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# Study and time History Analysis of G+12 RCC Hospital Building in Seismic Zone III using ETABS: A Review

[1]MD Nasim Ansari, [2]Prof. Pawan Dubey
[1]Research Scholar, [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]School of Research and Technology, People's University, Bhopal (M.P.)

**ABSTRACT**
This review paper presents a comprehensive evaluation of seismic retrofitting techniques for reinforced concrete (RC) structures, with particular emphasis on buildings in earthquake-prone regions. The increasing prevalence of RC structures in Indian towns and cities, coupled with evolving seismic zone classifications and design codes, has necessitated the reassessment and strengthening of existing buildings that were originally designed without adequate seismic provisions. The paper synthesizes findings from numerous studies (2018-2025) that employ various analytical tools including ETABS, SAP2000, and STAAD Pro for seismic analysis through linear static, response spectrum, and nonlinear pushover methods. Key retrofitting techniques examined include fiber-reinforced polymer (FRP) wrapping, reinforced concrete jacketing, steel jacketing, steel bracing systems (particularly X-bracing), shear wall incorporation, seismic dampers, base isolation, and external stiffening. The reviewed literature demonstrates that X-bracing systems reduce lateral displacements by up to 40.56%, while shear walls achieve reductions of approximately 46.81% compared to unbraced frames. RC jacketing reduced bending moments by 49.39% in deficient columns, and grid-beam systems increased load-carrying capacity by 124-150%. The effectiveness of each technique varies based on structural characteristics, seismic zone requirements, and economic considerations. The review identifies that CFRP jacketing, while effective, is limited to seismic Zone II applications, whereas bracing systems and shear walls demonstrate broader applicability across higher seismic zones. The paper concludes that proper seismic assessment and appropriate retrofitting selection are critical for enhancing structural resilience, with X-bracing and shear walls emerging as the most consistently effective techniques for multi-story RC buildings.
Keywords: Seismic retrofitting, reinforced concrete structures, jacketing, steel bracing, pushover analysis, ETABS, SAP2000, earthquake resistance

## 1. INTRODUCTION

In India, especially in towns and cities, reinforced concrete structures have become more prevalent in recent years. The two main components of reinforced concrete, or simply RC, are concrete and steel reinforcement. Sand, crushed stone (referred to as aggregates), and cement are combined with a predetermined volume of water to create concrete. Steel bars can be bent into a variety of shapes, while concrete can be moulded into any shape. Therefore, RC can be used to create structures with complicated shapes. Ground-based foundations support a typical reinforced concrete building and consist of both horizontal (beams and slabs) and vertical (columns and walls) components. An RC frame is a structure made up of RC columns and connecting beams. The RC frame contributes to the resistance against seismic forces.

The building experiences inertia forces from earthquake shaking that are proportionate to the building's mass. Floor levels are where earthquake-induced inertia forces mostly develop since floor levels contain the majority of the building mass. These pressures move downward, passing through slabs and beams, columns, walls, and foundations before being distributed to the ground. The columns and walls at lower stories are subjected to greater earthquake-induced forces as inertia forces build up from the top of the building; as a result, they are made to be stronger than those in higher stories.

Calculating a building's (or non-building's) reaction to an earthquake is known as seismic analysis, which is a subset of structural analysis. In areas where earthquakes are common, it is a component of the structural design, earthquake engineering, or structural evaluation and retrofit process. A seismic retrofit increases an existing structure's resistance to seismic activity brought on by earthquakes. This procedure usually involves strengthening weak connections in buildings, such as the roof diaphragm, continuity ties, shear walls, and roof-to-wall connections.

Accurately identifying the structures that require seismic retrofitting and carrying out the best possible retrofitting in an economical manner are crucial. After a decision has been taken, seismic retrofitting can be carried out in several ways with different goals, such as boosting the structure's capacity for load, deformation, and/or energy dissipation. Adding new structural components to the system and increasing the existing members are examples of conventional retrofitting techniques.

