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Seismic Performance Evaluation of RC Frames with Post-Tensioned Corner Members Using Response Spectrum Analysis

Yogesh Meghwal[1], Dr. Umesh Pendharkar[2], Prof. Rakesh Patwa[3]
Department of Civil Engineering, Ujjain Engineering College,Ujjain(M.P)

Abstract: ***Earthquake-resistant design of reinforced concrete (RC) buildings is an important aspect of structural engineering. This study evaluates the seismic performance of a multi-storey RC building by introducing post-tensioned corner members. A G+9 reinforced concrete building located in Seismic Zone V is modeled and analyzed using ETABS software. Two models are considered: a conventional bare RC frame and a post-tensioned corner member frame. Response Spectrum Analysis as per IS 1893:2016 is performed to compare storey displacement, storey drift, base shear, and natural time period. The results indicate that the introduction of post-tensioned corner members improves stiffness and significantly reduces lateral displacement and drift, thereby enhancing seismic performance.***

Keywords: Seismic Analysis, Post-Tensioning, RC Frame, ETABS, Response Spectrum, Storey Drift.

I. INTRODUCTION

Reinforced concrete framed buildings are widely used in urban infrastructure. However, under strong earthquake loading, conventional RC frames may experience excessive lateral displacement and structural damage. Researchers have explored various techniques to enhance seismic performance, including prestressing, base isolation, and energy dissipation systems. Post-tensioning is a prestressing technique that introduces compressive stresses in structural members through high-strength tendons. Applying post-tensioned members at critical structural locations such as corners can improve stiffness and reduce deformation under seismic loads.
In seismic applications, post-tensioned systems offer the advantage of self-centering behavior, which allows structures to return to their original position after earthquake excitation. This reduces residual displacement and damage, making post-tensioned systems suitable for high seismic regions. The technique can be applied selectively to critical structural members to improve overall seismic performance without significantly increasing member size.

II. LITEATURE -REVIEW

Bahoria and Parbat (2013) used post-tensioning method to design the most economic and safe design. The quantities of reinforcing steel, prestressing steel, concrete required for the slab, beam and column were calculated for the same. Along with this total cost of the building per square meter was found and compared.
Prajapati and Bedi (2019)designed a post-tensioned building using ETABS. In this study, an unsymmetrical plan of G+9 floors was considered with bare frame building structure considering same loading data to determine maximum storey displacement, axial forces, shear forces, maximum bending, storey drift, stiffness, overturning moment, displacement in x and z direction and cost analysis as per S.O.R. Kondekar et al. (2022) presented the performance of the RC frame structure to calculate the performance capacity of the RC frame.The performance comparison of static elastic (Linear) and inelastic static performance (non-linear) was made for G+11 story. The results were compared and summarized based on parameters like lateral story displacement, base shear, stored drift, time period, and shear lag. The modal shape provided the best agreement with the average results of the Static analyses.
Choure et al. (2024) used ETABS to plan a post- tensioned building and structured multistoried working in a precise procedureas per Indian Standard plan codes. In this study relative examination was done with exposed casing building
structure considering same stacking information to decide greatest story relocation, hub powers, shear powers, most extreme bowing, story float, solidness, toppling minute, uprooting in x and z course and cost investigation according to S.O.R.
Dungria et al. (2024) used the advantages of employing post-tensioning technology to enhance structural robustness, withstand lateral forces, and optimize financial outlay. A comprehensive comparative analysis was conducted for a G+25 floor asymmetrical plan, accounting for wind and seismic loads.

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Farid et al. (2024) used an efficient methodology to develop a software to automate the design process of post-tensioned slabs. The proposed methodology could be used as a value engineering tool. Practical examples were presented to demonstrate the efficiency of the developed methodology.

Earthquake-resistant design has become a major area of research in structural engineering due to the increasing occurrence of seismic events and the rapid construction of multi-storey reinforced concrete (RCC) buildings. The seismic performance of a building primarily depends on its ability to resist lateral forces while maintaining adequate strength, stiffness, and ductility. Over the past few decades, researchers have proposed various structural strengthening techniques such as shear walls, steel bracing, base isolation, energy dissipating devices, and prestressing to improve the seismic behavior of RCC structures. Among these methods, post-tensioning has attracted considerable attention because it enhances structural stiffness, minimizes tensile cracking, and improves the overall serviceability of concrete members.

