SEISMIC RESISTANCE SLAB: A TENSIONED APPROACH AND TRADITIONAL RCC.

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Abstract – In today's rapidly evolving global landscape, the construction sector stands as a linchpin of economic growth. While high-rise buildings are esteemed symbols of modernity, traditional Reinforced Concrete (RCC) methods often prove cost-prohibitive. This study delves into the advantages of employing Post-Tensioning technology to enhance structural robustness, withstand lateral forces, and optimize financial outlay. Post-Tensioned constructions are renowned for their superior cost-efficiency and durability over RCC, minimizing steel and concrete usage while maximizing room clear spans. The research utilizes ETABS (Extended Three-Dimensional Analysis of Building Systems) to design a Post-Tensioned high-rise in compliance with Indian Standard design codes. A comprehensive comparative analysis is conducted for a G+25 floor asymmetrical plan, accounting for wind and seismic loads.

***Key Words*: P.T. slab, R.C. slab, E-tabs, Overturning Moments, Displacements along both x and z axes..**

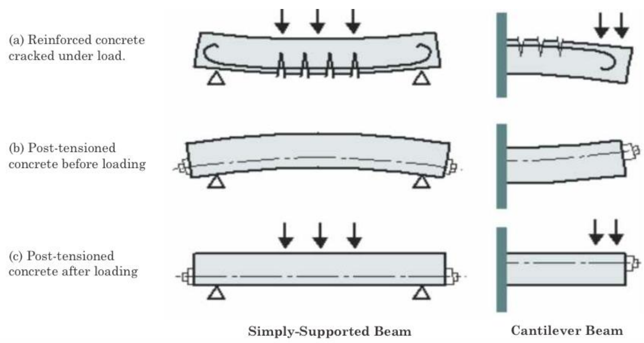
1.INTRODUCTION

Buildings must be designed to withstand natural forces like earthquakes and wind to ensure structural integrity and safety. ETABS software is integral in this process, offering advanced tools for comprehensive analysis and design. For seismic analysis, ETABS employs Response Spectrum Analysis and Time History Analysis methods. These predict how buildings will react to various frequencies and durations of ground shaking, aligning with Indian Standard IS 1893 for earthquake resistance. Simultaneously, ETABS addresses wind effects through static and dynamic wind load analyses per IS 875 (Part 3). Static analysis calculates forces based on building geometry and exposure, assuming steady wind pressure. Dynamic analysis considers wind's fluctuating nature, assessing responses to varying speeds and gusts over time. By integrating these analyses, ETABS facilitates detailed 3D modeling of G+25 reinforced concrete buildings, applying loads to simulate responses and identify vulnerabilities. This approach ensures compliance with safety standards, optimizing design for structural resilience and cost efficiency.

R.C.C(Reinforced Cement Concrete) slab :

An RCC slab is crucial in construction projects such as buildings and bridges, providing a flat, horizontal surface for floors and roofs. It typically consists of concrete reinforced with steel rebars to enhance its tensile strength. Construction begins with setting up formwork to define the slab's shape and dimensions. Structural drawings guide the placement of steel reinforcement to resist bending and shear forces. Once the reinforcement is inspected and approved, concrete is poured into the formwork and compacted to remove voids and air pockets. Curing follows to ensure the concrete reaches its required strength. After curing, the formwork is removed, unveiling a strong and durable RCC slab capable of supporting designated loads and serving as a functional surface for the structure.

PT(post tensioning) slab:



A Post-Tensioned (PT) slab is crucial in construction projects such as buildings and bridges, providing a level, horizontal surface for floors and roofs. Unlike traditional RCC slabs, PT slabs use high-strength steel tendons that are tensioned after the concrete has set to enhance load-bearing capacity. Construction begins by erecting formwork to define the slab's dimensions and shape. Structural drawings guide the precise placement of high-strength steel tendons within the formwork to effectively resist bending and shear forces. After inspection and approval of the tendon layout, concrete is poured into the formwork and compacted to eliminate voids and air pockets. Curing follows to ensure the concrete reaches its required strength. Subsequently, hydraulic jacks are used to tension the tendons and anchor them at the slab's ends, placing the slab under compression to improve resistance to cracking and increase load capacity. Once cured and tensioned, the formwork is removed, revealing a durable PT slab capable of supporting designated loads and providing a functional surface for the structure.

