Study of Seismic performance of Conventional and Retrofitted RC building using Response Spectrum Analysis

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Abstract **Earthquakes create tremendous devastation in terms of lifestyles, cash, and failure of structures. Consequently, increasing the Seismic resistance of systems is of extreme importance, specifically inside the case of old structures, and tall or high-priced systems. While a building has been designed according to a Seismic code, however the code has been upgraded in the later years, it effects deficiencies to exist in layout or creation of the structure. The additional Seismic resistance required for the structure is decided and Retrofitting techniques are proposed to obtain the desired Seismic strength. In this paper, conventional RC building of G+25 floors with and without Retrofitting is analyzed in ETABS software by Dynamic Response Spectrum method. In this study, parameters such as Storey Shear, Storey Stiffness, Displacement, Time-period were tested. The results of this study help improve our understanding of the seismic performance of Reinforced Concrete structures and provide insight into the development of strengthening strategies to improve the structure's ability to withstand seismic hazards.**

Keywords — Base shear, Bracing, Displacement, Earthquake, ETABS, Jacketing, Retrofitting, Storey Drift, Storey Stiffness,

I. INTRODUCTION

Earthquakes are one of the mainly unpredictable natural hazards. Earthquakes caused multiple hazards like loss of property and population loss. Several procedures are developed to prevent and mitigate losses in the event of earthquake. One of the famous and effective techniques is retrofitting existing buildings. Retrofitting to structure can effectively improve the performance of a building. Retrofitting an existing building is often considered to be more cost-effective than constructing a new building. It represents an opportunity to upgrade the overall performance, sustainability, and efficiency of an existing building. Seismic retrofitting is mainly done to provide existing structures with more resistance to seismic activity due to earthquakes. Retrofit of these structures before the earthquake provides a feasible cost-effective approach to reduce the hazard to occupants' safety and owners' investment. Recently occurred earthquakes show the vulnerability issues faced by the existing buildings due to the changes in the ground motions lately or which may have been constructed based on earlier codes. To protect from the risk triggered by seismic disaster to the life and property, the performance of the structures must be improved, and thus seismic retrofitting plays its role. Retrofitting also proves to be a better option catering to the economic considerations and immediate shelter problems rather than replacement of seismic deficient buildings. There is a significant reduction in the seismic vulnerability of the building after retrofitting of building.

II. LITERATURE SURVEY

Andre Almeida, Ricardo Ferreira [1]

The research on modern technology for seismic damage mitigation, such as base isolation and other passive control systems has been a major issue around the world, notably in Japan. After the 1995 Hyogo-Ken Nanbu earthquake, which led to numerous building collapses and costly structural repairs in the city of Kobe, modern seismic protection systems quickly grew to replace conventional structural solutions. The pursuit of innovative seismic protection solutions and their acceptance has also increased in other high seismicity countries and regions such as the USA and Italy. The awareness of the consequences of major seismic events around the world has resulted in a growing concern about the structural safety of both new and old structures. Given the impossibility of analyzing and intervening on all the structures simultaneously, it is essential to establish priorities for large-scale seismic assessment and retrofitting.

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G Navya, Pankaj Agrawal [2]

Earthquakes that occurred in the past show the vulnerability issues faced by the existing buildings due to the changes in the ground motions lately or which may have been constructed based on earlier codes. To protect from the risk triggered by seismic disaster to the life and property, the performance of the structures must be improved, and thus seismic retrofitting plays its role. Retrofitting also proves to be a better option catering to the economic considerations and immediate shelter problems rather than replacement of seismic deficient buildings. Two alternative approaches are conceptually adopted and implemented in practice for seismic retrofitting: the first approach focuses on upgrading the structure to resist earthquake induced forces (i.e. modifying the capacity) and is called conventional method of retrofitting. The second approach focuses on reduction of earthquake induced forces (i.e. modifying the demand) or unconventional approach. Seismic retrofitting is the modification of existing structures to improve the system behavior or its components repair/strengthening up to the performance it is expected. Detailed seismic evaluation and assessing the vulnerability of the structure are the key ingredients to arrive at an appropriate retrofitting scheme.

