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Research Paper

EVALUATION OF RETROFITTING METHODS FOR FAILURE RESISTANCE IN SKYSCRAPER STRUCTURES

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ABSTRACT

A skyscraper is a tall, continually occupied structure including several levels. The phrase formerly referred to a structure including a minimum of 35 to 50 stories, primarily intended for office, commercial, and residential purposes. A skyscraper, frequently referred to as a high-rise, typically denotes a structure over 50 meters (164 feet) in height. A prevalent characteristic of skyscrapers is the presence of a steel structure that underpins curtain walls. These curtain walls may rest on the underlying structure or are hung from the above framework, as opposed to typical load-bearing walls.

The load on a skyscraper mostly derives from the weight of the construction materials. In the majority of architectural projects, the mass of the structure significantly exceeds the mass of the materials it will support in addition to its own weight. In technical terminology, the dead load, representing the weight of the structure, exceeds the live load.

The fundamental concepts of design for vertical and lateral loads (wind and seismic) are same throughout low, medium, and high-rise buildings. As a structure ascends, both vertical and lateral loads become critical issues. The vertical loads escalate proportionately with the floor size and the number of levels. Conversely, the impact of lateral stresses on a structure is nonlinear and escalates significantly with height. The lateral loads will result in significant deflection and moments on steel components. Retrofitting the structure may mitigate these sorts of failures.

This examination will examine a 40-story skyscraper. Various retrofitting solutions, including shear walls, bracings, and fixed dampers, will be evaluated at many sites. The structure will be evaluated on medium soil and examined over all four zones. Moments, drift, torsion, and story shear will be compared across all situations.

The commercial software ETABS will be used for the analysis of a 120-meter tall skyscraper across several zones. The data will be analysed using tables and graphs to identify the best optimised option.

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1. INTRODUCTION

The designation "skyscraper" was first used for steel-framed structures including a minimum of 10 floors in the late 19th century, prompted by popular astonishment at the towering edifices emerging in prominent cities such as Chicago, New York City, Tokyo, and Beijing.

Architectural historians subsequently modified the structural meaning of the term skyscraper, influenced by mechanical advancements of the 1880s that facilitated the construction of towering multi-storey structures. This concept was predicated on the steel framework rather than load-bearing masonry, which reached its practical limit in 1891 with the Monadnock Building in Chicago.

The design and construction of skyscrapers entails the creation of secure, livable environments inside very tall structures. The structures must bear their own weight, withstand wind and seismic activity, and save inhabitants from fire. However, they must also be readily accessible, even on the top levels, and provide amenities and a pleasant environment for the inhabitants. The challenges in skyscraper design are regarded as some of the most intricate because to the necessary equilibrium among economics, engineering, and construction management.

2. SEISMIC RETROFITTING

Seismic retrofitting involves altering existing buildings to enhance their resilience against seismic activity, ground motion, or soil breakdown resulting from earthquakes. The need for seismic retrofitting is widely recognised due to an improved comprehension of seismic demands on buildings and recent experiences with significant earthquakes in metropolitan areas. Before the implementation of contemporary seismic codes in the late 1960s in industrialised nations (such as the US and Japan) and in the late 1970s in various other regions (including Turkey and China), several buildings were constructed without sufficient detailing and reinforcing for seismic safety. In light of the impending issue, several research studies have been conducted. Comprehensive technical recommendations for seismic evaluation, retrofit, and rehabilitation have been disseminated globally, including the ASCE-SEI 41 and the guidelines from the New Zealand Society for Earthquake Engineering (NZSEE).

The retrofit methods described above are also relevant for other natural disasters, including tropical cyclones, tornadoes, and intense winds from thunderstorms. While current seismic retrofitting practices primarily focus on structural enhancements to mitigate seismic hazards, it is equally crucial to address the risks and losses associated with non-structural components. It is crucial to recognise that no construction can be deemed earthquake-proof; nevertheless, seismic performance may be significantly improved by appropriate original design or future improvements.

INFILLS EXTERNAL BRACINGS

OBJECTIVES OF THE STUDY

The primary objectives of the present study are:

- To analyse the skyscraper by retrofitting it with shear walls, steel bracings and with friction dampers. For this
- Four models are developed
    - Model – 1(Normal Model)
    - Model – 2(Shear Walls)
    - Model – 3(Steel Bracings)
    - Model – 4(Friction Dampers)
- These models are analyzed for all the four earthquake zones by considering soil as medium type(II).

SCOPE OF THE INVESTIGATION

This study analyses a typical 40-story skyscraper using commercial ETABS v 9.4.7 through the Dynamic Method of Analysis. The structure is retrofitted with steel bracings, shear walls, and friction dampers at various locations, and the results are compared to the standard model to draw conclusions about its behaviour.

