

Seismic Analysis of G+30 RCC Framed Structure and Use of R.C Jacketing

Pratik S. Dahiwalé^{1,*}, R.S. Londhe²

Abstract

In high-rise buildings, such as G+30 reinforced concrete (RCC) framed structures, key concerns during seismic events include maintaining structural integrity, preventing catastrophic collapse, and ensuring the safety of occupants. Seismic retrofitting is a vital process aimed at enhancing the resilience of such buildings and infrastructure against earthquake forces, by strengthening their ability to withstand seismic activity. This abstract provides an overview of numerous seismic retrofitting projects implemented worldwide, focusing on the methodologies used, technologies adopted, and outcomes achieved. These projects integrate advanced materials and techniques, such as fiber-reinforced polymers (FRPs), base isolators, and energy-dissipating devices, which not only enhance the safety and longevity of existing structures but also minimize the economic losses associated with seismic events. The use of FRPs, for example, provides lightweight, high-strength solutions for reinforcing vulnerable structural elements, while base isolators decouple a building from ground movements, thereby reducing the forces transmitted during an earthquake. Energy-dissipating devices absorb and dissipate seismic energy, preventing structural damage and extending the building's lifespan. Case studies from regions with high seismic activity, such as Japan, California, and New Zealand, highlight the effectiveness of various retrofitting techniques. These examples demonstrate how adherence to local building codes, coupled with community engagement and education, plays a crucial role in the successful implementation of retrofitting initiatives. Furthermore, the ongoing challenges faced by seismic retrofitting projects—including funding limitations, stakeholder coordination, and the need for continuous advancements in engineering practices—are discussed, stressing the importance of proactive and innovative approaches to safeguard urban environments. This review underscores that comprehensive seismic retrofitting strategies are essential for reducing risks, protecting lives, and enhancing community resilience in earthquake-prone areas.

Keywords: Seismic retrofitting, structural resilience, RCC framed structure, fiber-reinforced polymers, base isolators, energy-dissipating devices, earthquake forces, structural integrity, collapse prevention, advanced materials,

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INTRODUCTION

Collapses or genuine harms of existing buildings amid solid seismic tremors have brought about in critical financial misfortunes, extreme wounds and misfortune of human lives. Given the late presentation of cutting-edge seismic benchmarks and the expansive a large number of the current poorly planned structures, the logical intrigued has continuously been centering on creating procedures for the seismic overhauling of existing buildings. Structures fall apart due to issues related with fortified concrete. Common catastrophes like seismic tremors have over and over illustrated the vulnerability of existing structures to seismic

impact and consequently actualizes like retrofitting and recovery of disintegrated structures are critical in tall seismic locales. In this way retrofitting and fortifying of existing fortified concrete structures has gotten to be one of the foremost critical challenges in Gracious designing. Engineers frequently confront issues related with retrofitting and quality improvement of existing structures. Commonly experienced designing challenges such as increment in benefit loads, changes in utilize of the structure, plan and/or development mistakes, corruption issues, changes in plan code controls, and seismic retrofits are a few of the causes that lead to the require for recovery & retrofitting of existing structures. Total substitution of an existing structure may not be a cost-effective arrangement and it is likely to ended up an expanded financial burden if updating may be a practical elective. In such events, repair and restoration are most commonly utilized arrangements.

The occurrence of delicate disappointment in reinforced concrete (RC) buildings poses a significant constraint on their seismic performance. This issue often arises due to insufficient transverse reinforcement in joints, a common deficiency in existing RC structures worldwide. Historical oversight and the lack of universally accepted theories and definitions for joint capacity have led to neglect in joint design and construction practices. Many older structures, developed prior to the 1970s, remain vulnerable to joint failures under seismic loads.

Recognizing the critical role of joints in overall building performance, recent research efforts have focused on developing effective and economical retrofitting techniques for traditional beam-column joints. Among these, fiber-reinforced polymer (FRP) systems have emerged as promising solutions. Experimental studies have highlighted the benefits of FRP in strengthening these joints, although they have also shown that poor-quality concrete substrates can significantly reduce their effectiveness due to potential FRP debonding. In such cases, replacing the substrate with shrinkage-free cement grout before applying FRP reinforcement is recommended, albeit at the cost of simplicity and rapid application characteristic of FRP systems. Beyond FRP, various other retrofitting methods exist, reflecting ongoing advancements in sustainable construction practices that emphasize environmental friendliness. Retrofitting not only enhances structural functionality but also reduces the environmental impact compared to traditional demolition and reconstruction methods, which generate substantial waste and pollution. In terms of practical applications, retrofitting techniques involve augmenting concrete areas with modern structural elements, such as steel angles and plates, to enhance shear or flexural capacities.

AIM AND OBJECTIVES:

1. Analysis of the G+30 RC frame high-rise structure with RC Jacketing
2. To Compare the Displacement, Storey shear and Storey drift of the buildings using ETABS software.

LITERATURES REVIEW

Mahmoudreza Mivehchi, Farzin Ansari (2008) al [1] presented, A computer software application incorporates nonlinear geometry and materials within the finite element domain, facilitating the analysis and design of structures using essential node elements to accurately solve problems in both static and dynamic scenarios. It presents final results alongside all requisite construction documentation and drawings. Research engineers now leverage high-speed personal computers to delve deeper into natural effects impacting human life. Among the various approaches requiring advanced technology is the transformation of physical space into mathematical space, computational problem-solving, and the translation of results back into physical space, aiming to streamline and expedite logical outcomes with computing power.

According to the study's findings, the software is perceived by critical managers as an effective leader in challenging situations, safeguarding against time-wasting issues and emphasizing meticulous oversight of output quantity and quality control.

Junwon Seo et al (2015) [2] evaluated, The U.S. Geological Survey has categorized the structure, which is located in Seismic Zone 4, as having the highest seismic risk. Commercially available software was used to generate a 3D finite element model for the seismic performance assessment. Response spectrum analysis and nonlinear time-history analysis are two commonly used techniques that were utilized to compute the structure's inter-story drift ratios. In order to evaluate each floor's seismic susceptibility, seismic fragility curves were created utilizing the time-history analysis ratios and FEMA criteria. The FEMA and LATBSDC restrictions were compared to the computed ratios from both techniques. Because of this, as height increased, floor-level fragility generally reduced for all FEMA performance levels, and the ratios obtained using the two techniques largely satisfied the defined limits.

Prathamesh Dingorkar, Ayush Srivastava et al (2016) [3] Studied, structures deteriorated over time, reaching a point where traditional repairs became impractical due to the extended downtime required for reconstruction. Retrofitting emerged as the practical solution to tackle these challenges. This involved enhancing the structural integrity of buildings by applying advanced techniques such as RC (Reinforced Concrete) jacketing and FRP (Fiber-Reinforced Polymer) wrapping. In the context of this article, a comparative study was conducted to analyze and quantify the effectiveness of these retrofitting methods in increasing the structural strength of weakened elements. RC jacketing involves encasing existing structural members with additional layers of reinforced concrete, while FRP wrapping uses fiber-reinforced polymers to externally strengthen and protect structural components. The study evaluated how each method contributed to enhancing the strength of deteriorated structural elements and compared their respective outcomes. By assessing the rate of strength improvement achieved through RC jacketing and FRP wrapping, researchers aimed to determine which retrofitting technique was more suitable for different types of structural deficiencies. Overall, the findings of this study provided valuable insights for structural engineers, helping them to make informed decisions about selecting the most effective retrofitting method based on specific structural requirements and desired strength enhancements. This approach aimed to prolong the lifespan of buildings and ensure their safety and functionality over time, despite the challenges posed by structural degradation.

Abu Hasan et al (2017) [4] Explored, many tall buildings like offices, houses, and factories were built without thinking about earthquakes? Yup, they ended up leaning and cracking because of it. So, in this study, a ten-story factory building (G+10) was looked at using a fancy software called ETABS 2015 to see how strong it is against earthquakes. They checked out each part of the building in seismic zones 1 and 3. Originally made for zone 1, the building did okay in terms of safety from earthquakes but wasn't so great for zone 3. In countries like Bangladesh, one common way to make buildings stronger is by adding something called RC jacketing. It's cheaper than other methods to make a building tougher. This research dug into ways to strengthen columns using RC jacketing, especially the ones that might not be strong enough according to the analysis.

They did some tests before and after adding the RC jackets to the building to see how well it would hold up in an earthquake. The goal was to come up with a plan for strengthening buildings using ETABS and compare how they do in earthquakes before and after getting upgraded. The results showed that buildings made for zone 1 might not be safe in zone 3. But adding RC jackets made a big difference! The structure became stronger and didn't move around as much during an earthquake. It also could handle more shaking and moving without falling down. So cool, right.