This study asserts a complete process of retrofitting on a building designed with two different philosophies i.e., as per IS 456: 2000 and IS 1893 (Part 1): 2002 and retrofitted with steel bracing. The fragility analysis was also carried out to indicate the probability of damage under different states which reduces considerably after retrofitting of building. This present study focuses on complete procedure of seismic vulnerability assessment and retrofitting of G+6 RC frame building designed by two design philosophies i.e. IS 456:2000 and the other with IS 1893:2002 (Part 1): 2002 along with a ductile detailing as per IS 13920:1993. Conventional retrofitting technique i.e. steel bracings is used to improve the elastic and post-yield behavior of the building for resisting the future seismic demand. The re-evaluation is carried out and verified that the seismic retrofitting is a viable method for up gradation of the structural capacity to a seismic deficient building.

Results show that there is a significant reduction in the seismic vulnerability of the building after retrofitting of building with steel bracing. The fragility analysis indicates that the probability of damage under collapse and extensive state of damage reduces considerably after retrofitting of building.

Jinkoo Kim [3]

In 2016 an earthquake with magnitude of 5.8 occurred near Gyeongju, southern city of Korea, and one year later another earthquake with magnitude of 5.4 occurred in Pohang. They were the largest earthquakes ever recorded in the Korean peninsula. Even though the magnitude of the Pohang earthquake was smaller than that of the Gyeongju earthquake, the structural damage caused by the Pohang earthquake was significantly larger due mainly to the fact that it occurred in a more densely populated area. More than one thousand building damages were reported after the Pohang earthquake. Many low-rise residential buildings with soft-first story were especially severely damaged during the Pohang earthquake. The story was taken in the aftermath of the Pohang earthquake, shear failure of columns and shear walls at the first story was the most common structural failure mechanism of buildings. Energy dissipation devices have been applied in buildings for mitigation of vibration induced by both wind and earthquakes (Omika et al. 2016). In Korea the seismic design code was enforced in 1989, and there remain a lot of buildings not designed for seismic load. After the two earthquakes, there have been huge demands for seismic retrofit of existing buildings.

This paper presents passive seismic retrofit devices recently developed by the author for seismic retrofit of building structures. The seismic performance of each device was verified by appropriate loading test and structural analysis. In this paper passive seismic retrofit devices for building structures developed by the author in recent years are introduced. The proposed damping devices were developed by slightly modifying the configuration of conventional devices and enhancing their effectiveness. First a seismic retrofit system consisting of a pin-jointed steel frame and rotational friction dampers installed at each corner of the steel frame was developed. Then two types of steel slit dampers were developed; box-type slit damper and multi-slit damper. In addition, hybrid dampers were developed by combining a slit damper and a friction damper connected in parallel. Finally, a self-centering system was developed by using preloaded tendons and viscous dampers connected in series. For each retrofit system developed, an appropriate analytical model was developed, and the seismic performance was verified by loading test and earthquake analysis of case study structures. Experimental and analysis results show that the proposed systems can be used efficiently to enhance the seismic performance of building structures.

III. METHODOLOGY

Seismic analysis is required in earthquake engineering to get the response of the structures due to seismic loading. Response of the structures is mainly Axial loads, Shear Force, Bending Moments etc. Various analysis methods have been developed for the seismic analysis of structures.

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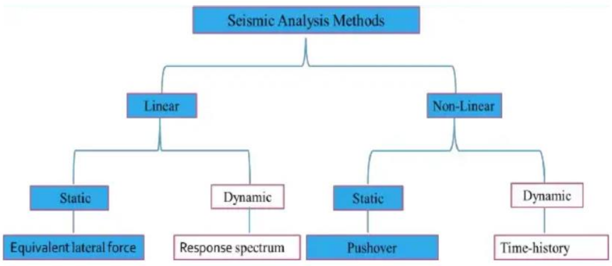

Figure 1. Methods

Methods of Dynamic Analysis

The methods of dynamic analysis are the Time History Method and Response Spectrum Method.

Time History Method: In Time-history analysis, step-by-step analysis of dynamical response of a building to a specified loading is done that may change with time. Time history analysis is used to determine the dynamic response of a structure to uninformed loading. For important structures, Time History Analysis should be performed for high rise buildings, irregular buildings as it more accurately predicts the structural response in comparison with the other two methods.

Response Spectrum Method: The word spectrum means the response of buildings having a broad range of time periods, is summarized in a single graph. Response spectrum analysis is effective for all types of structures. Response spectrum are curves plotted between peak response in terms of acceleration, velocity, and displacement and against its natural frequency due to set of earthquake ground motions or specified earthquake ground motion.