3. LITERATURE REVIEW

Thomas, N. and **Salonikios., (2007)** considered the reinforced concrete shear walls subjected to seismic loads the flexural shear, web shear and sliding shear mechanisms are. The measurements obtained from the tests of 11 wall specimens with aspect ratio 1.0 and 1.5 are used in order to set up analytical models that predict the deformations associated with each mechanism and the corresponding strength. The arrangement and quantity of the reinforcement of the specimens were chosen to ensure a flexural type of failure. It was observed during the tests that the web shear deformation increased until maximum strength reached.

After the point of maximum strength, web shear deformations decreased and sliding shear deformations along with the base of main flexural crack increased.

Su R.K.L., and **Wong, (2007)** carried an experimental study has been conducted on three reinforced concrete (RC) wall specimens to study the effects of axial load ratio (ALR) and confinement on their performance to artificial earthquake loads. The walls in the form of a slender vertical cantilever with an aspect ratio of 4, fabricated with high strength concrete and high longitudinal ratio were tested. The effects of ALR and confinement failure mode, ductility capacity, strength degradation, and axial load capacity were critically examined. Through this study, ALR is identified as an indispensable parameter for consideration in seismic performance assessment of RC shear walls.

M. Gloria Gomes, et. al., **(2012)** investigated the pressure distribution on commonly used irregular-plan buildings, wind tunnel tests were conducted on L- and U-shaped models over an extended range of wind directions. The experiments were carried out in a close-circuit wind tunnel under uniform inlet flow and the instantaneous surface pressures were recorded with a multi-channel pressure measurement system. Furthermore, the flow patterns around those irregular-shaped buildings were illustrated for some particular wind directions for which the velocity field was assessed. A CFD (Computational Fluid Dynamics) commercial code was used for this propose.

4. RETROFITTING

Retrofitting involves modifying an existing structure to safeguard it against floods and other risks, like severe winds and earthquakes. Retrofitting is a development in construction technology, including both techniques and materials, to address the rising frequency and severity of natural disasters and their impacts on structures. Numerous homes already in existence were constructed when knowledge about the frequency and locations of floods and other perilous occurrences was limited, as well as the methods for safeguarding structures. Conversely, houses being constructed today may profit from advancements informed by future insights. Consequently, retrofitting has emerged as an essential and significant instrument in hazard reduction.

Retrofitting specifically for earthquake hazards is often referred to as "**rehabilitation**".

In earthquake engineering terminology, Repair, Restoration and Retrofitting have acquired the following meanings:

- **Repair**: Actions taken for patching up of superficial defects and doing the finishes.
- **Restoration**: Action taken for restoring the lost strength of Structural elements.
- **Retrofitting**: Actions for upgrading the seismic restoring of an existing building. So that it becomes safer under the recurrence of likely future earthquakes.

NEED FOR SEISMIC RETROFITTING

- ❖ To ensure the safety and security of a building, employees, structure functionality, machinery and inventory
- ❖ Essential to reduce hazard and losses from non-structural elements.
- ❖ Predominantly concerned with structural improvement to reduce seismic hazard.
- ❖ Important buildings must be strengthened, whose services are assumed to be essential just after an earthquake like hospitals.

EARTHQUAKE RESISTANT RETROFITTING OF BUILDINGS:

For achieving safety of buildings against collapse in a future severe earthquake, the following retrofitting actions are recommended. The amount and placing of the retrofitting element depends upon the seismic zone, the importance of the building and the stiffness of the base soil.

Seismic Retrofitting Techniques are required for concrete constructions which are vulnerable to damage and failures by seismic forces. In the past thirty years, moderate to severe earthquakes occurs around the world every year. Such events lead to damage to the concrete structures as well as failures.

Thus the aim is to focus on a few specific procedures which may improve the practice for the evaluation of seismic vulnerability of existing reinforced concrete buildings of more importance and for their seismic retrofitting by means of various innovative techniques such as base isolation and mass reduction.

So Seismic Retrofitting is a collection of mitigation technique for Earthquake engineering. It is of utmost importance for historic monuments, areas prone to severe earthquakes and tall or expensive structures.

5. MODELLING

GEOMETRICAL PROPERTIES:

Height of typical Storey = 3 m

Height of ground Storey = 3 m

Length of the building = 21 m

Width of the building = 21 m

Span in both the direction = 21 m

Height of the building = 120 m

Number of stores = 40

Wall thickness = 230 mm

Slab Thickness = 150 mm

Grade of the concrete = M 30

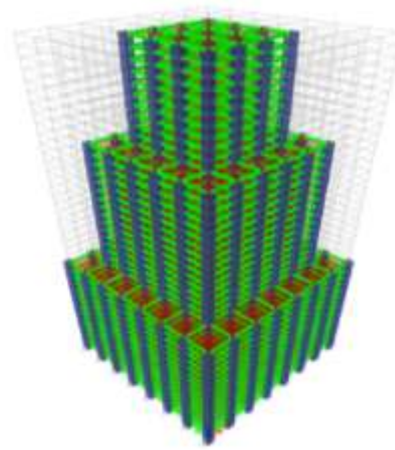
Grade of the steel = Fe 500

Thickness of shear wall = 230 mm

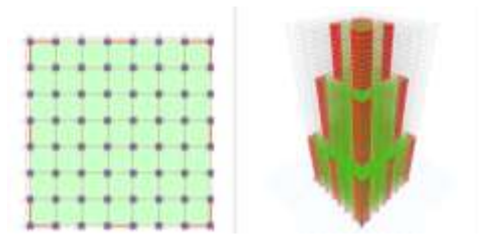
Support = Fixed

Column sizes = 0.6m X 0.6m

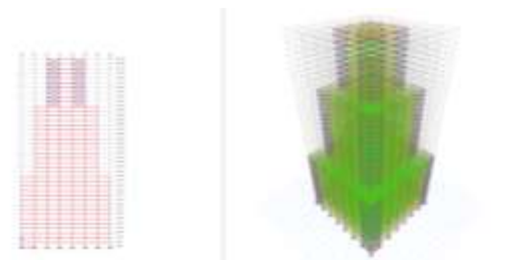
Beam size = 0.4 m X 0.4 m



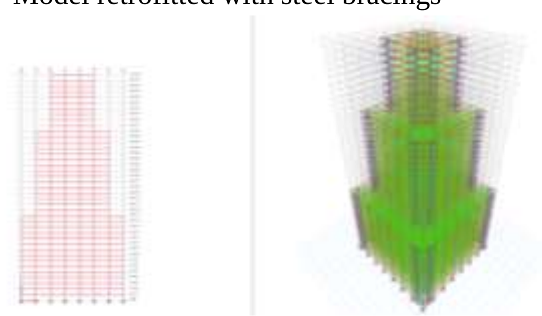
General model



Model retrofitted with shear walls



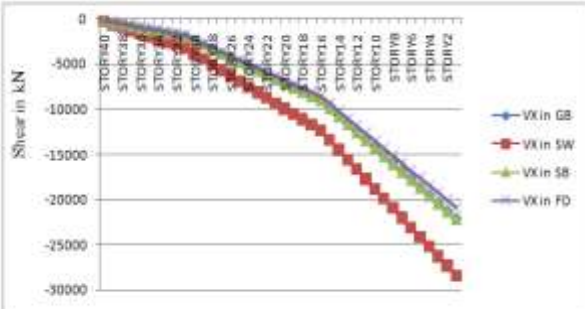
Model retrofitted with steel bracings



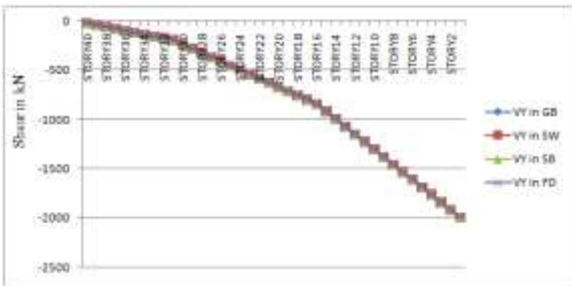
Model retrofitted with friction dampers

6. RESULTS AND ANALYSIS

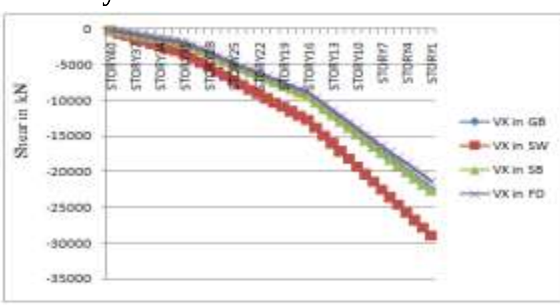
STORY SHEAR



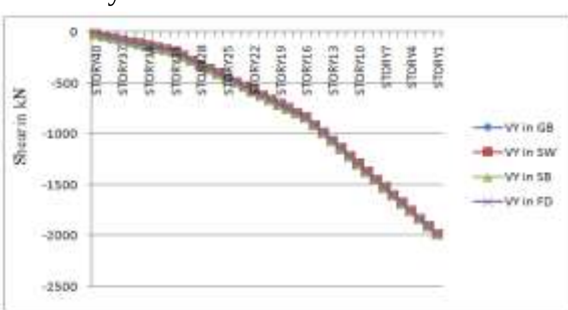
Storey Shear in X-Direction for Zone II



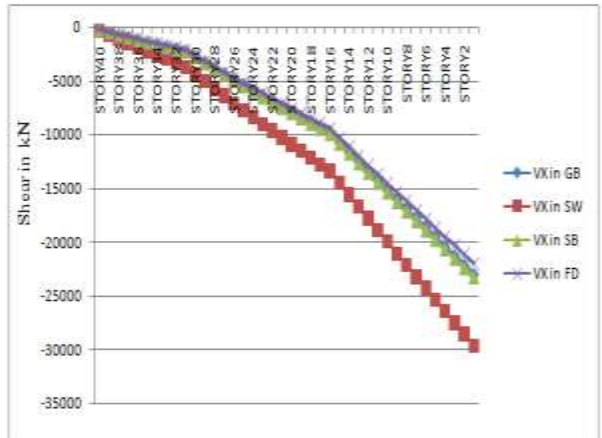
Storey Shear in Y-Direction for Zone II



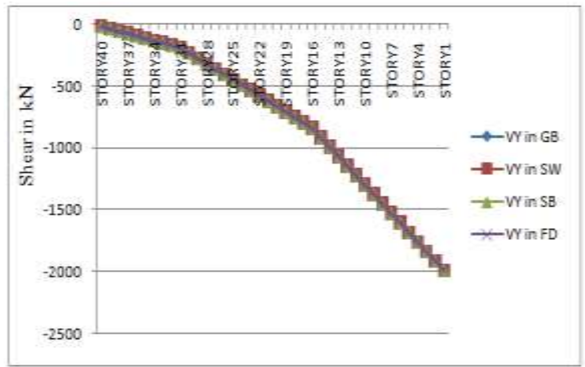
Storey Shear in X-Direction for Zone III



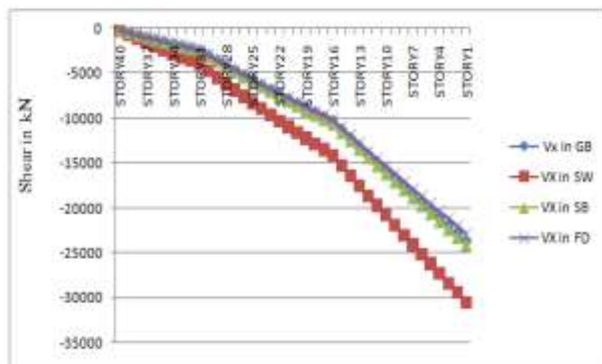
Storey Shear in Y-Direction for Zone III