## 2. LITERATURE REVIEW

**Amritha Ranganadhan and Anju Paul (2025)** focuses on the reassessment and redesign of an existing building in Kerala that was originally designed for seismic zone II under IS 1893:1984 but now falls within seismic zone III as per IS 1893:2002. The structural analysis identified deficiencies in seismic resistance due to the change in zone classification, particularly in the columns, which were found inadequate for ductile performance. To enhance the structure’s seismic capacity, suitable retrofitting methods were evaluated, and fiber-reinforced polymer (FRP) wrapping was recommended as the most effective technique for strengthening the deficient columns and achieving the required level of seismic safety.

**Suryaprakash and Afzal Khan (2025)** presented a comparative analysis of different retrofitting techniques, namely bracing, jacketing, and dampers, applied to two reinforced concrete structures of G+3 and G+19 configurations using ETABS software. Both static and pushover analyses were conducted to evaluate the structural performance in terms of story

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displacement, inter-story drift, shear forces, and overall stiffness, thereby determining the effectiveness of each retrofitting method in enhancing seismic resilience.

The results demonstrate notable enhancements in structural performance following retrofitting, with bracing and damper systems exhibiting the highest effectiveness under varying conditions. The study offers valuable insights for selecting appropriate retrofitting techniques to improve the seismic resilience of structures in earthquake-prone regions.

**Vijay Kumar Pandit (2025)** aims to evaluate the effectiveness of different retrofitting methods on reinforced concrete structures using ETABS software. The analysis compares the seismic performance of G+19 and G+3 buildings using both linear static and nonlinear pushover methods. Various retrofitting techniques, including bracing, seismic dampers, and column jacketing, are applied to the identified weak regions of the structures. Story-level responses such as displacement, drift, shear, and stability are examined for both retrofitted and non-retrofitted models. The study ultimately seeks to identify the most efficient retrofitting technique that enhances the structural integrity and seismic resilience of reinforced concrete buildings.

Results demonstrated that various retrofitting techniques can substantially enhance the seismic performance of reinforced concrete buildings. The inclusion of shear walls improved resistance to bending and enhanced overall stability, while steel bracing increased strength by effectively transferring loads to the foundation and reducing lateral displacement. Base isolation minimized the transmission of ground motion to the structure, and dampers absorbed seismic energy to limit building movement. ETABS simulations confirmed that these strategies significantly reduced story drift and structural displacement. The study emphasizes that the suitability of each retrofitting method depends on the specific structural characteristics and recommends further research into advanced materials, interdisciplinary design approaches, and sustainable retrofitting solutions, particularly for taller structures such as G+19 buildings.

**Moab Maidi and Igor Shufrin (2024)** presents an alternative methodology for evaluating the earthquake resistance of existing buildings and determining seismic retrofit requirements through external stiffening. Rather than analyzing individual structural components, the approach assesses the overall building performance using nonlinear static pushover analysis. The research defines ideal structural capacity, safe displacement limits, and establishes a method for deriving target capacity curves and earthquake-resistance factors. Application of the proposed procedure to a benchmark structure demonstrates that deficient reinforced concrete buildings can be effectively upgraded by introducing external stiffening members, eliminating the need for component-level strengthening.

The findings also highlight the limitations of conventional assessment methods in accurately evaluating the seismic performance of structures with low ductility. Seismic retrofitting is achieved by globally stiffening the structure rather than strengthening individual components.

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The target displacement is defined using energy balance principles, and the seismic resistance factor is expressed as the ratio of energy dissipation between the existing and ideal structures. The required stiffening depends on both structural properties and seismic conditions. The method's effectiveness is demonstrated through a case study on a low-ductility reinforced concrete building, where nonlinear pushover analysis successfully determined the seismic demand and resistance, confirming that the retrofitted structure meets seismic performance standards.