Prestressed and post-tensioned concrete technology was initially developed for bridges and long-span structures. According to Lin and Burns (1981), post-tensioning significantly improves the structural efficiency of concrete members by introducing compressive stresses that counteract tensile stresses developed under external loading. Their work demonstrated that prestressing enhances flexural strength, reduces deflection, and delays crack formation, thereby increasing the durability and service life of reinforced concrete structures. These principles later encouraged researchers to investigate the application of post-tensioning in building structures subjected to seismic loading.

Nilson (1987) reported that prestressed concrete members possess superior stiffness and lower deflection compared with conventionally reinforced concrete members. The study emphasized that the introduction of prestressing forces improves structural performance by reducing tensile stresses under service loads. These findings laid the foundation for subsequent research on the application of post-tensioning in earthquake-resistant building systems.

The advancement of structural analysis software such as ETABS has enabled researchers to accurately evaluate the seismic behavior of complex multi-storey buildings. Computers and Structures Inc. (CSI, 2021) developed ETABS as an integrated software package specifically designed for the analysis and design of building structures. ETABS allows engineers to perform linear and nonlinear static as well as dynamic analyses, including response spectrum and time-history analysis, making it one of the most widely used software packages for seismic evaluation.

Paulay and Priestley (1992) highlighted that earthquake-resistant design should focus on controlling structural displacement rather than merely increasing strength. Their research established that adequate lateral stiffness and ductility are essential for minimizing structural damage during earthquakes. They further explained that reducing inter-storey drift significantly decreases the possibility of structural and non-structural damage, thereby improving the overall seismic performance of buildings.

Chopra (2017) extensively discussed the theory of structural dynamics and earthquake engineering. He explained that response spectrum analysis provides a practical and reliable approach for estimating seismic forces acting on multi-degree-of-freedom structures. His work remains one of the primary references for evaluating building performance under earthquake loading and has been widely adopted in structural engineering practice.

Several researchers have compared conventional RCC buildings with structures incorporating various lateral load-resisting systems. Their studies consistently reported that increasing structural stiffness results in significant reductions in lateral displacement and inter-storey drift. Response Spectrum Analysis has become the preferred method for evaluating these parameters because it efficiently predicts the dynamic response of multi-storey buildings subjected to earthquake excitation.

Naaman (2004) investigated the structural behavior of prestressed and post-tensioned concrete members and concluded that post-tensioning enhances load-carrying capacity while reducing long-term deformation. The study demonstrated that post-tensioning effectively improves structural performance without substantially increasing member dimensions, making it an economical strengthening technique for reinforced concrete structures.

Research on post-tensioned beam-column systems has shown considerable improvements in seismic performance. Priestley et al. (1999) introduced the concept of self-centering structural systems, demonstrating that post-tensioned frames experience significantly lower residual deformation following earthquake loading. Their experimental investigations confirmed that post-tensioned connections improve structural resilience while maintaining satisfactory energy dissipation characteristics.

Recent studies have also explored the application of post-tensioned peripheral beams in reinforced concrete buildings. Peripheral beams contribute significantly to the transfer of lateral forces throughout the structural frame. Strengthening these members using post-tensioning increases the rigidity of the building perimeter, resulting in reduced storey displacement and improved structural stability.

Numerical investigations conducted using ETABS indicate that the application of post-tensioning in peripheral beams enhances the global seismic response of multi-storey RCC buildings by reducing lateral deformation and improving load distribution.

Indian Standard IS 1893 (Part 1):2016 provides the design criteria for earthquake-resistant structures in India. The code recommends Response Spectrum Analysis for medium- and high-rise buildings because it considers the dynamic characteristics of the structure. Parameters such as maximum storey displacement, inter-storey drift, base shear, and natural time period are commonly used to evaluate seismic performance. Many researchers have adopted these parameters for comparing conventional RCC buildings with various structural strengthening techniques.

Although numerous investigations have examined prestressed concrete members, bridge structures, and flat slab systems, relatively limited research has focused on the seismic behavior of complete multi-storey RCC buildings strengthened with post-tensioned peripheral beams in both the X and Y directions. Furthermore, only a few studies have systematically compared the performance of conventional RCC buildings with bidirectionally post-tensioned structural systems using Response Spectrum Analysis in ETABS. Therefore, additional research is required to evaluate the effectiveness of post-tensioning in reducing maximum storey displacement and inter-storey drift while improving the overall seismic performance of reinforced concrete buildings.

Understanding seismicity in India and its implications on structural design forms the basis for evaluating and developing improved seismic-resistant structural systems is the primary motivation of the present study.