Del Vecchio et al. (2018) [5] Explored, many tall buildings like offices, houses, and factories were built without thinking about earthquakes? Yup, they ended up leaning and cracking because of it. So, in this study, a ten-story factory building (G+10) was looked at using a fancy software called ETABS 2015 to see how strong it is against earthquakes. They checked out each part of the building in seismic zones 1 and 3. Originally made for zone 1, the building did okay in terms of safety from earthquakes but wasn't so great for zone 3. In countries like Bangladesh, one common way to make buildings stronger is by adding something called RC jacketing. It's cheaper than other methods to make a building

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Valeti Immanial, R. Sai Teja et al. (2018) [6] Seismic tremors posed significant risks to life, property, and structural integrity. Seismic retrofitting, crucial in modern engineering, often involved column jacketing as a primary method. Various materials like RCC, Steel, and FRP were commonly used for reinforcing columns. However, the choice among these materials was typically subjective, influenced by material availability and the skills of construction teams. Unfortunately, the interaction between these materials and the existing column materials was often overlooked during structural design. In seismic zones, particularly in Indian scenarios where 5 to 10-story RC buildings were prevalent, it was crucial to address modeling inaccuracies in retrofitting strategies such as column strengthening. To explore these aspects, an eleven-story reinforced concrete building originally located in zone 2 (which was upgraded to zone 3) was studied. The focus was on column retrofitting using three materials: RCC, Steel, and FRP, each evaluated through practical models. Analysis was conducted using the Response Spectrum method with ETABS software. Ultimately, the study found that FRP jacketing proved most effective in enhancing the strength and deformation capacity of retrofitted columns.

Fauzan et al. (2019) [7] Upon analysis based on auxiliary assessment utilizing the Indonesian the analysis of the standard code, SNI 03-1726-2012, it was determined that the building lacked sufficient strength to withstand the combined loads on the structure, notably seismic forces. Consequently, seismic improvements were deemed necessary. Two methods for retrofitting were put forth and examined in this research: concrete jacketing and shear walls. Concrete jacketing, as a method, entailed increasing the size of cross-sectional dimensions and introducing reinforcement bars to structural elements like pillars and columns that were deemed insufficient to withstand operational loads. The implementation of concrete jacketing necessitated the reinforcement of multiple structural elements. As an alternative retrofitting approach, a proposal was made to include concrete shear walls. These shear walls are custom-designed structural walls integrated into buildings to counter lateral forces generated within the wall plane due to seismic events. Ultimately, it was established that both retrofitting techniques proved effective in reducing internal forces and displacements within the building. Considering effectiveness and efficiency, it was recommended to employ shear walls as the preferred retrofitting strategy for fortifying the structure.

T. Mukhopadhyay et al. (2019) [8] The article presented a concise overview of structural condition monitoring and retrofitting/strengthening of buildings, featuring a practical case study on reinforcing an existing historical building. It emphasized the necessity of condition evaluation for existing structures to ensure their serviceability and safety, especially following short-term events like earthquakes or long-term degradation over time. This evaluation aimed to assess the structure's capacity to meet operational requirements under varying loading conditions or modifications to its structural framework due to new regulatory requirements. Additionally, it underscored the importance of condition assessment and strengthening for the seamless expansion of existing structures. After evaluating the structure's condition, the article explored options whether to retrofit (or strengthen) or demolish the structure based on the severity of its condition. Specifically, it detailed a basic condition assessment conducted on a historical masonry building.

SYSTEM DEVELOPMENT

The present study conducted by sequential analysis of a prominent Northern Mumbai building of G+40 RC frame structure height 121m from Ground level. only with shear wall. The aim of study is to find out the differences in the Displacement, Storey shear and Storey drift of the buildings using ETABS software for comparing the conventional analysis and RC.jaketing of high rise RC frame structure analysis in seismic zone III (Response spectrum analysis) Table 1[9-11].

Load Consideration

The loads which are considered for this analysis are Dead loads, Live loads from IS code 875:2015 & Earthquake loads from IS code 1893:2016

Dead load: IS code 875 part 1 (Code of practice for design loads- DEAD LOAD)

1. The dead load includes the self-weight of the beam, column and slab.
2. Floor finish = 1 kN/m² (page no. 29 IS code 875 part 1)
3. Terrace water proofing = 1 kN/m²
4. External wall loads on periphery = 7.22 kN/m²

Load calculation,

External Wall load = External wall thickness x unsupported length of wall x
 Unit weight of concrete hollow block

5. Internal wall load = 3.22 kN/m²

Live load: IS 875 part 2 (Code of practice for design loads- IMPOSED LOAD)

1. Live load on all floors = 3 kN/m²
2. Live load on top floor = 2 kN/m²

Earthquake Load: IS Code 1893:2016 (Criteria for Earthquake Resistant Design of Structure)

1. Seismic Zone = IV and V
2. Importance factor = 1.2
3. Response reduction factor, R = 5
4. Type of soil = medium soil

Table.1. Geometric parameters of model.

Sr.no	Type of structure	SMRF
1	No. of storeys	G+30
2	Overall height of building	105m
3	Floor dimensions	31m x 30m
4	Grade of Steel	Fe500
5	Grade of Concrete	M40, M30
6	<u>Column dimensions</u>	500mm x 650mm and 800mm x 800mm
7	<u>Beam dimensions</u>	300mm x 650mm and 300mm x 700mm
8	Slab thickness	150mm
9	<u>RC jacketing</u>	500mm x 650mm and 800mm x 800mm
10	Shear wall thickness	200mm
11	Extremal wall thickness	230mm
12	Internal wall thickness	150mm
13	Bottom storey height	4.5m
14	Typical storey height	3.5m
15	Support	Fix support

Plan and 3D View of Structure in Etabs Software

Response Spectrum Method

The term "spectrum" refers to a graphical representation summarizing the response of buildings across a wide range of time periods in a single graph. Linear elastic response spectrum analysis is applicable to various types of structures. Response spectra are curves that depict the peak response of a single-degree-of-freedom system in terms of displacement, velocity, and acceleration against its natural frequency, considering specified earthquake ground motion or a set of such motions [12-14].

Two types of models of G+30 multistorey building is prepared for analysis are as following.

- *Model 1:* G+30 RCC framed structure.
- *Model 2:* G+30 framed structure with RC Jacketing.

The plan view and 3D view of RCC framed structure is shown in Figures 1 and 2 respectively. Similarly, Figures 3 and 4 shows the plan view and 3D view of model 2. Figure 5 and 6 shows the plan view and 3D view of model 3, and Figure 7 and 3.8 shows the plan view and 3D view of model 4.

Results and Discussion

Story Displacement in X Direction in Zone V

Figure 4., it is found that maximum displacement in X direction in zone- IV for RCC framed structure i.e. in model 1 is 165.78 mm, and because of increase in stiffness in RC Jacketing framed structure maximum displacement is decreased. In model 2 the maximum storey displacement is 126.34 mm which is 23.79% reduction as compared to model 1[15-17].

4.3.2 Story Displacement in Y Direction in Zone V

Figure 5, it is found that maximum displacement in Y direction in Zone-V for RCC framed structure i.e. in model 1 is 163.69 mm, and because of increase in stiffness in RC Jacketing framed structure maximum displacement is decreased. In model 2 the maximum storey displacement is 122.91 mm which is 24.91 % reduction as compared to model 1[18-20].