Analysis Software – ETABS Computers and Structures Inc. product "ETABS" (Extended 3D analysis of Building Systems), is structural engineering software which is used in the construction industry. It is developed to analyse and design multi-story buildings and it is highly efficient. It is packed with a system consisting of templates and modeling tools, analysis methods, solution techniques and code-based load prescriptions. This is loaded with CAD-like drawing tools with grid representation and interface. In ETABS we can perform design and analysis of high-rise irregular buildings. Number of data views, model windows, model manipulation can be done using ETABS. This software has several benefits in the construction industry, modeling and designing. It can also be used for the analysis of bracings, moment frames and RC shear walls.

Retrofitting: Seismic retrofitting is the modification of existing structures to improve the system behavior or its components repair/strengthening up to the performance it is expected. It is not financially feasible to replace all deficient structures, and hence retrofitting of existing deficient structures is a necessary option. The ability of structures to achieve adequate deformation capacity plays a significant role in the prevention of structural failures in seismic events. Ductile structures dissipate more energy. The deformation capacity of existing structures can be enhanced by modifying certain substructure elements and connections. Columns are typically retrofitted to increase the overall ductility of the structure. Several retrofitting techniques such as Bracings, reinforced concrete jacketing and steel jacketing have been developed to rehabilitate structurally deficient columns.

Types of Retrofitting: Retrofitting can be classified depending upon the area of application as local retrofitting and global retrofitting. When retrofitting is applied to members like column, Beam, footing etc. it is called local retrofitting. And when it is applied to whole building is called Global Retrofitting.

Jacketing with Fiber Reinforced Polymer: Fiber reinforced polymers (FRP) have attracted the attention of researchers as an alternative material for retrofitting reinforced concrete elements. Compared to steel and concrete jacketing, FRP wrapping has several advantages, including extremely low weight-to-strength ratios, high elastic moduli, resistance to corrosion, and ease of application. In addition, unidirectional FRP wrapping can improve column ductility without considerable stiffness amplification.

Bracing: Bracing significantly contributed to the structural stiffness and reduced the maximum inter storey drift of the frames. In designing of earthquake resistant structures Bracing systems are frequently used. The bracings are the RC or steel members which are connected to the corners of the floor frame for every storey of the structure. Bracings such as cross (X) bracings, V bracings, inverted V, K bracings are considered as one of the best economic methods to minimize the lateral forces. They are easy to install in the structure.

Followings are the types of the Bracings.

a) Forward Bracings
b) Backward Bracings
c) V Type Bracings
d) Inverted V Bracings
e) K Type Bracings
f) X Bracings

Models considered for the study.

For current study, G + 25 storey RC Building is considered. The building is symmetrical in plan and elevation. Plan of building is as shown in figure.

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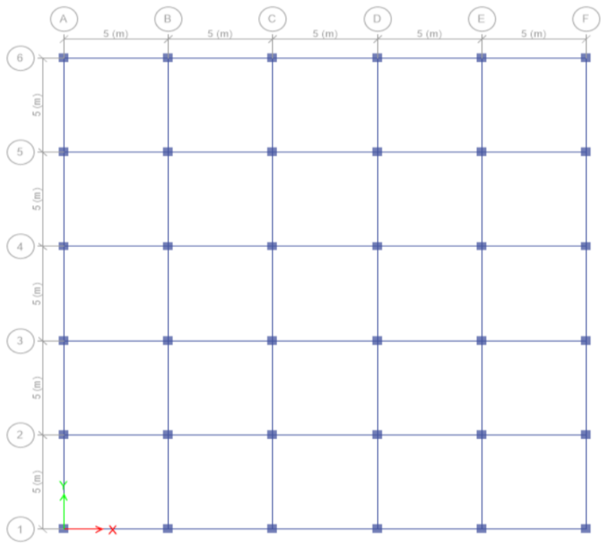