1.2 Objective

- Evaluate and compare structural performance of tensioned slabs vs. traditional RCC slabs under seismic and wind loads.
- Assess resilience of tensioned slabs and RCC slabs to seismic and wind forces.
- Analyze efficiency of both approaches in enhancing seismic and wind resistance, considering strength, flexibility, and deformability.
- Identify strengths and weaknesses of tensioned slabs versus RCC methods for slab design and construction.
- Utilize ETABS software for structural analysis

2. Literature Review

[1] Bahoria, Boskey Vishal, and Dhananjay K. Parbat. "Analysis and design of RCC and post-tensioned flat slabs considering seismic effect." *International journal of engineering and technology* 5.1 (2013): 10.

The post-tensioning method is increasingly favored in modern construction for its economic and safe design applications. This study focuses on designing a post-tensioned flat slab for a G+4 office building using load balancing and an equivalent frame method. Four different floor systems are evaluated, and calculations for quantities of reinforcing steel, prestressing steel, and concrete needed for slabs, beams, and columns are presented in tabular format. Each case's total building cost per square meter is determined for a comprehensive cost comparison. The introduction highlights the importance of floor systems in overall building costs and introduces post-tensioning as an efficient solution, listing technical and economic advantages. The conclusion underscores additional benefits of post-tensioned construction, emphasizing its versatility across different building scenarios and outlining specific advantages of post-tensioned slabs over traditional reinforced concrete slabs, including cost-effectiveness and increased span capabilities.

[2] Satwika, Vanteddu, and Mohit Jaiswal. "Comparison of RCC and Post-Tensioned Flat Slabs Using ETABS." *IOP Conference Series: Earth and Environmental Science*. Vol. 982. No. 1. IOP Publishing, 2022.

This study focuses on addressing the issue of insufficient punching shear capacity in flat slabs, a common structural challenge. Conventional methods such as increasing slab thickness or column size often conflict with architectural objectives. The research introduces post-tensioning as a solution to enhance flat slab strength, comparing conventionally reinforced concrete (RCC) flat slabs with post-tensioned flat slabs using various tendon profiles. Post-tensioned slabs demonstrate superior punching shear capacity even with shallower depths, resulting in enhanced cost-effectiveness. The study highlights several advantages of post-tensioning, including increased clear spans, reduced slab thickness, minimized cracking and deflection, lighter building structures, accelerated construction timelines, improved water resistance, and decreased reliance on traditional reinforcement. It explores technical details, benefits, and contrasts with traditional flat slabs, emphasizing the potential of post-tensioning to improve structural performance.

[3 Nighot[1], Shubham, Sopan Chinchole, Rohan Kapgate, and Sujesh D. Ghodmare[4]. "Analysis and design of post tension slab using ETABS software." (2020).

The construction industry is increasingly adopting post-tensioning for its numerous advantages, although countries like India have yet to fully appreciate its benefits, particularly in the context of flat slabs. This study utilizes ETABS software to evaluate the cost-effectiveness, strength, and serviceability of post-tensioned flat slabs in a commercial building (G+7). Findings indicate significant cost advantages compared to traditional RC flat slabs, positioning post-tensioning as highly suitable for multi-story structures. This method not only enhances structural strength and durability but also improves aesthetic appeal while offering an economical alternative. The study underscores the broad applicability of post-tensioned slabs and concludes with a favorable comparison over RC slabs in terms of concrete and steel utilization.

[4] Chou, Chung-Che, and Jun-Hen Chen. "Seismic tests of post-tensioned self-centering building frames with column and slab restraints." *Frontiers of Architecture and Civil Engineering in China* 5 (2011): 323-334.