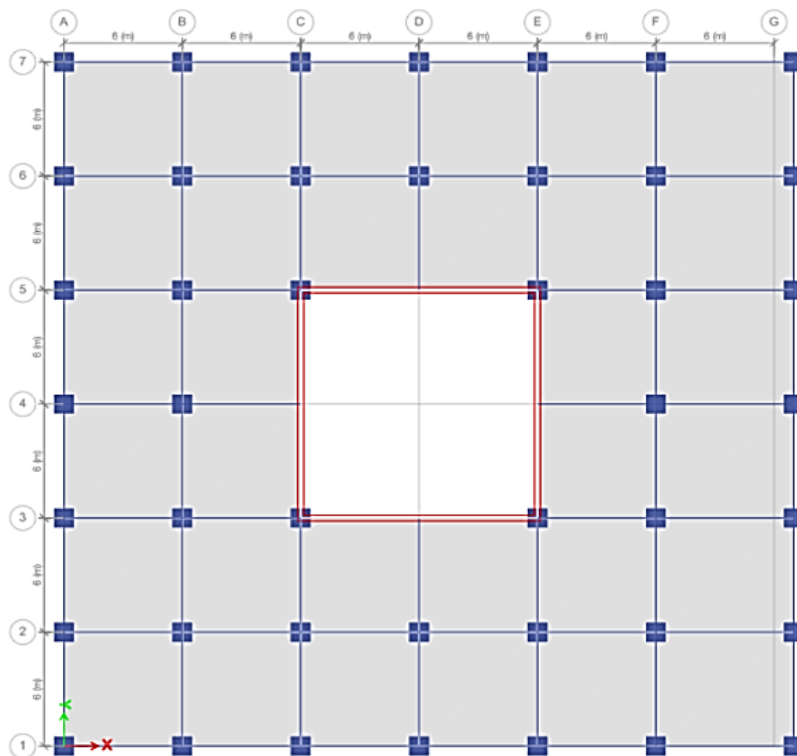


Figure 1. Floor plan of RCC framed structure

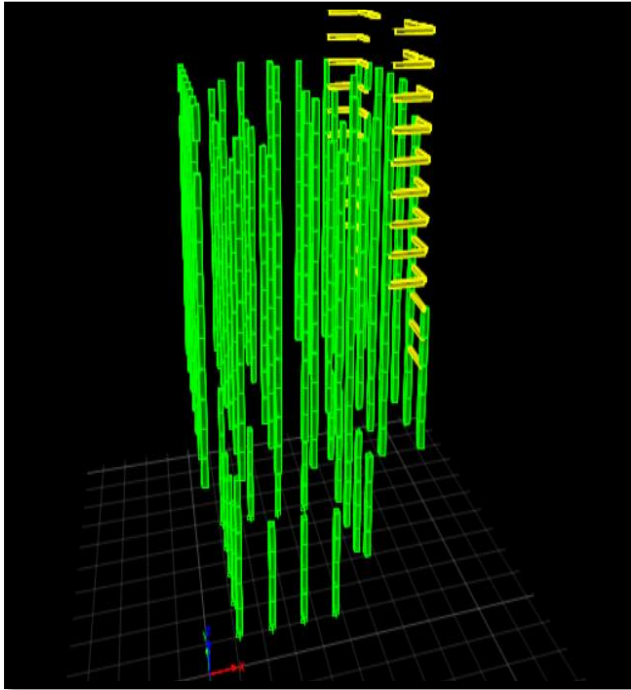


Figure 2. 3D view of RCC framed structure.

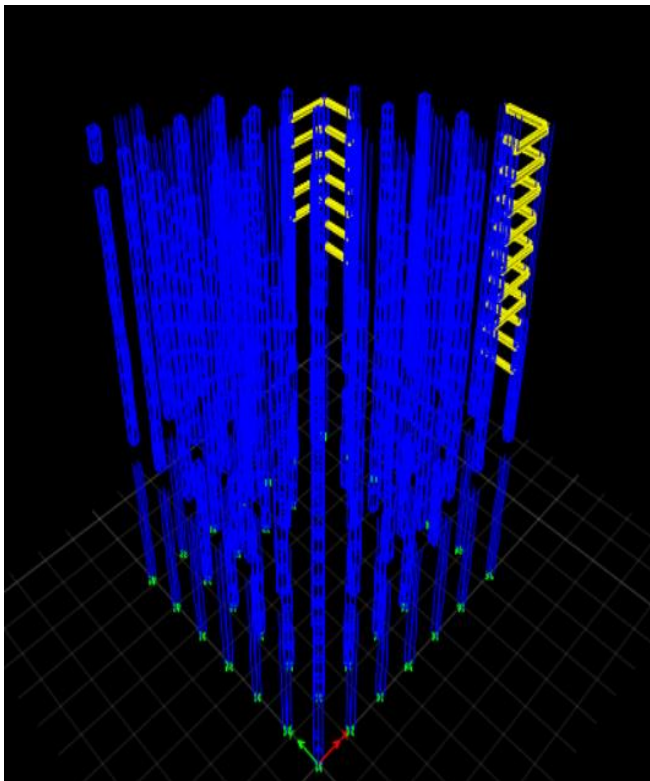


Figure 3a. 3D view of RC jackating zone V.

Story Displacement in X Direction in Zone IV

Figure 6, it is found that maximum displacement in X direction in zone-IV for RCC framed structure i.e. is model 1 is 108.63 mm. In model 2 the maximum storey displacement is 82.34 mm which is 25.20% reduction as compared to model 1 [20-22].

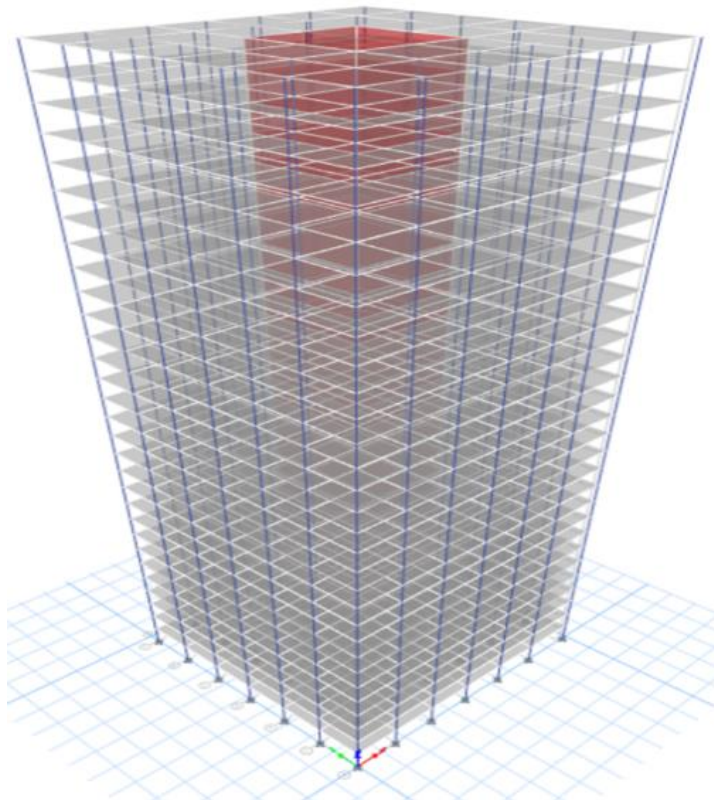


Figure 3b. 3D view of RC jacking zone IV.

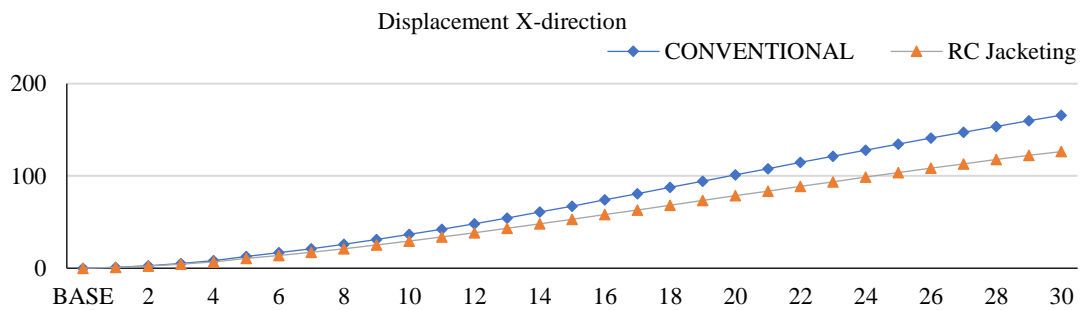


Figure 4. Storey displacement in X direction in zone IV.

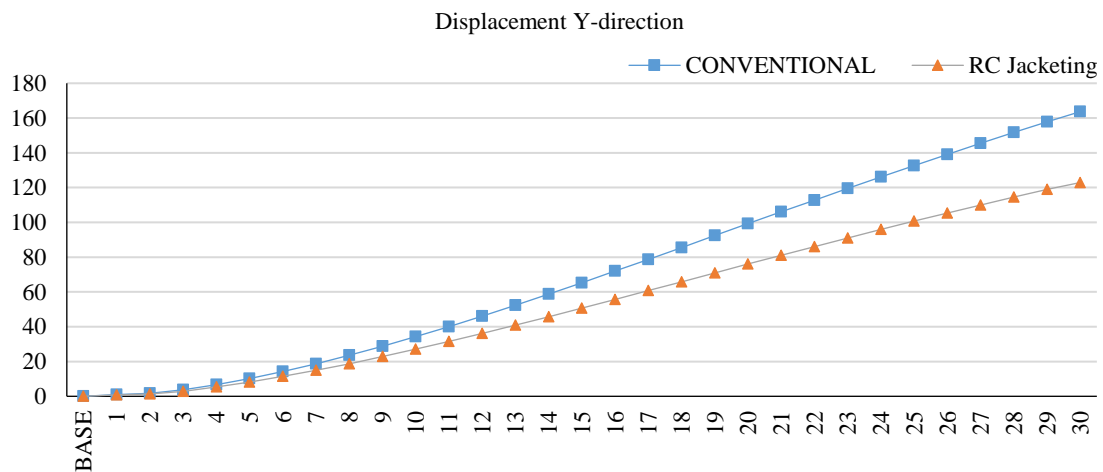


Figure 5. Storey displacement in Y direction in zone V.