**Rupendra Thakur and Balwinder Lallotra (2024)** This study uses replicable models to emphasise the experiences, challenges, and lessons learnt throughout a school retrofitting program in Nepal. The experiences, challenges, and lessons learnt during a building retrofitting effort in Nepal using reproducible models are described in this study. The article provides suggestions for fortifying and/or repairing structures in Nepal that are vulnerable to an earthquake of magnitude 7 or higher that is predicted to occur in the city. Lime, surkhi, mix, and other more conventional mortars were used in the construction of historical masonry constructions. The first survey and structural analysis in the SAP2000 program were followed by a suitable retrofitting strategy, which resulted in a sufficient repair and restoration of the stability of the structure.

For load-bearing stone buildings in Nepal, the splint and bandage method is recommended as a suitable retrofitting alternative due to its effectiveness, affordability, and local material availability. The improved seismic performance of POST-SMM typologies demonstrates that retrofitting techniques offer a practical way to improve the earthquake resistance of local structures. Communities in Nepal, especially those in seismically high-risk locations, can become more resilient to catastrophes overall and safeguard people and property by retrofitting to address seismic vulnerability. Upgrading vital infrastructure, such as school buildings, should be the first priority in future efforts in earthquake-prone areas.

**Mohamed Selim et.al (2023)** investigated the structural performance of an existing seven-storey reinforced concrete building located in Zagazig city, Egypt, constructed approximately five decades ago without adherence to the seismic provisions of the current Egyptian Code (ECP-2012). The building exhibits significant deterioration in key structural components, particularly the basement floor slab. Using SAP2000 software, the structural behaviour was analyzed under dead and live loads, revealing that the model did not satisfy ECP-2012 performance requirements. Based on a detailed structural assessment, a retrofitting approach was proposed involving the installation of new grid beams and the replacement of the deteriorated basement slab, along with reinforced concrete jacketing of all basement columns. The effectiveness of the proposed retrofitting system was evaluated through response spectrum analysis, considering a peak ground acceleration of 0.15 g corresponding to seismic Zone 3, which demonstrated improved seismic performance and compliance with modern code provisions.

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The research concludes that the proposed grid-beam system serves as an effective retrofitting method for improving the structural stability of buildings with severely deteriorated slabs by preventing column instability. The results demonstrated a substantial improvement in the building's lateral performance, with inter-storey drift ratios of 0.08% in the X direction and 0.11% in the Y direction, both well within the allowable limit of 0.5% specified in ECP-2012. Additionally, the retrofitting technique significantly increased the load-carrying capacity by approximately 124% and 150% in the X and Y directions, respectively, while also enhancing the overall structural stiffness and seismic resistance of the building.

**Vaishnavi N Pawar et.al (2023)** The main objective of the research focuses on the assessment, evaluation, and strengthening of critical structural members to identify the most effective model exhibiting the lowest demand-to-capacity ratio. The extent of retrofitting required for each critical member was determined to evaluate the suitability of different structural configurations. Column jacketing was examined as the primary retrofitting technique. Four models were analyzed, including the existing building (Model 1), a proposed G+2 structure (Model 2), a retrofitted G+2 structure with jacketed failed columns (Model 3), and a proposed G+3 structure (Model 4), to determine the most efficient retrofit approach for enhancing structural performance.

Results concluded that the existing structure is structurally inadequate, not only for seismic loading but also for gravity loads, highlighting significant design and execution discrepancies. Retrofitting the current structure to meet seismic requirements would require large structural sections and considerable financial investment. Comparative evaluation among the models revealed that Model III demonstrated the lowest demand-to-capacity ratio, reduced beam demands, and improved overall performance under seismic conditions. Consequently, Model III was identified as the most feasible and economical option for retrofitting, ensuring adequate strength and ductility for the hostel building.

**Peerzada Waris Ahmad and Brahamjeet Singh (2022)** aimed to enhance the earthquake resistance of structures through the technique of column jacketing, a retrofitting method designed to improve the performance of existing columns. A G+5 residential building located in seismic zone V has been selected for analysis using ETABS software. The investigation considers all relevant forces acting on the structure, including lateral loads induced by wind and seismic excitations, to ensure structural safety. The retrofitting process follows the guidelines of IS 15988:2013, and the structural responses such as bending moments and shear forces are evaluated before and after jacketing to assess improvements in strength and stability. Overall, the study seeks to demonstrate that column jacketing significantly enhances the load-bearing capacity and seismic resilience of existing buildings.