Figure 2. Study Model

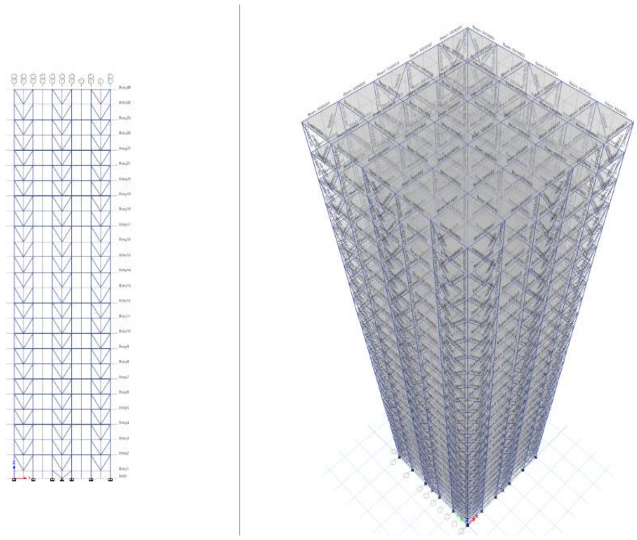

Figure 4. Retrofitted building

Model analysed.

In the present study 2 models are considered, which are described below -

1. Conventional building (i.e. without retrofitting technique)
2. Retrofitting applied to the above building.

Figure shows conventional building and building with steel bracings.

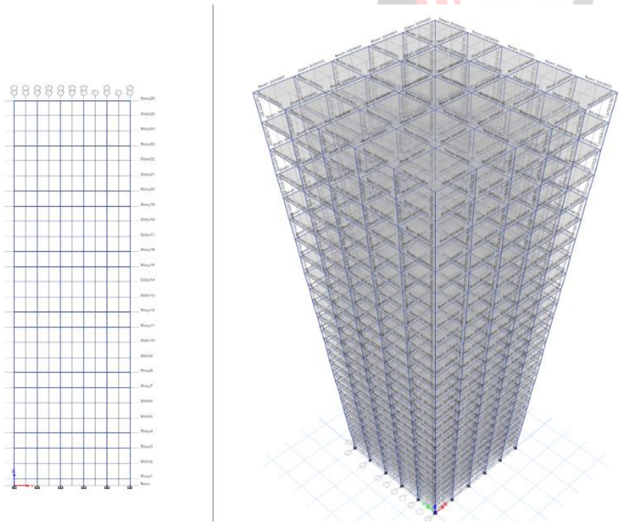

Figure 3. Conventional building

Table 1. Seismic design data, section, and material properties

Zone factor	0.36 (Zone - V)
Importance factor	1.5
Response reduction factor	5
Soil Type	Soft Soil
Damping Ratio	5%
Column size	500 x 500 mm
Beam size	00 x 600 mm
Bracing	ISMB 600
Slab	150 mm
Grade of concrete	M-25
Grade of steel	Fe 500
Unit weight of concrete	25 kN/m3
Number of storey	G + 25 (26 storey)
Area of each floor	625 Sqm. (25 x 25 m.)

Dynamic analysis

Dynamic analysis of structure is done using ETAB software by Response Spectrum method. Multiple modes of the structure are considered in the Response Spectrum method. Response is recorded for each mode. The acquired data is then compiled to get an overall response of the structure. Different modal combination techniques such as absolute sum method, complete quadratic combination (CQC) and square root sum of squares (SRSS) are used. For three types of soil specified by IS - 1893 (part I) figure 13 shows response spectra.

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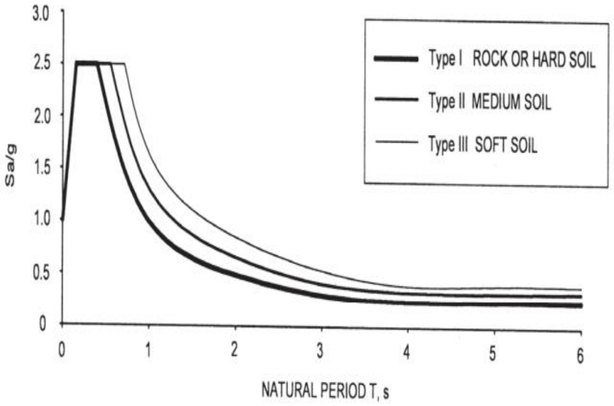

Figure 5. Response Spectra

IV. RESULT AND DISCUSSION

1. Storey shear (base shear): The Storey shear is a function of mass and stiffness of the structure. And hence the base shear is more for Retrofitted structure as stiffness of retrofitted structure is more than conventional structure.
Base shear is the extreme predictable lateral/ horizontal force that may occur due to earthquake ground motions at the base of the building.
Calculation of this base shear (V) is depending on following:

• Condition of soil at the construction site.
• presence of any seismic activity like geological faults
• Seismic ground motion probability.
• Ductility level of structure, configurations of structure and the weight of the structure.
• The natural time-period of structure when it is subjected to seismic loading.