Story Displacement in Y Direction in Zone IV

Figure 7, it is found that maximum displacement in Y direction in zone-IV for RCC framed structure i.e. is model 1 is 110.82 mm. In model 2 the maximum storey displacement is 83.63 mm which is 24.53% reduction as compared to model 1 [23-25].

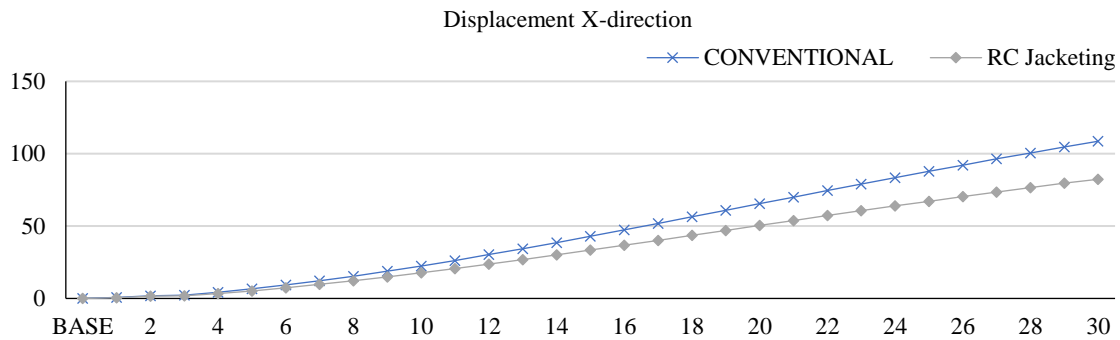


Figure 6. Storey stiffness in X direction.

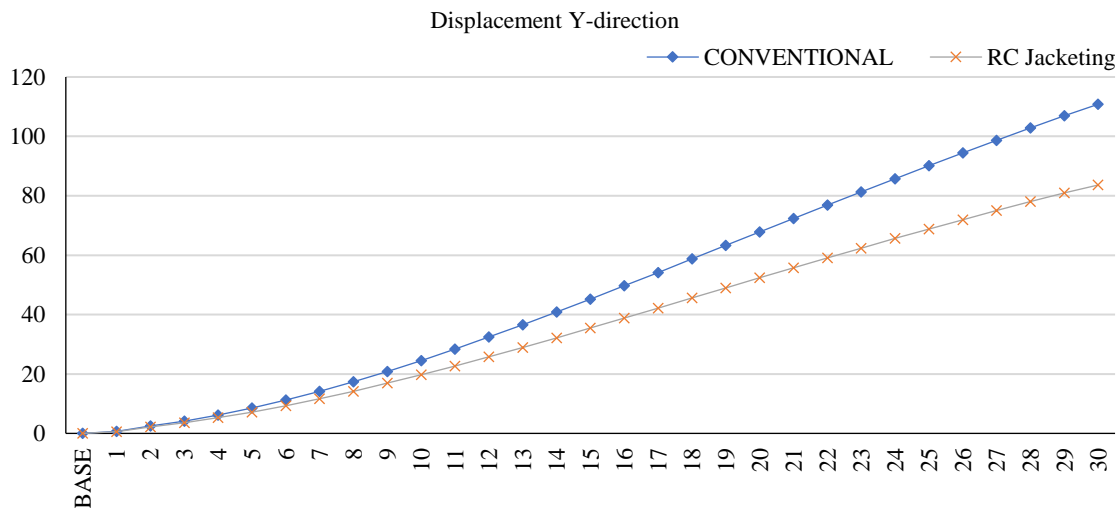


Figure 7. Storey displacement in Y direction in zone IV.

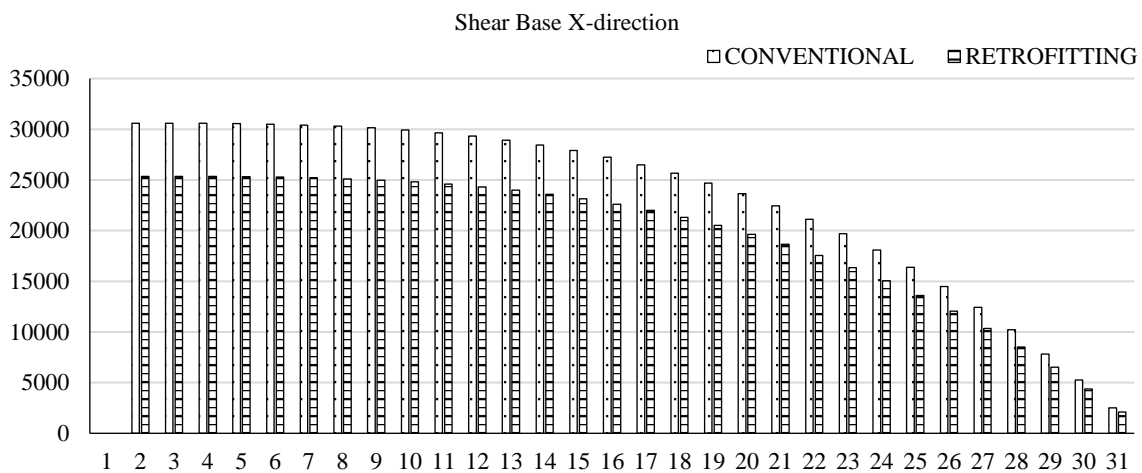


Figure 8. Storey shear in X direction in zone V.

Story Shear

Storey Shear in X Direction in Zone V

The comparison of storey shear in X direction in zone V between RCC and RC Jacketing framed structures reveals significant insights into their performance regarding maximum storey shear. Figure 8 shows maximum storey shear to be 30696.77 kN for the RCC framed structure i.e. model 1. The model 2 shows a reduction in storey shear by 16.46% which brings the value to 26354.089 kN [26].

Storey Shear in Y Direction in Zone V

The comparison of storey shear in X direction in zone V between RCC and RC Jacketing framed structures reveals significant insights into their performance regarding maximum storey shear. Figure 9 shows maximum storey shear to be 30596.77 kN for the RCC framed structure i.e. model 1. The model 2 shows a reduction in storey shear by 16.58% which brings the value to 25354.09 kN.

Storey Shear in X Direction in Zone IV

The comparison of storey shear in X direction in zone IV between RCC and RC Jacketing framed structures reveals significant insights into their performance regarding maximum storey shear. Figure 10 shows maximum storey shear to be 19902.37 kN for the RCC framed structure i.e. model 1. The model 2 shows a reduction in storey shear by 16.46% which brings the value to 17546.64 kN.

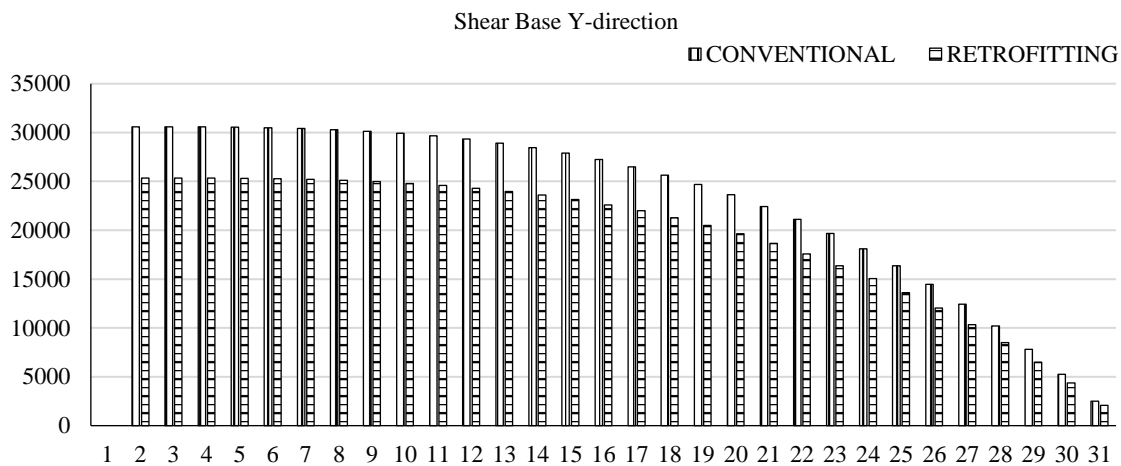


Figure 9. Storey shear in Y direction in zone V.