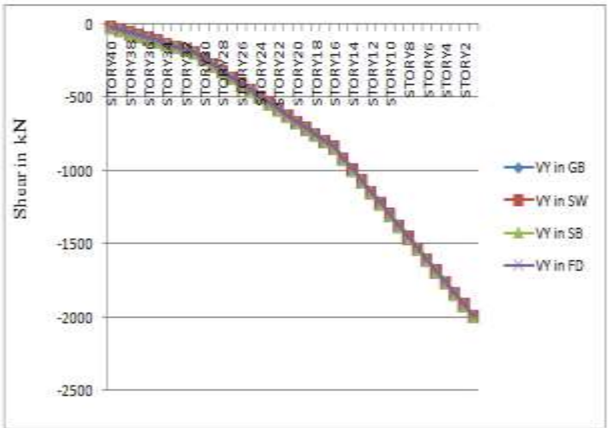
Storey Shear in X-Direction for Zone IV



Storey Shear in Y-Direction for Zone IV

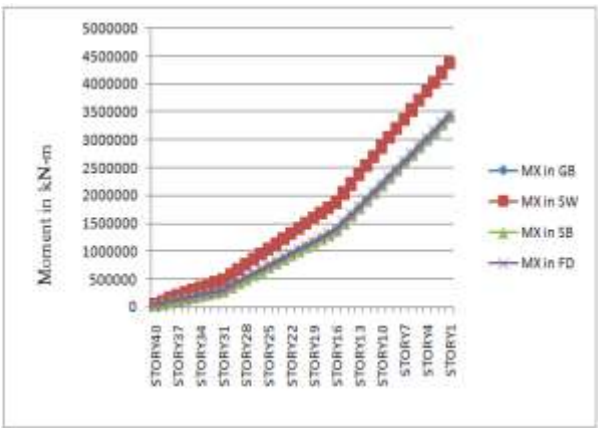


Storey Shear in X-Direction for Zone V

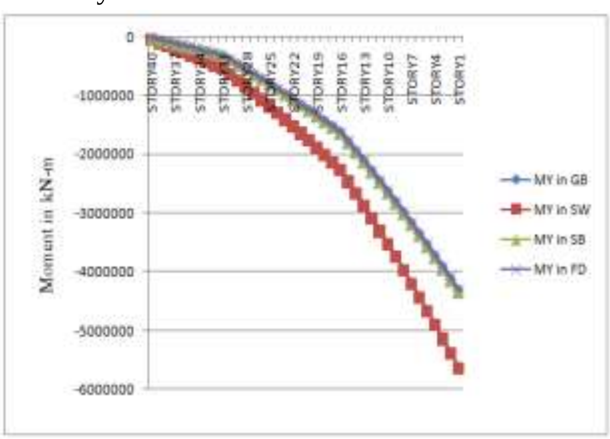


Storey Shear in Y-Direction for Zone V

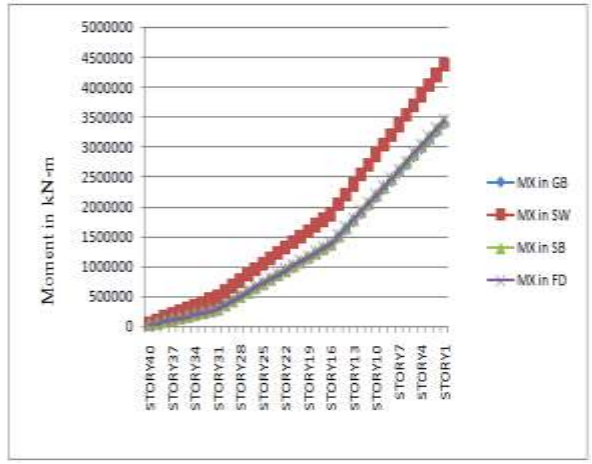
STOREY MOMENT



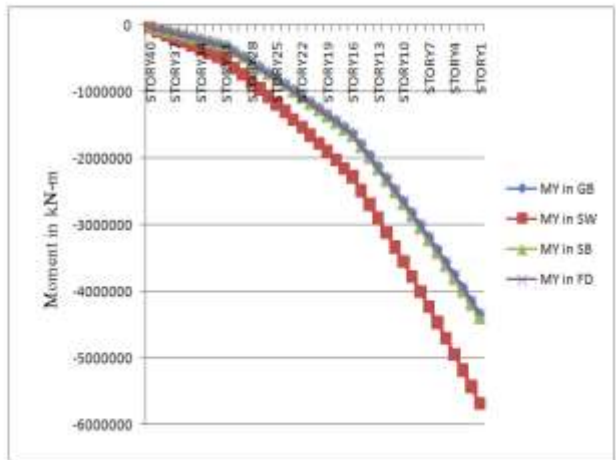
Storey Moment in X-Direction for Zone II