Fig.6 compares the base shear of conventional and retrofitted structures. Retrofitted structures have higher base shear because they are stiffer than traditional structures.

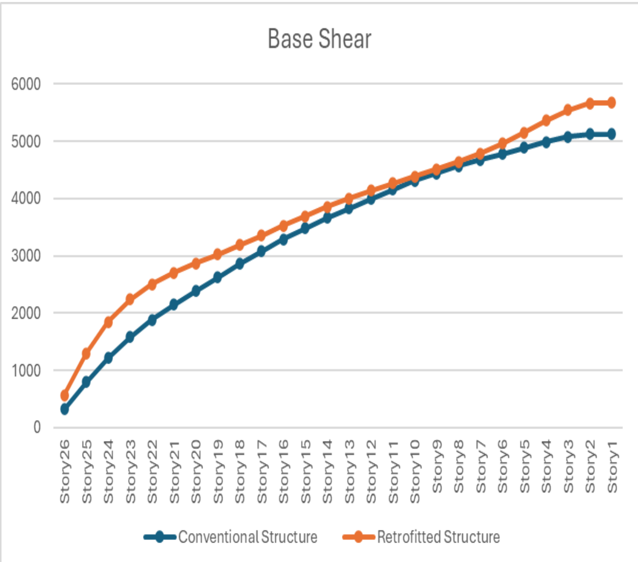

Figure 6. Base shear comparison graph

2. Displacement: Displacement is calculated for both the structures. As per the IS code, allowable lateral displacement is H/500. Conventional structure has failed in this criterion. As shown in fig. 7, It is found that Retrofitted structure has very good control over displacement. And Retrofitted structure has fulfilled the displacement criterion given in IS code.

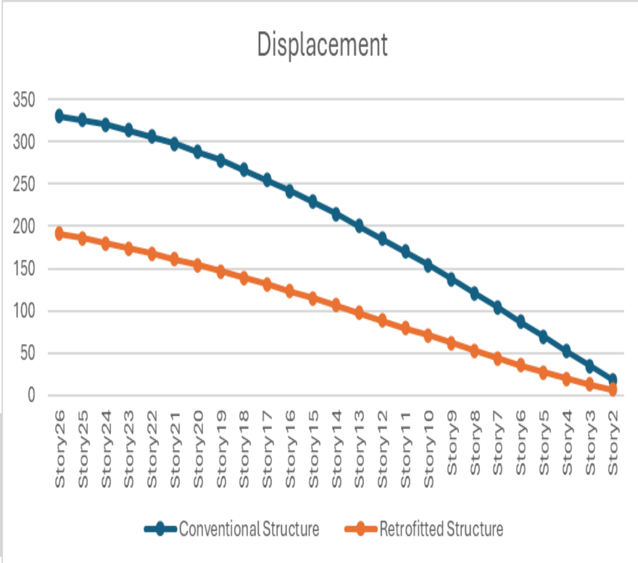

Figure 7. Displacement comparison graph

3. Storey stiffness: The resistance of a certain floor level (storey) in a building structure to lateral deformation or displacement is referred to as storey stiffness. This characteristic affects how a building reacts to horizontal forces like those caused by wind or earthquakes. As shown in fig.8, it is found that Storey Stiffness of conventional structure is much less than retrofitted structure.