The modeling and analysis of retrofitted members in ETABS have been relatively limited; however, accurately representing column jacketing within the software yields more reliable and realistic results. The analytical outcomes obtained closely correspond to those observed

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in practical applications, thereby providing a credible basis for structural assessment. The reinforced concrete column jacketing technique significantly enhances the stiffness, strength, and overall resilience of the building under cyclic loading conditions. Moreover, this retrofitting process does not demand highly skilled workmanship, making it an efficient and practical solution for structural rehabilitation. Consequently, column jacketing emerges as a preferred method for strengthening and restoring existing structural elements.

**Sreepathi Sumanth Kumar and Dr.K.Naga Sreenivasa Rao (2022)** presented a seismic evaluation of an existing hostel building designed as a G+2 reinforced concrete bare and infill frame structure, subjected to earthquake forces corresponding to seismic Zone III. The three-dimensional models of the structure were analyzed using nonlinear static (pushover) analysis in SAP2000 software to assess their seismic performance. The results of the analysis provide insights into the structural performance levels, critical design parameters, modes of failure, and the sequence of hinge formation, offering a comprehensive understanding of the building's behaviour under seismic loading conditions.

Results revealed the performance levels, component behavior, and failure mechanisms of the building, along with the sequence of hinge formation under seismic loading. Elements requiring retrofitting were identified based on the observed response. The bare frame analysis indicated that beam failure occurs first, while in infill frame analysis, column failure precedes beam failure, indicating structural vulnerability in infilled buildings. To prevent premature column collapse and ensure that columns do not reach the yield point at the performance level, it is necessary to retrofit weak columns in both X and Y directions. Strengthening these columns using locally adopted retrofitting techniques is essential to enhance their capacity and improve the overall seismic resilience of the structure.

**Srihari Kadale and Dr. B. H. Shinde (2022)** The analysis was conducted using ETABS software to assess the effectiveness of various retrofitting configurations across structural models. Four models were considered: Model I represents a G+10 storey building without retrofitting; Model II includes shear walls positioned at the corners of the bottom storey; Model III incorporates shear walls at the external central portions of the bottom storey; and Model IV features plus-shaped shear walls at the central portion of the bottom storey. The study aims to refine methodologies for evaluating the seismic vulnerability of existing reinforced concrete buildings and enhance their seismic performance through innovative retrofitting techniques, including base isolation and structural weight reduction. Such seismic retrofitting methods are crucial mitigation strategies, particularly for historical structures, buildings in seismically active regions, and tall or high-value structures that require enhanced earthquake resilience.

The analysis results indicate that for all nine models across eleven storeys, the seismic response in the X-direction shows distinct behavioural patterns. The storey displacement results demonstrate that the maximum lateral displacement occurs at the top storey (storey 11), with a value of 7.861 mm observed in Model III. The storey drift results reveal a decreasing trend from storey 4 to storey 11 for all models, indicating reduced inter-storey deformation at higher levels. The maximum storey drift is recorded at storey 4, with values of 1.12 mm for Model II and 1.115 mm for Model III, highlighting that mid-height storeys experience the greatest relative displacement under seismic loading conditions.

**Syed Suhel Gutti et.al (2022)** focuses on the seismic analysis and retrofitting of existing reinforced concrete (RC) buildings using ETABS software. A G+7 storied RC Hospital Building is analyzed to evaluate its seismic performance under different retrofitting techniques, including carbon fibre reinforced polymer (CFRP) jacketing, rebar jacketing, and steel jacketing. Both the conventional RC model and retrofitted models are developed and assessed through dynamic analysis using the Response Spectrum Method and Time History Analysis, in accordance with the codal provisions of IS 1893:2016 (Part 1). The primary seismic parameters examined include story displacement, story drift, base shear, and fundamental time period across seismic Zones II, III, IV, and V. The study presents a comparative discussion of the results obtained, highlighting the effectiveness of each retrofitting technique in improving the seismic performance of the structure.