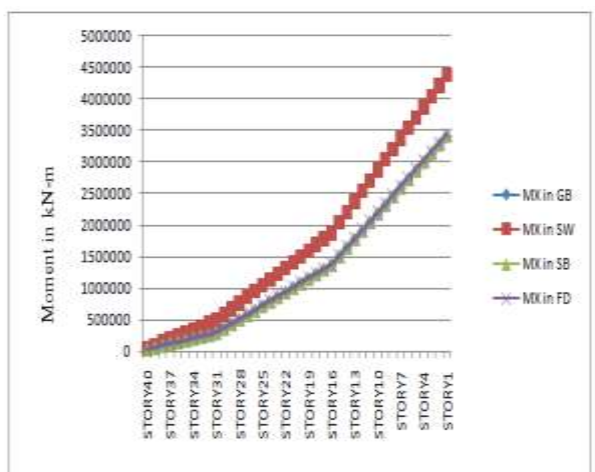
Storey Moment in Y-Direction for Zone II



Storey Moment in X-Direction for Zone III



Storey Moment in Y-Direction for Zone III



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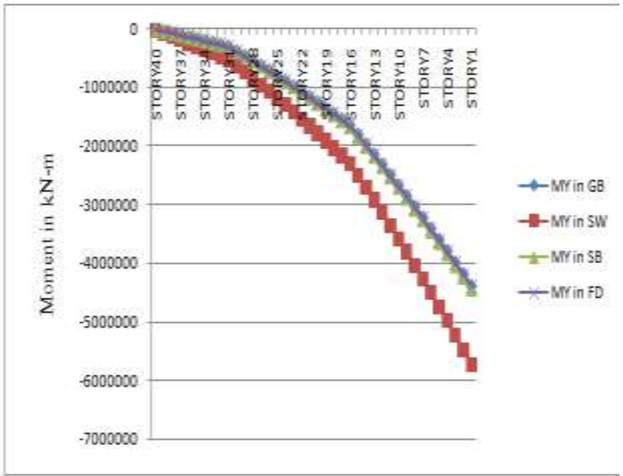
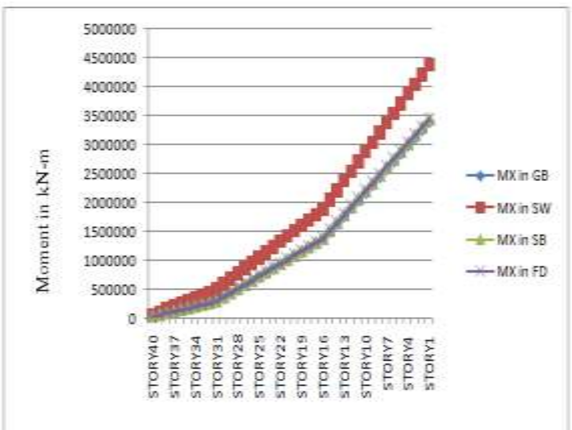
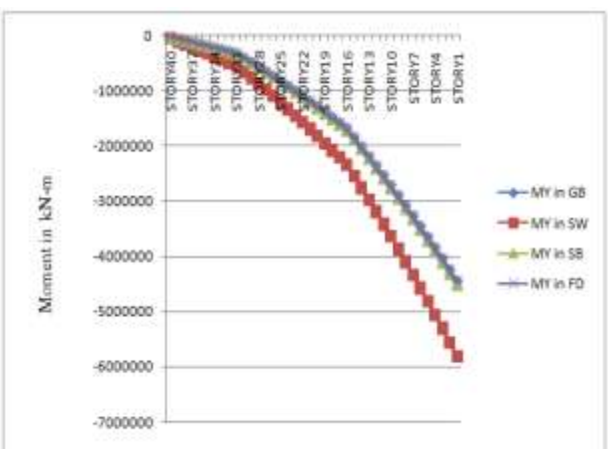
Storey Moment in X-Direction for Zone IV