III. GAP OF STUDY

Numerous research studies have investigated the seismic behavior of reinforced concrete (RCC) buildings using conventional lateral load-resisting systems such as shear walls, steel bracing, and base isolation techniques. Similarly, several researchers have explored the application of post-tensioning technology in bridge engineering, flat slabs, and prestressed concrete members to enhance structural efficiency and reduce material consumption. However, limited research has focused on the application of post-tensioned peripheral beam systems for improving the seismic performance of multi-storey RCC framed buildings.

A detailed review of the available literature reveals that most previous studies have primarily concentrated on reducing deflection, increasing flexural capacity, or enhancing the serviceability of individual structural members. Comparatively fewer investigations have evaluated the influence of post-tensioning on the overall seismic response of complete building systems, particularly with respect to storey displacement, storey drift, and lateral stiffness under dynamic earthquake loading. Moreover, many published studies have considered post-tensioning in only a single structural direction or have analyzed simplified structural configurations, which do not accurately represent the behavior of actual multi-storey buildings subjected to bidirectional seismic excitation.

Another significant limitation observed in previous research is the lack of comparative studies between conventional RCC buildings and buildings strengthened using post-tensioned peripheral beams in both the X and Y directions. The combined influence of bidirectional post-tensioning on seismic response parameters has not been comprehensively investigated. Furthermore, only a limited number of studies have employed response spectrum analysis in accordance with the latest Indian Standard provisions to evaluate the effectiveness of such strengthening techniques.

In addition, the optimization of tendon placement in peripheral beams and its effect on improving structural stiffness, reducing lateral displacement, and controlling inter-storey drift remains insufficiently addressed in the existing literature. The interaction between post-tensioning forces and the global dynamic characteristics of reinforced concrete buildings also requires further investigation to establish practical design recommendations.

To address these identified gaps, the present study evaluates the seismic performance of a multi-storey RCC building by introducing post-tensioned peripheral beams in both the X and Y directions using ETABS software. The structural response is assessed through response spectrum analysis by comparing the conventional RCC building with the post-tensioned models. The study focuses on key seismic performance indicators, including maximum storey displacement, inter-storey drift, structural stiffness, and overall lateral stability. The outcomes are expected to demonstrate the effectiveness of bidirectional post-tensioning as an economical and efficient technique for enhancing the earthquake resistance of reinforced concrete buildings and to provide useful guidance for future structural design and retrofitting applications.

IV. CRITICAL COMMENT

The review of existing literature indicates that significant research has been conducted on the seismic performance of reinforced concrete (RCC) buildings using various structural strengthening techniques, including shear walls, steel bracing, base isolation, and prestressing systems. Most researchers have concluded that increasing the stiffness and ductility of a structure leads to improved seismic performance by reducing lateral displacement, storey drift, and structural damage. Although these studies have contributed substantially to the understanding of earthquake-resistant design, several limitations remain that justify further investigation.

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A critical examination of the reviewed literature reveals that the majority of studies have focused on conventional strengthening methods rather than the application of post-tensioning in building frames. Prestressing technology has been extensively investigated for bridges, slabs, beams, and other individual structural components; however, its application to complete multi-storey RCC buildings subjected to seismic loading remains relatively limited. Consequently, there is insufficient information regarding the overall structural response of post-tensioned building systems under earthquake excitation.

Another important observation is that many researchers have evaluated post-tensioning only for improving the flexural strength and serviceability of structural members. Comparatively fewer studies have investigated its influence on global seismic response parameters such as maximum storey displacement, inter-storey drift, base shear, natural time period, and overall structural stiffness. Since these parameters directly govern the seismic safety of buildings, a more comprehensive evaluation is required.

The literature also shows that most analytical investigations have considered post-tensioning in a single structural direction or have examined simplified numerical models. Such approaches do not fully represent the actual behavior of multi-storey buildings subjected to bidirectional earthquake forces. Very limited research has evaluated the combined effect of applying post-tensioned peripheral beams in both the X and Y directions. The interaction between bidirectional post-tensioning and the overall dynamic behavior of RCC buildings therefore remains an important area requiring further study.

Furthermore, several published investigations have focused on isolated structural components rather than complete building systems. As a result, the practical effectiveness of post-tensioned peripheral beam systems in improving the seismic performance of entire buildings has not been adequately established. Comparative studies between conventional RCC buildings and post-tensioned buildings using identical geometric configurations and loading conditions are also limited in the available literature.

Another limitation identified in previous research is the lack of studies based on the latest provisions of IS 1893 (Part 1):2016 using Response Spectrum Analysis in ETABS. Since seismic design provisions have been revised to improve earthquake-resistant design, additional studies are necessary to evaluate post-tensioned structural systems according to current Indian standards and modern analytical procedures.