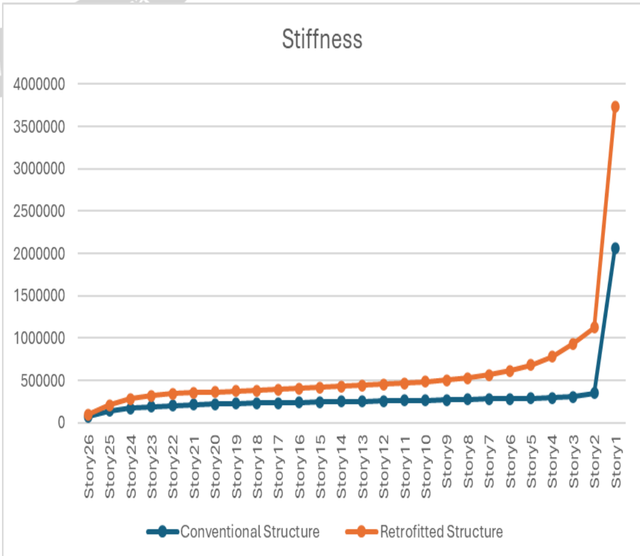

Figure 8. Stiffness comparison graph

4. Storey drift: Inter storey drift of the structure is relative displacement between adjacent storeys. As per IS 1893, allowable storey drift is 0.004 times the storey height.

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Results in fig.9 show that conventional structure has failed to satisfy the storey drift criteria. However Retrofitted structure is safe in this criterion also.

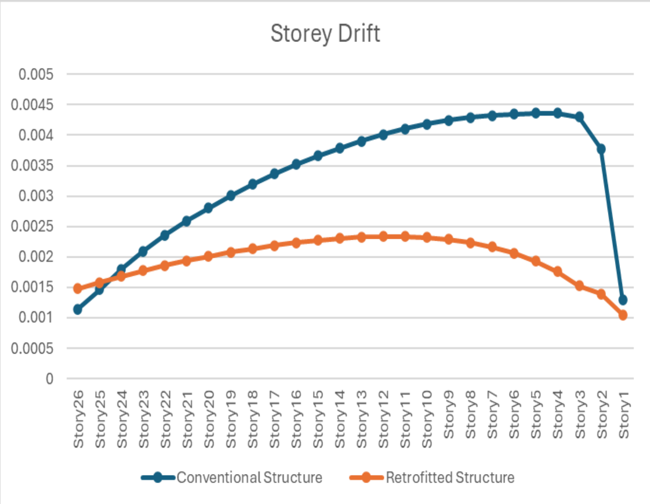

Figure 9. Story Drift comparison graph

5. Time period: Stiffness of Retrofitted structure more than the conventional structure. And hence the fundamental time period for Retrofitted structure is less than Conventional Structure as shown in fig.10.

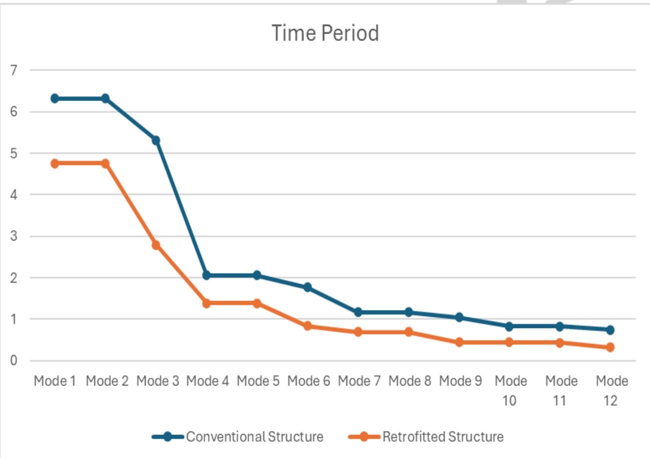

Figure 10. Time Period comparison graph

V. CONCLUSION

This study shows that reinforcement is important for improving the seismic performance of reinforced concrete structures and emphasizes the importance of using modern analysis methods to guide the design and reinforcement process in the earthquake zone. This study reveals the following points:

1) Stiffness of Retrofitted structure is more than the conventional structure. And due to this displacement and storey drift of retrofitted structure is less as compared to conventional structure.
2) Conventional structure fails to fulfill the criteria given for storey drift and storey displacement, whereas retrofitted structure fulfills these criteria and is safe for accommodation.
3) The stiffness of retrofitted structure is more and hence the base shear is more for Retrofitted structure as stiffness of retrofitted structure is more than conventional structure.
4) Time period of retrofitted structure is less than the time-period of conventional structure due its high stiffness.

Overall, retrofitting RC buildings significantly improves their seismic performance, making them safer and more resilient to earthquake forces. This underscores the importance of retrofitting strategies in seismic design and the need for ongoing assessment and enhancement of existing structures to protect lives and property.

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