Storey Moment in Y-Direction for Zone IV

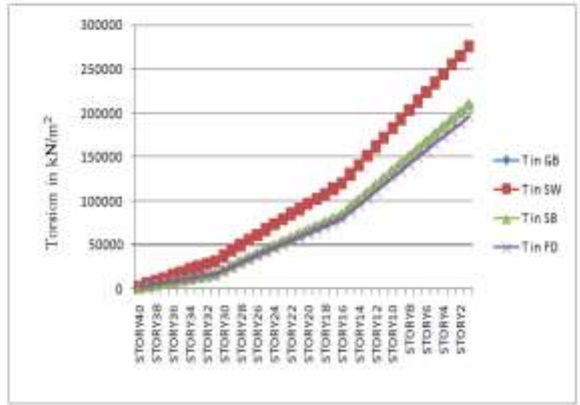


Storey Moment in X-Direction for Zone V

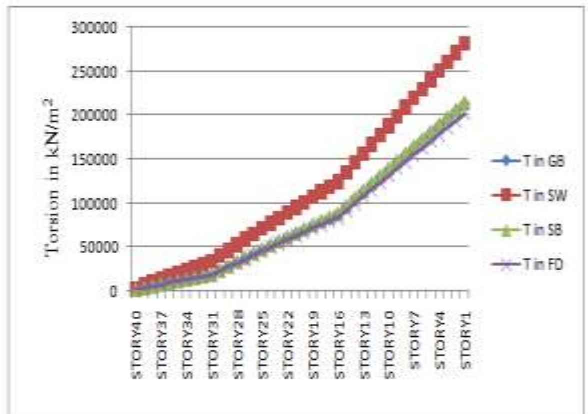


Storey Moment in Y-Direction for Zone V

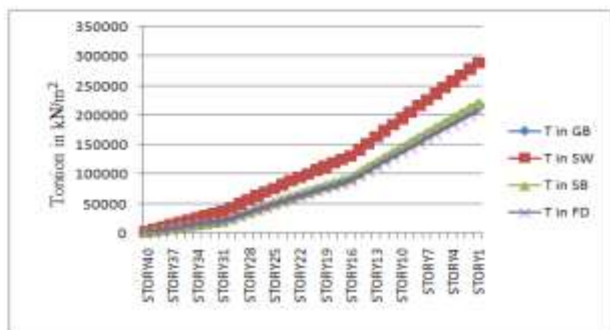
TORSION



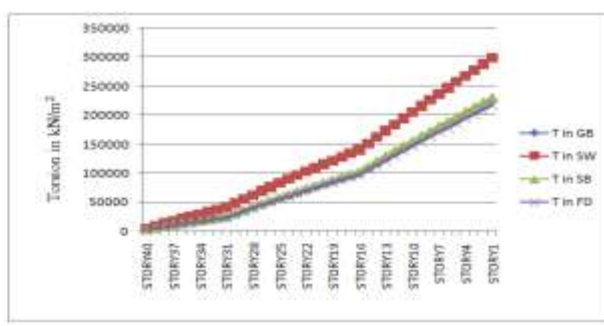
Torsion for Zone II



Torsion for Zone III

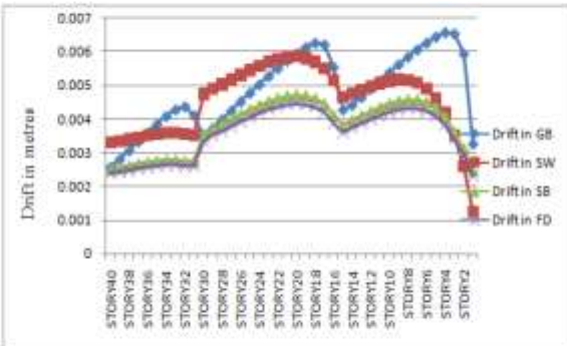


Torsion for Zone IV

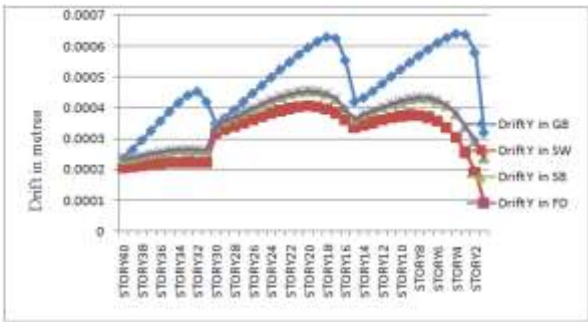


