed to yield in both tension and compression without instability. It consists of a steel core (yielding element) encased within a restraining mechanism, typically a steel tube filled with mortar or concrete, which prevents lateral buckling of the core. A debonding layer is provided between the core and the casing to ensure that axial forces are carried only by the core while the casing provides lateral support. This configuration results in a stable and symmetrical hysteresis behavior under cyclic loading, making BRBs highly effective in dissipating seismic energy. Due to their superior ductility, stiffness, and predictable performance, BRBs are widely used in high-rise buildings, bridges, and retrofitting of existing structures to improve seismic resilience and reduce structural damage during earthquakes.

3.3 FLAG SHEAR WALLS

This are a specialized type of shear wall used in buildings to resist lateral forces such as wind and seismic activity. While many high-rise and mid-rise buildings around the world employ various forms of shear walls, specific cases where Flag Shear Walls have been used are not always publicly documented by that name.

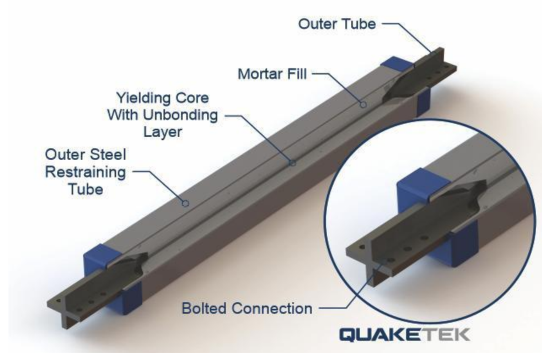

Fig. 2: Important structural concept/retrofitting system from thesis study.

IV. CONCLUSION

The study concludes that seismic retrofitting techniques significantly improve the behavior of soft-storey RC buildings under earthquake loading. The retrofitted structures demonstrated reduced storey displacement, lower inter-storey drift, and improved stiffness compared to conventional models. Among the techniques studied, Flag shear walls and BRB systems showed the most effective performance in controlling seismic response. The findings support the adoption of modern retrofitting strategies for improving safety and resilience of irregular high-rise buildings. The SMA system also shows considerable improvement, with the added advantage of deformation recovery due to its self-centering behavior. Similarly, the Flag Wall system improves performance by controlling displacement through controlled rocking and self-centering action. Although conventional bracing systems reduce displacement, their effectiveness is comparatively lower due to the possibility of buckling under compressive forces.Furthermore, displacement is observed to be higher in G+30 buildings compared to G+20 structures due to increased height and flexibility.In terms of inter-storey drift, the maximum drift in the baseline model occurs at the soft-storey level, indicating a critical zone of structural weakness.

IV. ACKNOWLEDGEMENT

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