This study explores post-tensioned (PT) self-centering moment frames as a seismic-resistant alternative to conventional moment-resisting frames (MRFs). It introduces a methodology to assess column restraint and beam compression forces based on column deformation and gap openings across all stories of a PT frame. Cyclic tests conducted on a full-scale, two-bay by one-story PT frame validate this approach. Additionally, the paper proposes using a sliding slab to minimize restraints on PT frame expansion and presents shaking table tests on a reduced-scale, two-by-two bay one-story PT building structure. The findings illustrate self-centering behavior with minimal variations in peak drifts, even during earthquake simulations, underscoring the seismic resilience potential of PT structures. The study addresses challenges associated with column and slab restraints in PT self-centering frames, offering insights and testing methodologies for further advancement and practical application in construction

[5] Prajapati, Deepak, and Komal Bedi. "Post Tensioning Building Analysis Considering Seismic Zone V using Analysis Tools ETABS." (2019).

In today's rapidly evolving and competitive environment, the construction sector plays a crucial role in national development, particularly with the widespread admiration for high-rise buildings. While Reinforced Concrete (RCC) has traditionally dominated construction methods, there is a growing shift towards Post-Tensioning for high-rise structures. Post-Tensioned buildings offer significant economic and durable advantages, reducing the required quantities of steel and concrete compared to RCC and enabling larger clear spans in rooms. This study focuses on the design of a Post-Tensioned building using ETABS software, which is specialized for systematic multistoried building design conforming to Indian Standard codes. The comparative analysis includes an asymmetrical G+9 floor plan, accounting for wind loads and soil conditions typical of black cotton soil. Parameters evaluated include storey displacement, axial and shear forces, bending moments, drift, stiffness, overturning moments, and cost analysis based on Schedule of Rates (S.O.R). The research aims to demonstrate the economic and structural benefits of Post-Tensioning in the construction of high-rise buildings.

[6] Yogesh Poptani ,Prerna Girepunje Lokesh Singh" Analysis of Behavior of Post Tensioning Slab for Various Framing Under the Influence of Lateral Load" International Journal of Scientific Research in Civil Engineering January-February-2019, Volume 3, Issue 1

In modern construction practices, post-tensioning systems are preferred over pre-stressing systems due to their reduced losses and flexibility in tendon shaping. Post-Tensioned (PT) tendons are commonly utilized in flat slabs to enhance crack and deflection control, enabling larger span-to-thickness ratios (typically 35 to 45), compared to Reinforced Concrete (RC) slabs which typically achieve ratios up to 30. PT systems also contribute to reducing floor-to-floor heights and overall structural weight. Additionally, post-tensioning enhances construction efficiency, sustainability, and durability. However, it is crucial to understand and analyze the behavior of flat slab systems under lateral forces, particularly in seismic regions. Evaluating the seismic resistance of such buildings, with or without a Lateral Force Resisting System, is essential. Nonlinear static analysis serves as a valuable tool in this context, providing a practical and intermediate solution to predict forces and deformation demands caused by seismic motions. This approach assists in accurately assessing structural strength and is particularly beneficial for performance-based design.

[7] Navyashree K , Sahana T.S" USE OF FLAT SLABS IN MULTI-STOREY COMMERCIAL BUILDING SITUATED IN HIGH SEISMIC ZONE International journal of research in engineering and technology January-February-2019, Volume 3, Issue 1

In contemporary construction practices, reinforced concrete (RC) frame buildings are prevalent, but flat slab buildings offer distinct advantages such as architectural flexibility, efficient space utilization, simplified formwork, and expedited construction timelines. However, their structural efficiency under seismic loading is a concern. This study investigates six buildings with varying heights (G+3, G+8, and G+12 storeys) using E-Tabs software to evaluate their performance under seismic zone IV conditions. Comparing conventional RC frame structures with flat slab structures, the study analyzes parameters including lateral displacement, storey drift, storey shear, column moments, axial forces, and natural time periods. The findings underscore the need for enhanced seismic design measures in flat slab constructions to optimize their performance in earthquake-prone regions. Key conclusions highlight that moments peak at lower levels and vary with height, column behavior shifts with increased height, and columns are designed for combined dead and earthquake loads, with seismic load combinations being critical. Additionally, column moments are generally higher in flat slab buildings, ranging from 10% to 20% more than in RCC frames depending on storey height. Base shear peaks at lower levels and decreases with height but increases significantly overall with building height, with flat slab buildings exhibiting 8% to 13% lower base shear compared to RCC buildings. Lateral displacement increases with storey height, being highest at the top storey and 28% to 57% greater in flat slab buildings, while natural time periods increase with building height, being 14% to 33% longer in flat slab buildings, peaking at modes 1 and 2 and decreasing notably thereafter.