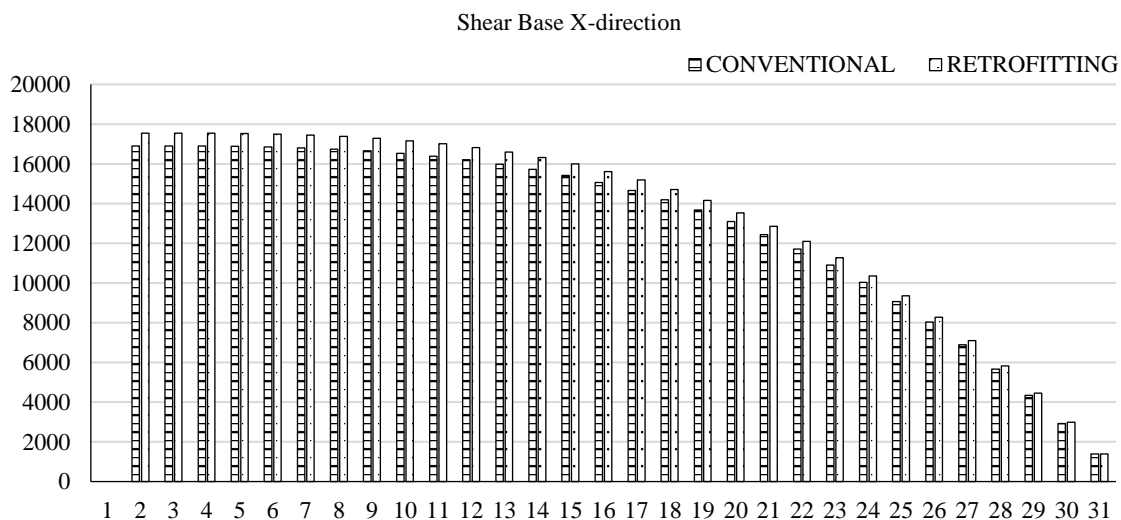


Figure 10. Storey shear in X direction in zone IV.

Storey Shear in Y Direction in Zone IV

The comparison of storey shear in X direction in zone IV between RCC and RC Jacketing framed structures reveals significant insights into their performance regarding maximum storey shear. Figure 11 shows maximum storey shear to be 16902.73 kN for the RCC framed structure i.e. model 1. The model 2 shows a reduction in storey shear by 16.58% which brings the value to 17546.6495 kN.

Storey Drift

Storey Drift in x Direction in Zone V

Figure 12, it is found that maximum storey drift in X direction in zone- V for RCC framed structure i.e. is model 1 is 0.001948. In model 2 the maximum storey drift is 0.001465 which is decreased by 31.26% as compared to model 1.

Storey Drift in Y Direction in Zone V

Figure 13 it is found that maximum storey drift in Y direction in zone-V for RCC framed structure i.e. is model 1 is 0.001953. In model 2 the maximum storey drift is 0.001465 which is decreased by 27.12% as compared to model 1.

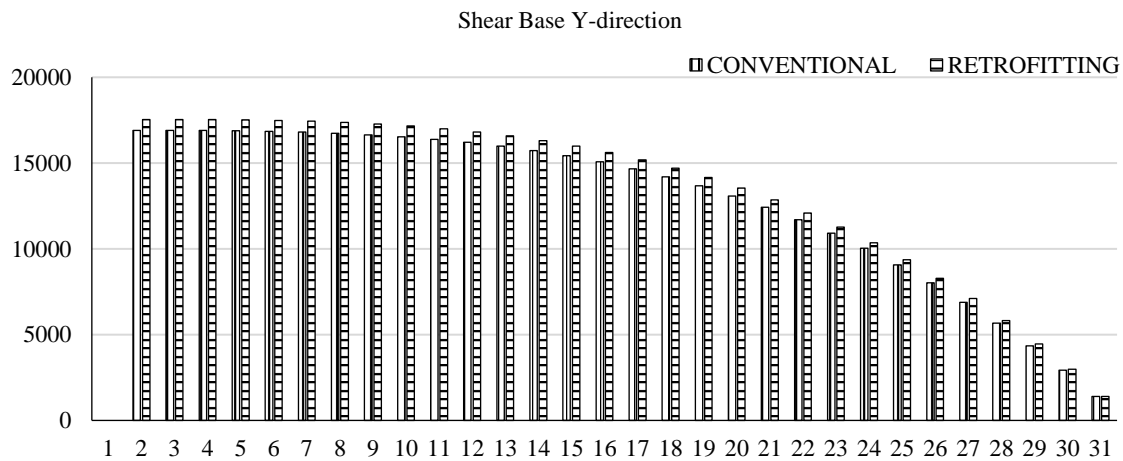


Figure 11. Storey shear in Y direction in zone IV.

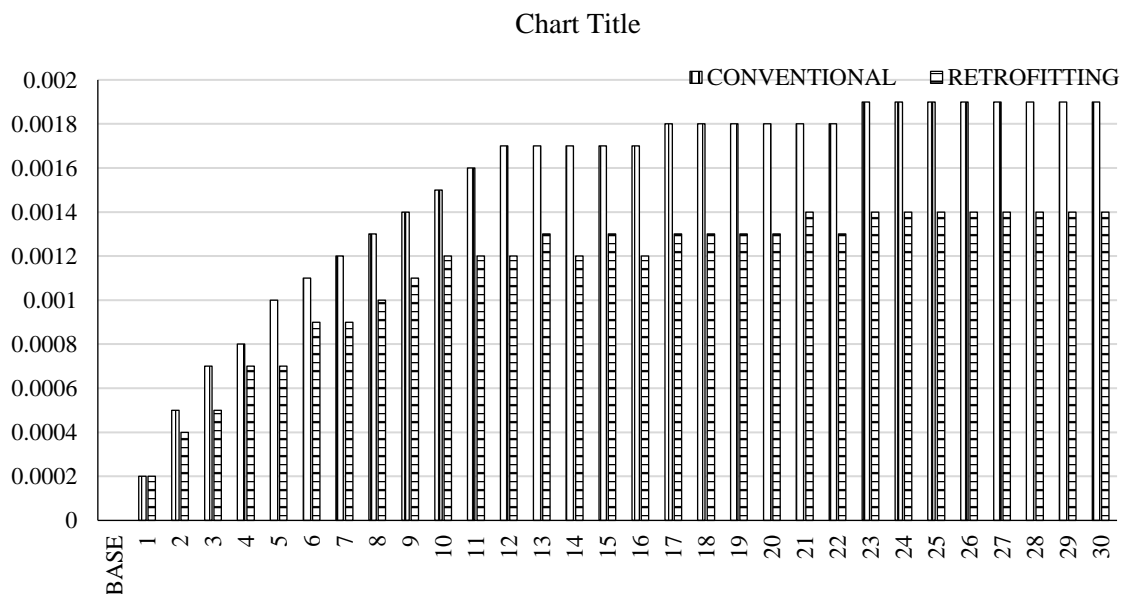


Figure 12. Storey drift in X direction in zone V.

Storey Drift in X Direction in Zone IV

Figure 14, it is found that maximum storey drift in X direction in zone-IV for RCC framed structure i.e. is model 1 is 0.0086 In model 2 the maximum storey drift is 0.000533 which is decreased by 31.26% as compared to model 1.

Storey Drift in Y Direction in Zone IV

Figure 15 it is found that maximum storey drift in Y direction in zone-IV for RCC framed structure i.e. is model 1 is 0.00086. In model 2 the maximum storey drift is 0.000539 which is decreased by 27.12% as compared to model 1.