Torsion for Zone V

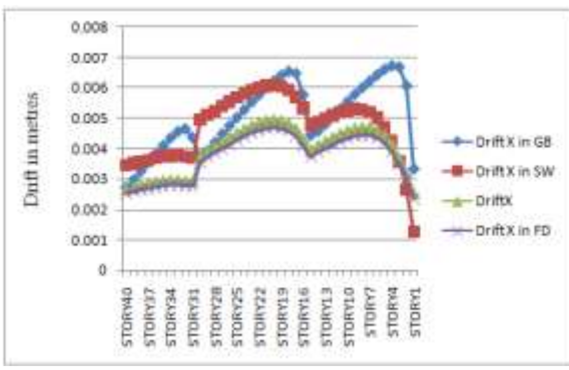
STOREY DRIFT



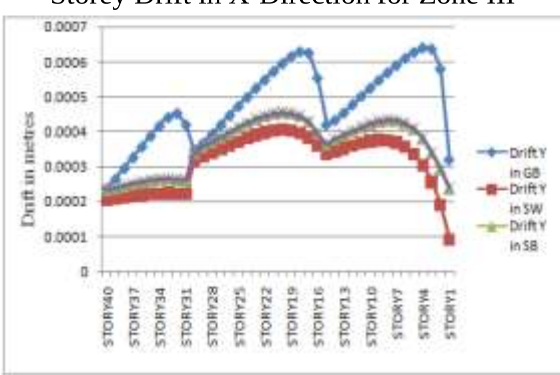
Storey Drift in X- Direction for Zone II



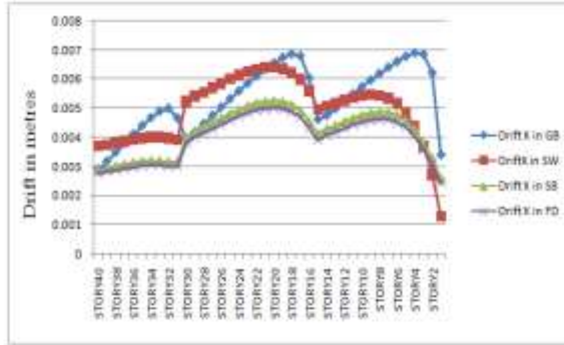
Storey Drift in Y-Direction for Zone II



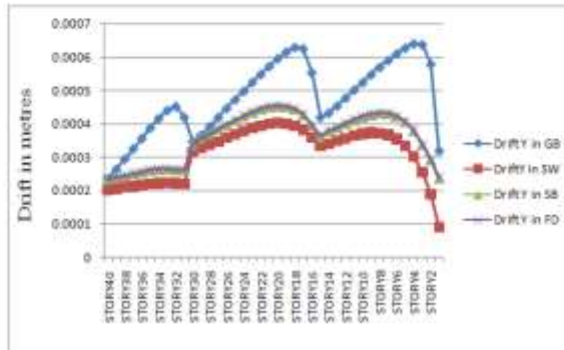
Storey Drift in X-Direction for Zone III



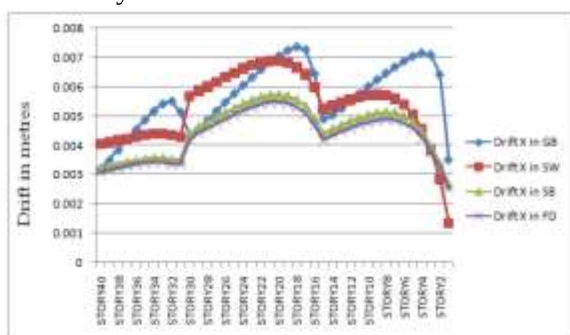
Storey Drift in Y-Direction for Zone III