3. MODELING

DESIGN DATA OF BUILDING	DATA
NUMBER OF STORY	G+15,G+20,G+25
TYPICAL STRORY HIGHT	3,3.2,3.5
COLUMN SIZE	300X600 mm
SHEAR WALL SIZE	375X1500 mm
BEAM SIZE	375X900 mm
THICKNESS OF SLAB	200 mm
GRADE OF CONCRETE	M35
GRADE OF STEEL	FE 500
WALL THICKNESS	230 mm

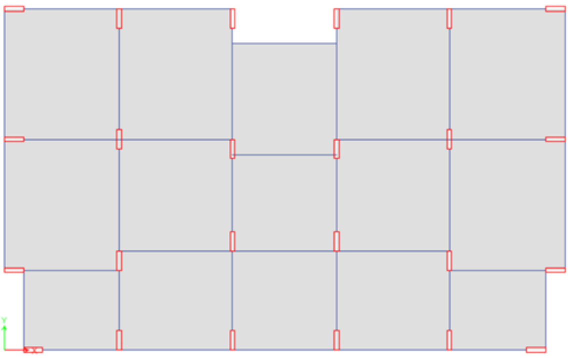
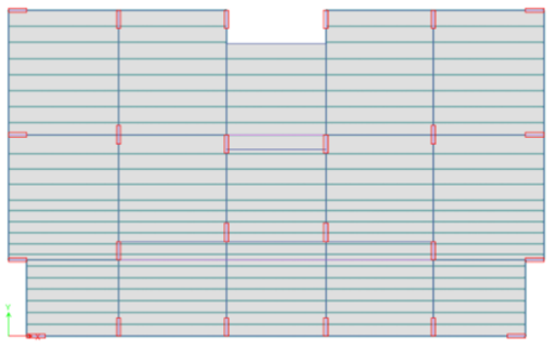