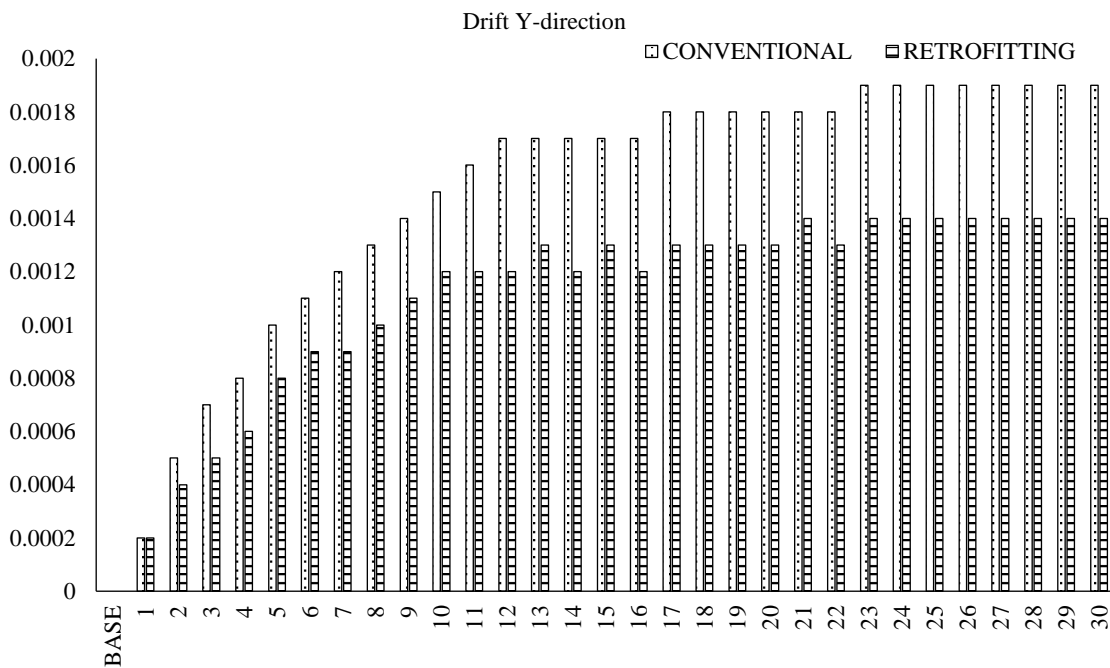


Figure 13. Storey drift in Y direction in zone V.

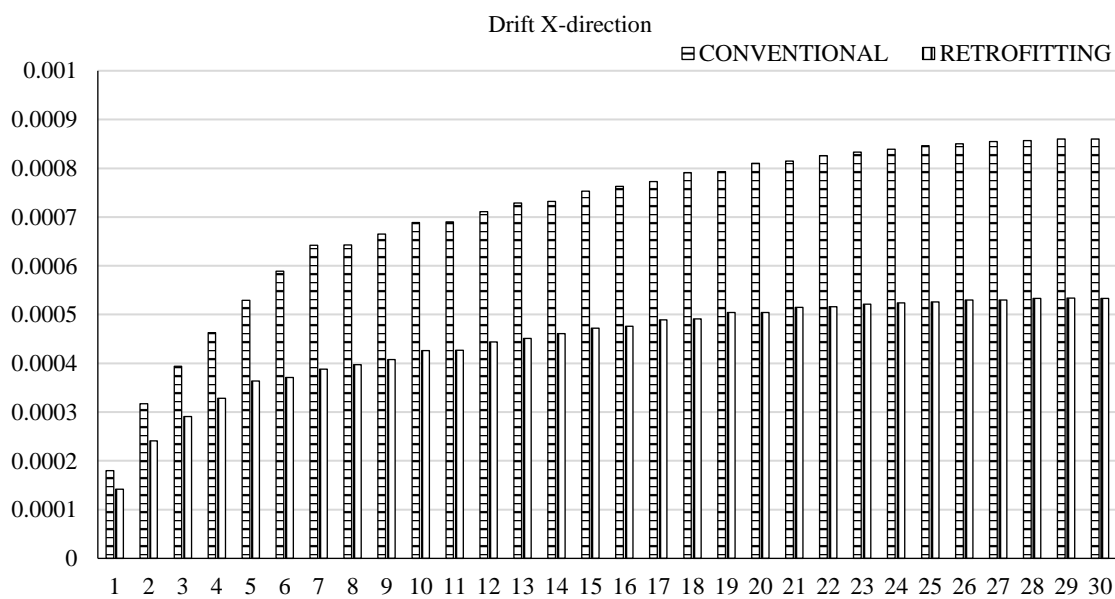


Figure 14. Storey drift in X direction in zone IV.

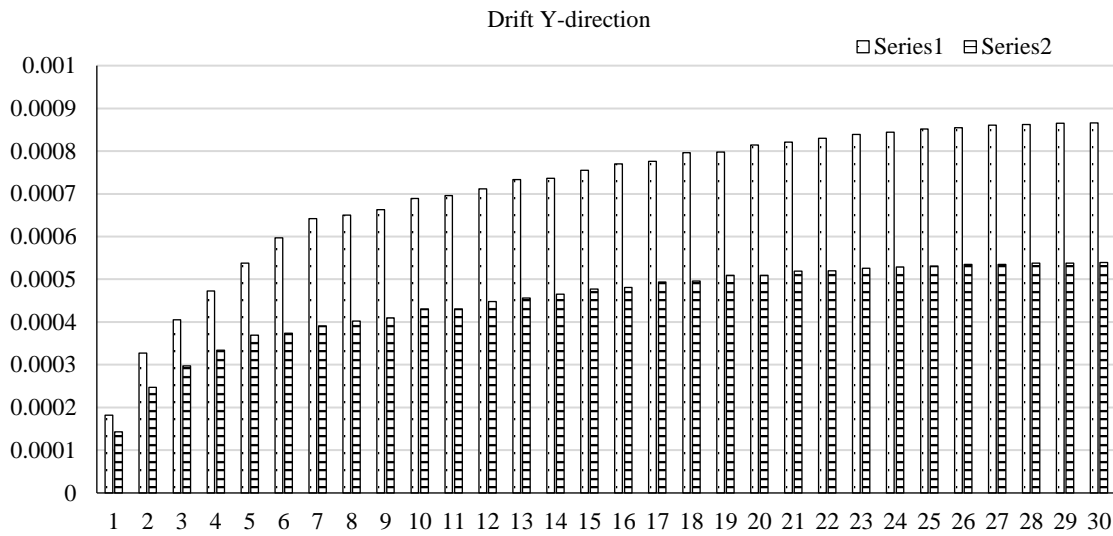


Figure 15. Storey drift in Y direction in zone IV.

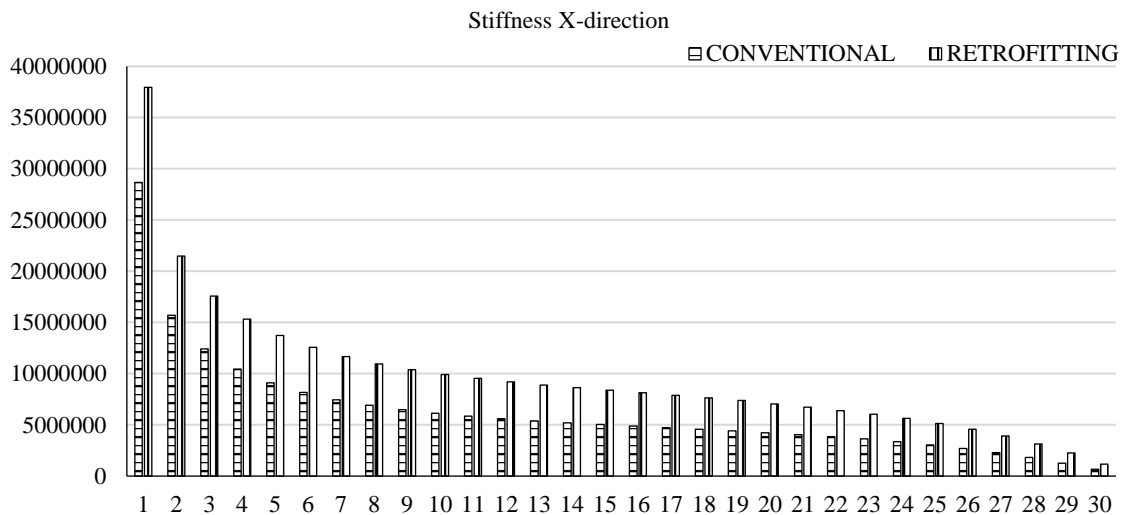


Figure 16. Storey Stiffness in X direction in zone V.

Storey Stiffness

Storey Stiffness in X direction

Among the four models analysed for story stiffness in the X-direction, Model 1 serves as the baseline for comparison. In this analysis, Model 2 demonstrates the 14.06% increment in stiffness compared to Model 1. Rcc frame 28680553mm and RC Jacketing value is 37952222mm Figure 16.

Storey Stiffness in Y Direction

Among the four models analysed for story stiffness in the Y-direction, Model 1 serves as the baseline for comparison. In this analysis, Model 2 demonstrates the 14.06% increment in stiffness compared to Model 1. Rcc frame 29057515mm and RC Jacketing value is 38393381mm Figure 17.

Storey Stiffness in X Direction

Among the four models analysed for story stiffness in the X-direction, Model 1 serves as the baseline for comparison. In this analysis, Model 2 demonstrates the 14.06% increment in stiffness compared to Model 1. Rcc frame 30680552.67mm and RC Jacketing value is 399555379.57mm Figure 18.