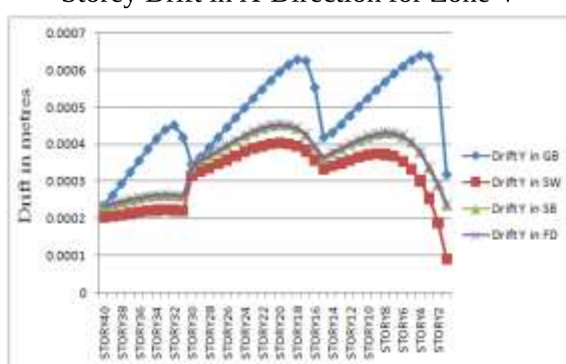
Storey Drift in X-Direction for Zone IV



Storey Drift in Y-Direction for Zone IV

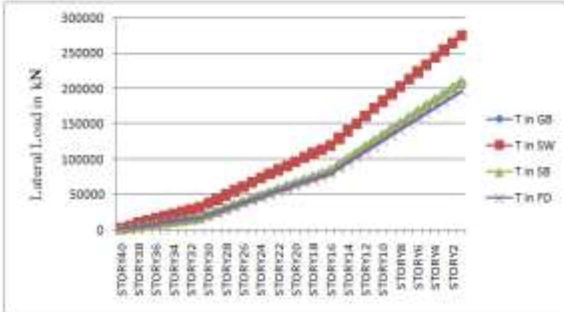


Storey Drift in X-Direction for Zone V

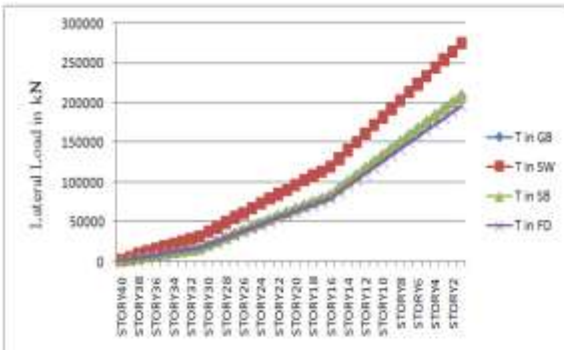


Storey Drift in Y-Direction for Zone V

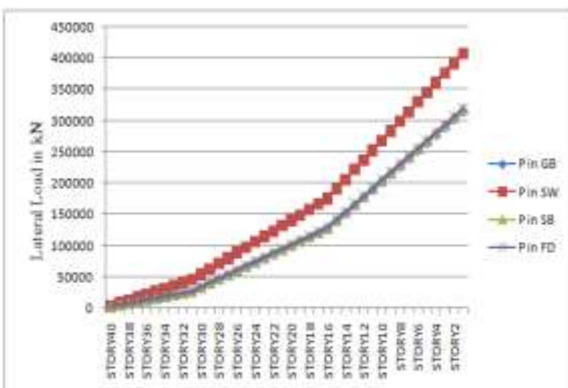
LATERAL LOAD



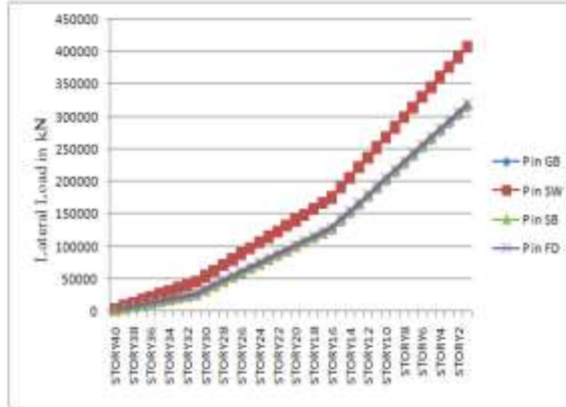
Lateral Load in Zone II



Lateral Load in Zone III



Lateral Load in Zone IV



Lateral Load in Zone V

7. CONCLUSIONS

Based on the aforementioned findings, the following conclusions have been drawn:

1. Among the three retrofits used, friction dampers provide superior performance, leading to the conclusion that they are the most effective retrofits.
2. Optimal control of drift in the X-direction is achieved when the structure is retrofitted with friction dampers, then complemented by steel bracings and shear walls.
3. In relation to the drift in the Y-direction, optimal control is attained with shear walls, and both steel bracings and shear walls produce identical results.
4. The reductions seen when the structure is retrofitted with shear walls and steel bracings nearly align with those reported when using friction dampers in terms of drift in the X-direction.
5. The optimal control of drift is evident in all models along the Y-direction when the structure is retrofitted with friction dampers.
6. Aside from drift, there is an increase in all metrics, notably concerning shear walls, due to the additional stresses from the retrofits on the structural parts.
7. The retrofitting of the structure with friction dampers results in a reduction in all metrics throughout almost every zone.

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