FIG 1: RCC MODEL



` **FIG 2: PT MODEL**

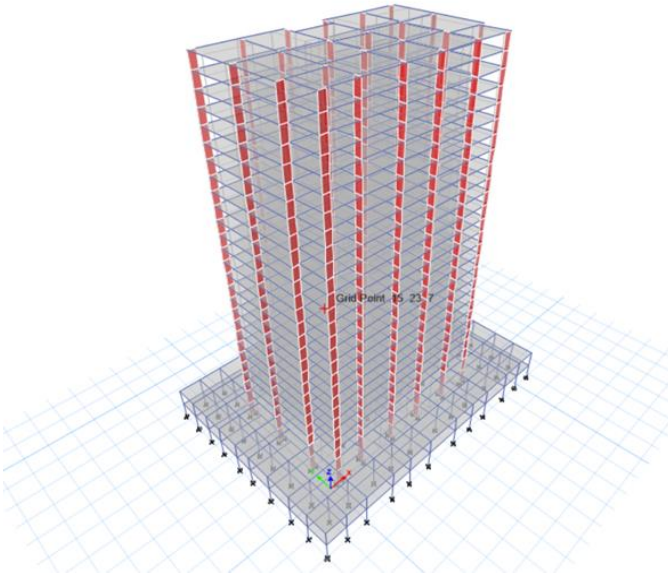


FIG 3: RCC-G+25 STORY

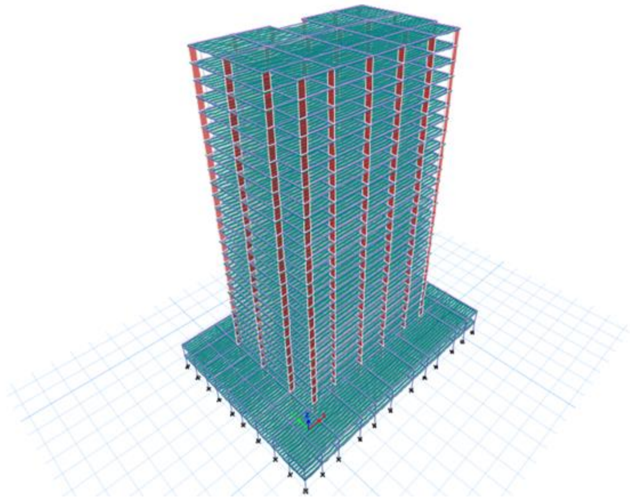


FIG 4: PT-G+25 STORY

4. RESULT

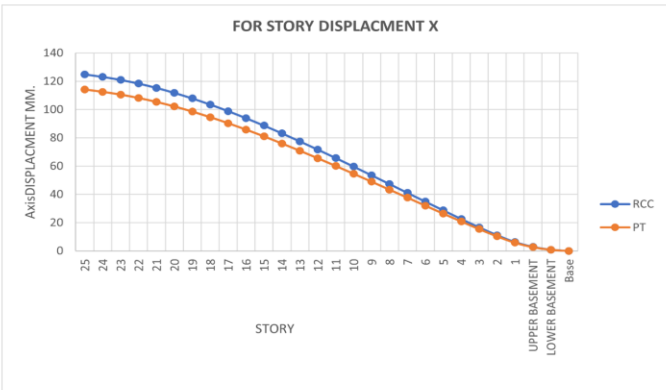


FIG 5: DISPLACMENT IN X DIRECTION

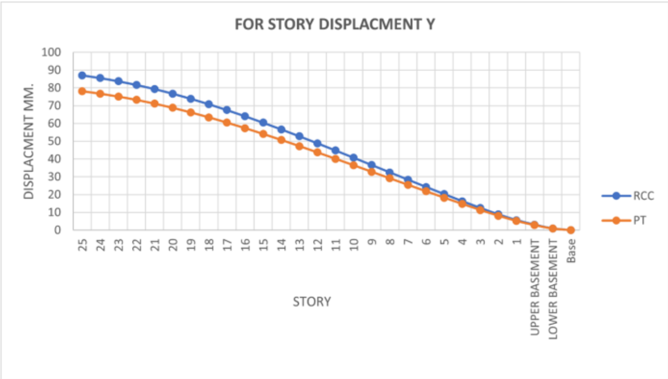


FIG 6: DISPLACMENT IN Y DIRECTION

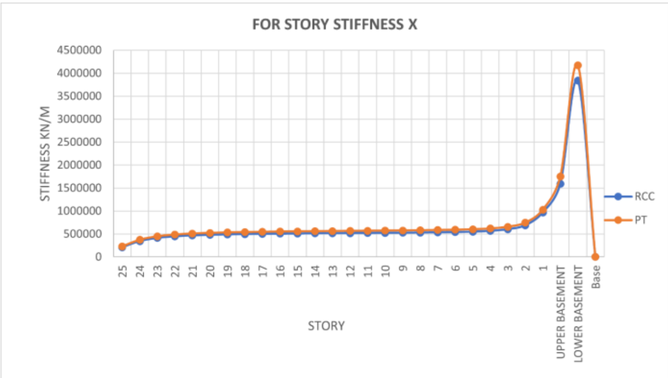


FIG 7: STIFFNESS IN X DIRECTION

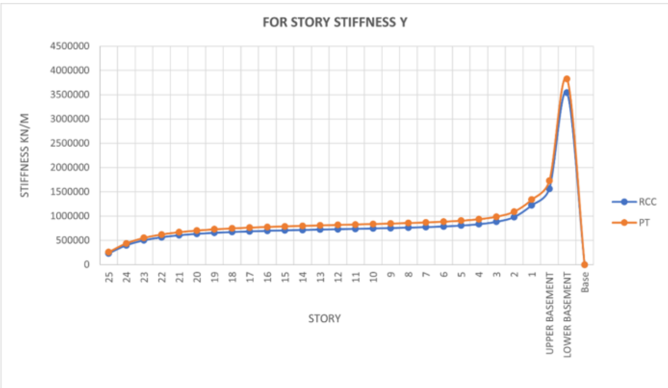


FIG 8: STIFFNESS IN Y DIRECTION

3. CONCLUSIONS

- Introduction of post-tensioning reduces bending moments, allowing for more economical section designs compared to bare frames.
- Post-tensioned structures minimize storey shear, thereby reducing the risk of unbalanced forces and enhancing structural stability against wind pressures.
- Axial forces in post-tensioned frames are efficiently distributed in vertical members, contributing to structural efficiency.
- Post-tensioning significantly reduces relative displacement, improving overall stability compared to bare frame structures.
- Comparative analysis across axial force distribution, storey stiffness, shear response, displacement characteristics, and bending moments consistently favors PT slab systems over RCC slab frames.
- PT slabs exhibit approximately 20% less displacement under applied loads compared to RCC slabs, indicating superior stability.
- PT slabs demonstrate approximately 12% greater stiffness than RCC slabs, highlighting their enhanced structural rigidity and ability to resist deformation.
- In summary, PT slabs offer superior structural stability, efficiency, and cost-effectiveness compared to traditional RCC slabs.

REFERENCES

[1] Bahoria, Boskey Vishal, and Dhananjay K. Parbat. "Analysis and design of RCC and post-tensioned flat slabs considering seismic effect." *International journal of engineering and technology* 5.1 (2013): 10.