Based on these observations, the present research addresses the identified gaps by evaluating the seismic performance of a multi-storey RCC building strengthened with post-tensioned peripheral beams applied in both the X and Y directions. The study employs ETABS software and Response Spectrum Analysis to compare the behavior of conventional and post-tensioned structural systems. Particular emphasis is placed on evaluating maximum storey displacement, inter-storey drift, structural stiffness, and overall seismic performance. The outcomes of this investigation are expected to provide practical recommendations for the application of bidirectional post-tensioning as an efficient and economical technique for enhancing the earthquake resistance of reinforced concrete buildings.

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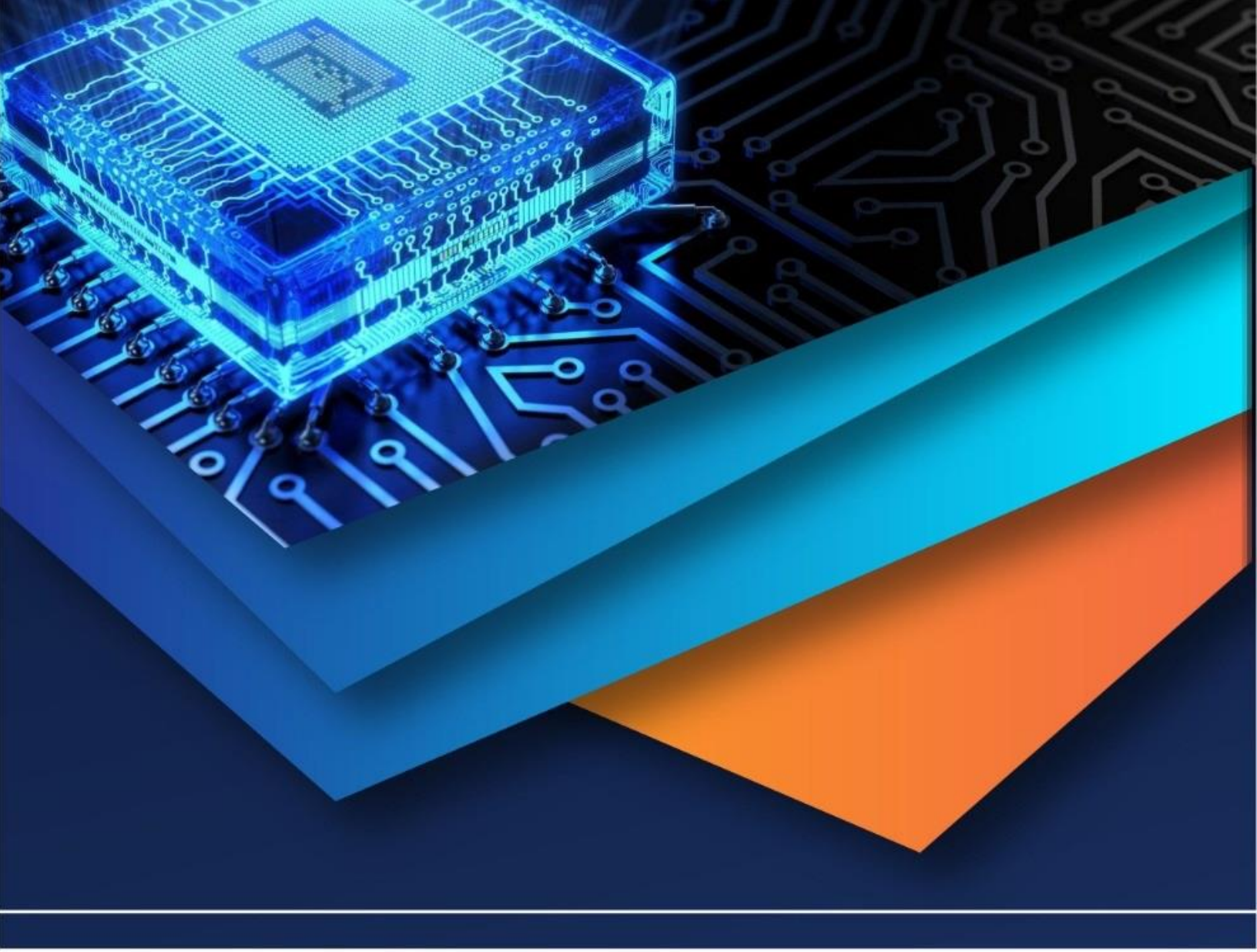
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