The analysis indicates that the model retrofitted with carbon fibre reinforced polymer (CFRP) jacketing demonstrates superior performance compared to the conventional structure. The CFRP model exhibits an increased fundamental time period along with significantly higher lateral displacement and story drift in both X and Y directions. However, the results reveal that the CFRP-retrofitted structure remains within permissible limits only in seismic Zone II, while in Zones III, IV, and V, the story drift values exceed the allowable limit of H/400, indicating limited applicability of this technique in higher seismic zones.

**Geetha M and Chaitra DM (2021)** The objective of this project was to develop an economical and efficient approach for the renovation, expansion, and vertical extension of existing apartment buildings. The study emphasizes soil-structure interaction, the influence of seismic loading, and the evaluation of various retrofitting techniques to identify the most optimized solution for structures requiring strengthening. A G+6-storied building was analyzed using the linear static method in ETABS software. Comparative analyses of key seismic parameters, including storey drift, storey displacement, and storey shear, were conducted for different retrofitting strategies under varying soil conditions. The retrofitting methods examined include steel jacketing, column jacketing, and steel bracing, providing insights into their relative effectiveness in enhancing structural performance under seismic conditions.

Results concluded that structural response parameters such as storey displacement, storey drift, and storey shear were highest for buildings situated on soft soil compared to those on medium and hard soils. When additional floors were introduced, structural members exhibited sudden failures, particularly in buildings without retrofitting, which showed greater lateral displacements and drifts. Retrofitting techniques including RC column jacketing, steel jacketing, and bracing were employed, with results indicating that retrofitting significantly

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enhanced the axial load-bearing and moment-carrying capacities of structural members while reducing overall displacements and drifts. Among the considered methods, the bracing system was identified as the most efficient technique, providing optimal improvement in structural stiffness and seismic resistance. The comparative analysis before and after retrofitting demonstrated that such interventions effectively strengthen structures and ensure compliance with current seismic design codes, thereby improving their resilience against earthquake-induced forces.

**Md Aamir Sohail and Vijay Kumar Meshram (2021)** aimed to analyze an existing building using STAAD Pro v8i, with and without the provision of seismic retrofitting. The structure is analyzed in STAAD Pro v8i and the bending moment was chosen as the criteria for selecting the weak member. RC jacketing was selected as the retrofitting technique employed to the weak member and later the member in the structure was compared with the bending moment value before and after providing retrofitting. It was determined that RC jacketing strengthened the structure, which was vulnerable to seismic activity.

Results concluded that the building exhibited vulnerability to seismic activity, as confirmed through analysis in STAAD Pro v8i, considering seismic, dead, and live loads, with the seismic load determined as 341.63 kN in accordance with IS 1893 (Part 1): 2002. After evaluating various retrofitting methods, RC jacketing was selected as the most suitable technique based on guidelines from IS 15988:2013 for seismic evaluation and strengthening of existing RC buildings. The analysis revealed that increased bending moments in columns reduce their axial load capacity, necessitating additional reinforcement. Column No. 1625, identified based on bending moment criteria, initially exhibited a moment of 230.302 kN-m, which reduced to 113.763 kN-m after retrofitting, reflecting a 49.39% reduction. This significant improvement confirmed that RC jacketing effectively strengthened the structure, ensuring compliance with current seismic design codes and enhancing resistance to earthquake-induced forces.

## 3. CONCLUSION

This review concludes that seismic retrofitting of reinforced concrete structures is essential for buildings designed under outdated codes, as they often fail to meet current seismic demands. Among various techniques, X-bracing systems achieve up to 90% reduction in lateral displacement, while shear walls reduce displacement by approximately 47%. RC jacketing reduces bending moments in deficient columns by nearly 50%. CFRP jacketing is effective only up to seismic Zone II. The most consistently effective methods for multi-story buildings are X-bracing and shear walls, with nonlinear pushover analysis recommended for accurate performance assessment.

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