[2] Satwika, Vanteddu, and Mohit Jaiswal. "Comparison of RCC and Post-Tensioned Flat Slabs Using ETABS." *IOP Conference Series: Earth and Environmental Science*. Vol. 982. No. 1. IOP Publishing, 2022.

[3] Nighot[1], Shubham, Sopan Chinchole, Rohan Kapgate, and Sujesh D. Ghodmare[4]. "Analysis and design of post tension slab using ETABS software." (2020)..

[4] Chou, Chung-Che, and Jun-Hen Chen. "Seismic tests of post-tensioned self-centering building frames with column and slab restraints." *Frontiers of Architecture and Civil Engineering in China* 5 (2011): 323-334.

[5] Prajapati, Deepak, and Komal Bedi. "Post Tensioning Building Analysis Considering Seismic Zone V using Analysis Tools ETABS." (2019).

[6] www.reinforcementproductsonline.co.uk was first indexed by Google in January 2018

[7] https://sanfieldindia.in/browse/page/BuildingPostTensionedSlab

[8] Poptani, Yogesh, K. Divya Kotecha, and Lokesh Singh. "Analysis of Behavior of Post Tensioning Slab for

Various Framing Under The Influence of Lateral Load: A Review." *International Journal of Scientific Research in Civil Engineering* 4.1 (2020): 57-62.

[9] Navyashree, K., and T. S. Sahana. "Use of flat slabs in multi-storey commercial building situated in high seismic zone." *International journal of research in engineering and technology* 3.08 (2014): 439-451.

[10] Arkadiusz Mordak and Zbigniew Zee Manko (2016) “Effectiveness of Post-tensioned prestressed concrete road bridge realization in the light of research under dynamic loading”,“9th International conference, Bridge in Danube Baisn” Vol 1, ISSN 3463-4521

[11] Alpa Sheth“Effect of perimeter frames in seismic performance of tall concrete buildings with shear wall core and flat slab system” The 14th World Conference on Earthquake

[12] Rafal Szydlowski and Barbara Labuzek (2017),“Post-Tensioned Concrete Long-Span Slabs in Projects of Modern Building Construction”, “IOP Conf. Series: Materials Science and Engineering”, Vol 3, ISSN 4562-2132, pp 245.