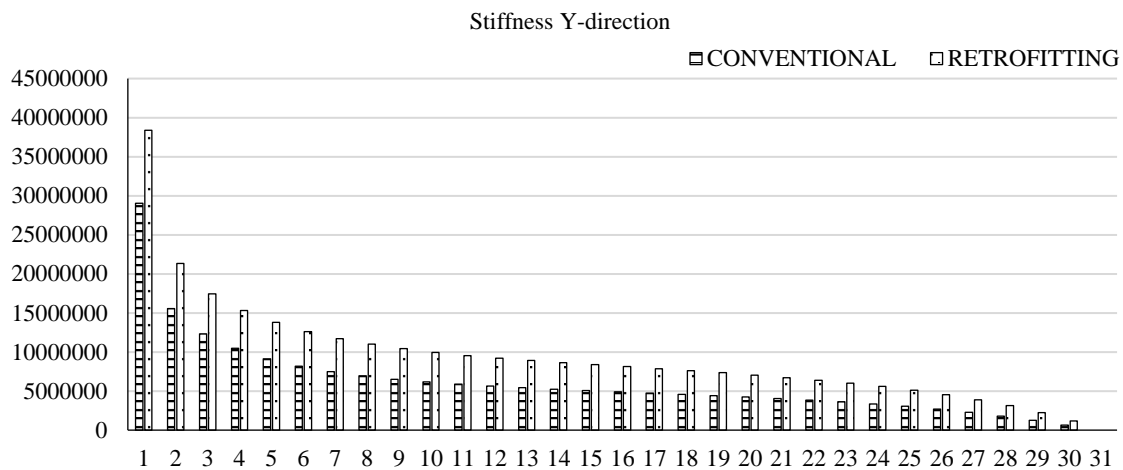


Figure 17. Storey stiffness in Y direction.

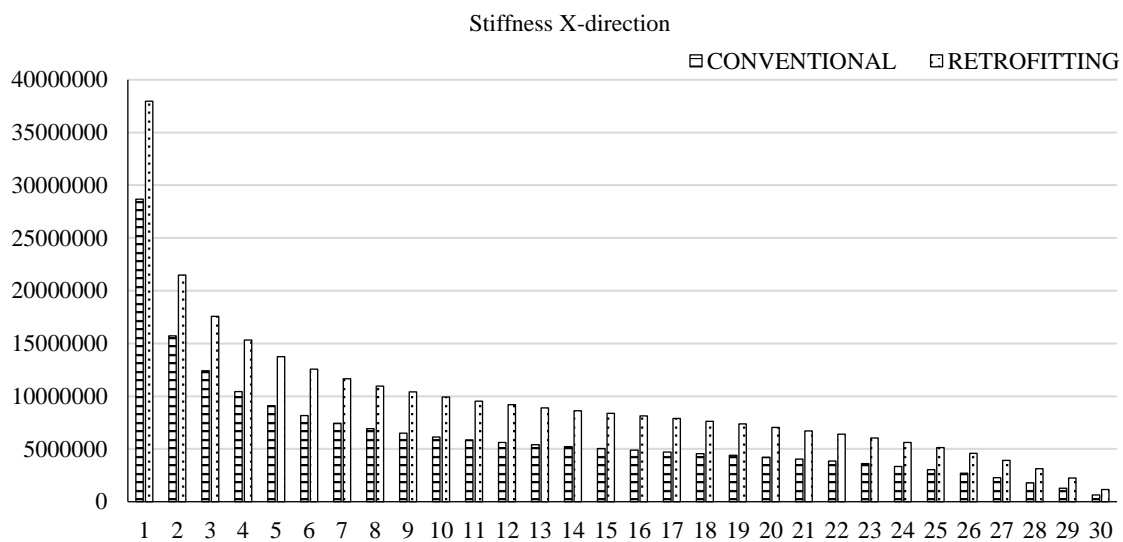


Figure 18. Storey Stiffness in X direction in zone IV.

Storey Stiffness in Y Direction

Among the four models analysed for story stiffness in the Y-direction, Model 1 serves as the baseline for comparison. In this analysis, Model 2 demonstrates the 14.06% increment in stiffness compared to Model 1. Rcc frame 30057514.92mm and RC Jacketing value is 40393143mm Figure 19.

Overtuning Moment

Overtuning Moment in X Direction in Zone IV

Figure 20, it is found that maximum overturning moment in X direction in zone V for RCC framed structure i.e. model 1 is 999341.502 kN-m. In model 2 the maximum overturning moment is 974801.923 kN-m which is decreased by 10.58% as compared to model 1 Figure 20.

Overtuning Moment in X Direction in Zone V

Figure 21, it is found that maximum overturning moment in X direction in zone V for RCC framed structure i.e. model 1 is 999341.502 kN-m. In model 2 the maximum overturning moment is 974801.923 kN-m which is decreased by 10.58% as compared to model 1.

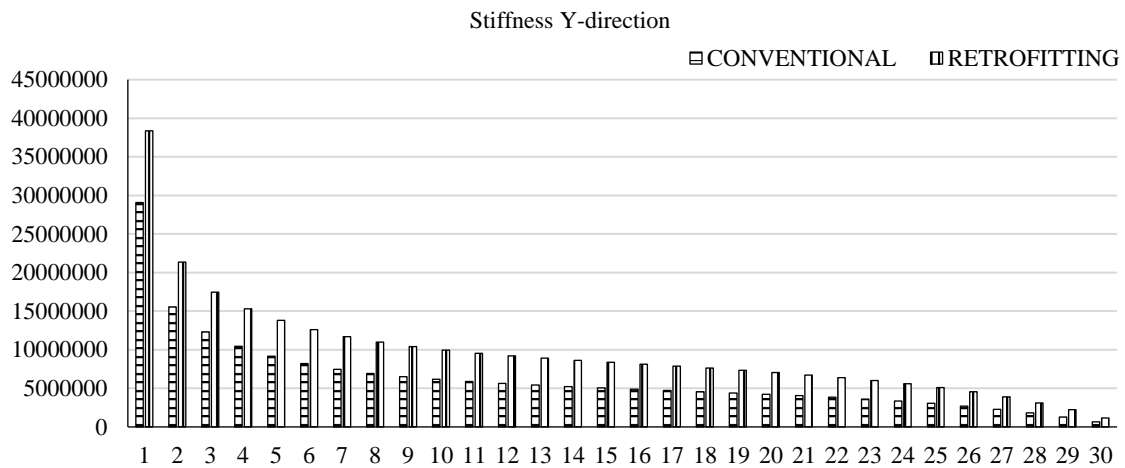


Figure 19. Storey stiffness in Y direction.

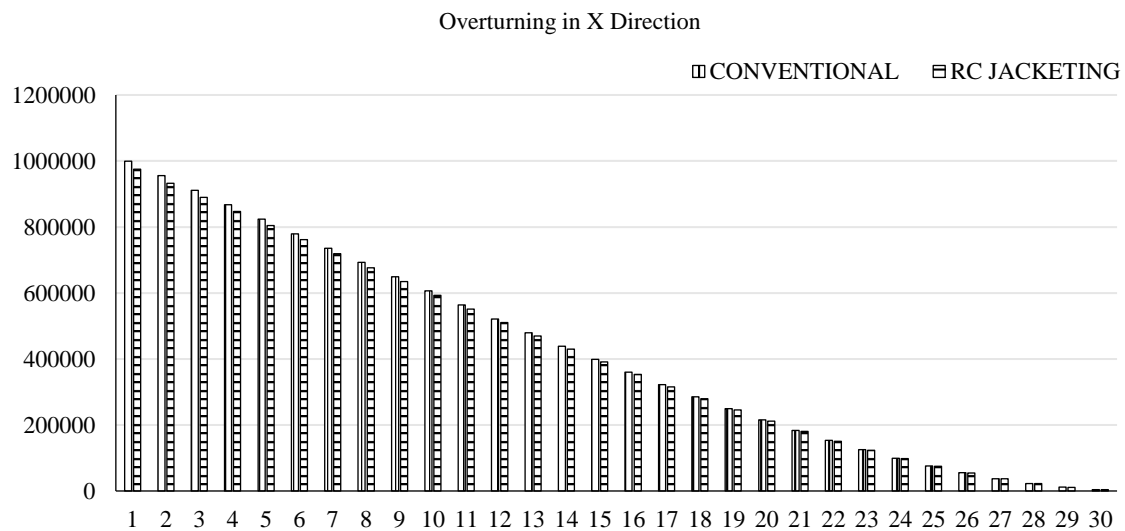


Figure 20. Overturning moment in X direction.

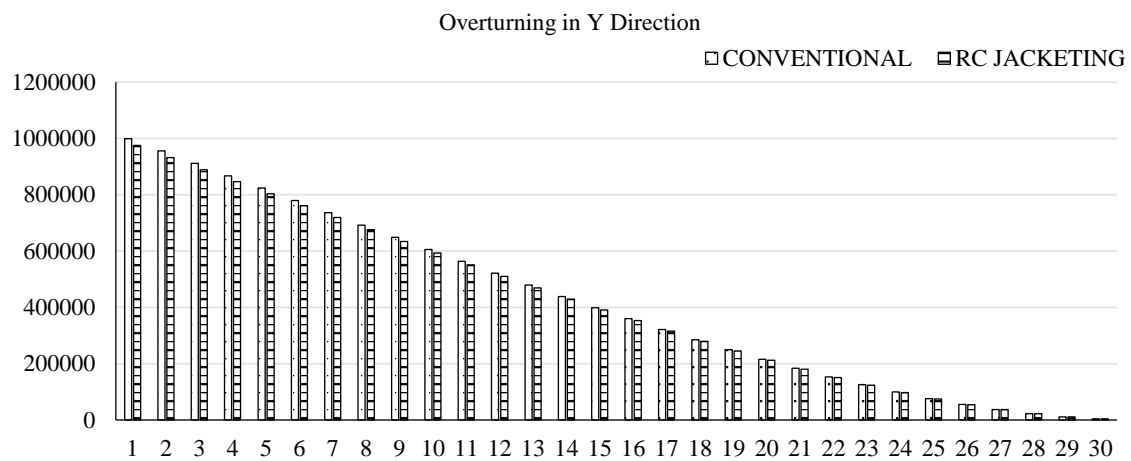


Figure 21. Overturning moment in Y direction.

Overturning Moment in Y Direction in Zone IV

Figure 22-23, it is found that maximum overturning moment in Y direction in zone IV for RCC framed structure i.e. model 1 is 678885.668 kN-m. In model 2 the maximum overturning moment is 662824.9488 kN-m which is decreased by 2.36% as compared to model 1.

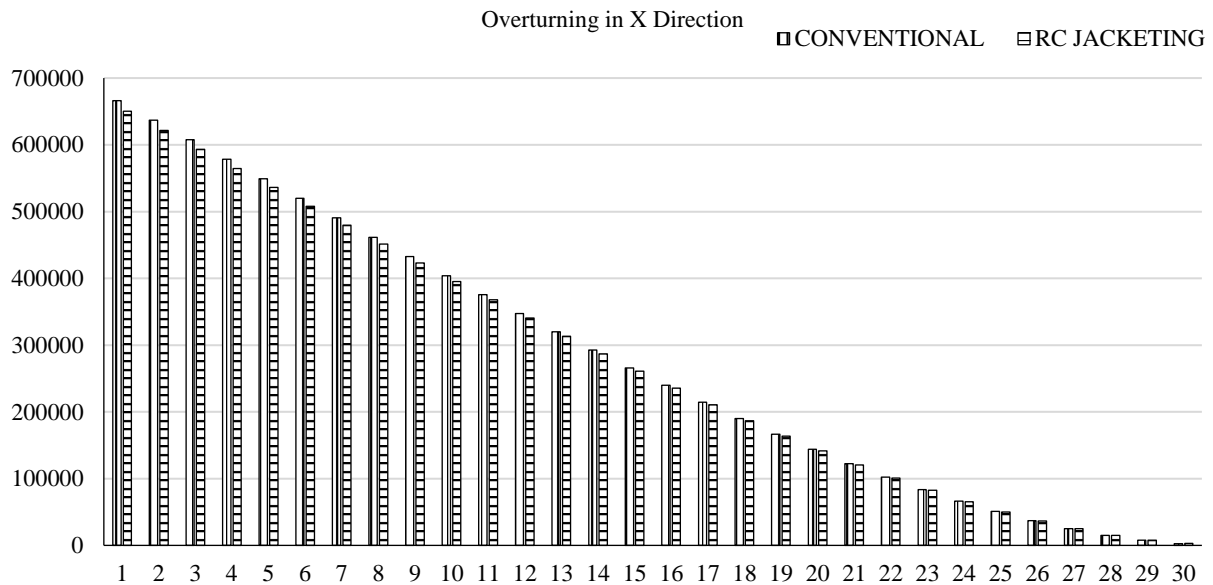


Figure 22. Overturning moment in X direction.

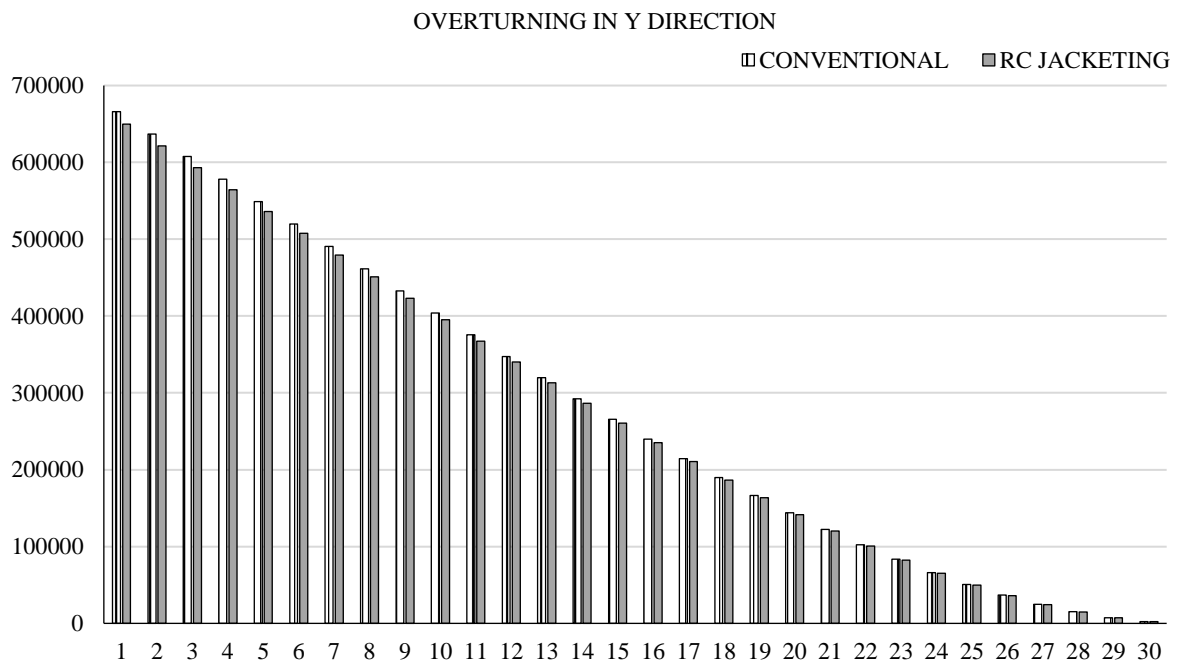


Figure 23. Overturning moment in Y direction.

CONCLUSIONS

The recent literary work done with regard to RC Jacketing are reviewed and the following observations are drawn. In the present work, G+30 height rise building is modeled using ETABS software as per IS 1893-2016 and IS 16700-2017. Two models are considered. Model 1 is ordinary

RCC framed structure as baseline for comparison. In model 2 RC Jacketing. The result of various parameters like, storey displacement, storey shear, storey drift, storey stiffness, overturning movement are compared.

Following conclusions are obtained:

1. From above research papers it can be said that, the retrofitting is an advance technique for improvement of RC structures i.e. to strengthen the existing structure or repair the structure which has been deteriorated or damaged by seismic load.
2. It was observed that RC Jacketing led to a significant reduction in displacement compared to the ordinary RCC framed structure. Specifically, the results indicated a reduction in displacement ranging from 25% to 30%.
3. From the above research, it was observed that RC Jacketing resulted in a reduction in base shear by 16% to 20% compared to the ordinary RCC framed structure. Additionally, RC Jacketing led to an increase in stiffness by 25% to 30% relative to the baseline RCC framed structure.
4. The RC Jacketing significantly enhances the overall stiffness of the structure compared to the ordinary RCC framed structure. This increase in stiffness is crucial for improving the seismic performance of the building.
5. Model 2 (RC Jacketing) exhibits reduced storey displacements compared to Model 1 (ordinary RCC framed structure). This reduction indicates that the jacketing effectively controls displacements under seismic loads, thereby enhancing the structural stability.

RC jacketing is not effective in addressing overturning issues, as it does not adequately mitigate overturning forces.

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