A Critical Review on Structural Performance of Post-Tensioned and Reinforced Concrete Slab Systems with Raft Foundation Design in Multistorey Buildings

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Abstract—The study presents a comprehensive review of research focused on the comparative performance of post-tensioned (PT) and reinforced concrete (RC) slab systems, along with the analysis and design approaches for raft foundations in multistorey buildings. The reviewed literature spans analytical, experimental, and numerical studies using software such as ETABS and SAFE to assess parameters including cost, material efficiency, deformation, and seismic performance. Results across multiple studies indicate that post-tensioned slabs generally improved structural efficiency and cost-effectiveness for large-span and high-rise applications. The review highlights importance of integrating optimized PT systems and raft foundation systems for sustainable, cost-effective, and performance-based structural design.

Index Terms—Post-tensioned (PT), Flat slab, Raft, SAFE, Tendons, Cost Effective.

I. INTRODUCTION

The evolution of post-tensioned (PT) slab systems has emerged as a preferred solution for multistorey and long-span structures. The growing urban demand for high-rise and large-span buildings necessitates floor systems and foundation designs that minimize material usage while maintaining the serviceability, strength and structural stability.

Reinforced concrete (RC) flat slabs often require higher slab thicknesses and reinforcement quantities, leading to increased dead load and cost. Post-tensioned flat slabs, in contrast, employ high-strength steel tendons that induce compressive stress in concrete, counteracting tensile stresses and thereby permitting reduced slab thickness and longer spans. Several researchers have demonstrated that PT slabs can achieve up to 25–60% reduction in bending moments and shear forces compared to conventional slabs, with notable decreases in the concrete and the reinforcement quantities.

The application of advanced analytical tools such as ETABS and SAFE has enabled precise modeling of PT behavior under various loading conditions. These studies consistently show that post-tensioning not only improves load-carrying capacity but also enhances crack control, deflection characteristics, and seismic performance.

Parallel to slab advancements, foundation systems have also evolved to accommodate higher loads and complex soil conditions. The use of finite element-based design through software such as SAFE has simplified the design of raft foundations, enabling more accurate simulation and settlement behavior under different loads. When designed in conjunction with PT slab systems, they offer a holistic approach toward achieving structural efficiency, cost reduction, and enhanced seismic resistance.

The purpose of this review is to consolidate existing knowledge on PT slab systems and raft foundations, identify comparative outcomes, and highlight design trends, and performance parameters. This synthesis aims to guide structural engineers in adopting integrated post tensioned slab and raft foundation solutions for sustainable and optimized structural design.

II. CORRESPONDING LITERATURE

A. Comparative Analysis of RCC and Post-Tensioned Slabs

Omar Ahmad (2022)[1] has presented the financial comparative study between post-tensioned and reinforced concrete flat slab. The materials used were M30 grade concrete for post tensioning and M25 grade concrete for RCC flat slab. The steel bars used had yield strength of 400 Mpa in both cases. The thickness of RCC slab was considered as 32 cm. And post tensioned slab thickness was 26 cm. In post tensioned slab additional tendons were used. After designing and calculating the quantity of materials and costing, he graphically compared both the slabs and finally stated that the post tensioned flat slab proved to be economical that reinforced concrete flat slab.

Soubhagya Ranjan Rath et al. (2019)[2] has stated the comparative study on analysis and designing of post tensioned flat slab vs conventional RCC slab. Modelling of tall structure was done using ETABS software and further SAFE software was used for analyzing slabs and stated that concrete quantity in post tensioned slab is saved. Also, typical rebar quantities are reduced. The comparison of graphical results of story drifts of both structures was done and found out that story drifts are more in PT structure compared to RCC due to its flexibility in seismic loads. Also, PT flat slabs have 7% - 10% lower slab displacement than conventional flat slabs. Lastly it was concluded that, considering slab forces, PT flat slab results in almost 60% less force than compared to the normal conventional slab, slab steel quantity in PT slab gets decreased by 25% as compared to the conventional slab.

P.V.L. Narasinga Rao et al. (2018)[3] performed the cost analysis of two-way slab and post tension slab. A slab panel of size 5×9.38 m is designed as two-way slab and post tension slab as per provisions of respective IS codes. After comparative analysis, they stated that the depth of PT slab is 47.82% less than two-way slab. Also, the cement requirement of Post tension slab is 9% less than two-way slab, the requirement of fine aggregates for post tension slab is 18% less than two-way, for the coarse aggregate, post tension slab is 0.54% less than two-way slab. Quantity of Steel required for two-way slab is also 7% less than the post tension slab and the cost of Post tension slab is 15% less than that of two-way slab. Furthermore, they recommended to use post tensioned slab for multi-story structures which reduce cost of construction.

Osama Khalid Abdelaziz et al. (2021)[4] Evaluated the cost of Post-tensioned Slabs in multi-story buildings considering seismic effect. They analyzed G+12 multi-storey building designed by the two approaches: traditional flat slabs, and post tensioned slabs considering the seismic effects. The parameters considered in the parametric study was of various spans of 6 m, 8 m, and 10 m. These buildings are rested on a raft foundation with bearing capacity equal to 200 kN/m². The building was assumed to be in seismic zone III, soil class C is assumed as building rests on medium dense sandy soil with an importance factor of 1 and a response reduction factor of 5. Superstructure design was done using ETABS and SAFE to design raft foundation. After analyzing the results and comparing them with charts and graphs, they concluded that Post-tensioned PT buildings have better behaviour against seismic load also post-tensioned slabs have lower value for deflection than the traditional flat slab, post-tensioning slabs with spans over 6m offer direct reduction in construction duration by 25% to 37%.

Jnanesh Reddy R K et al. (2017)[6] have presented the comparative study of post-tensioned and RCC flat slab in multi-story commercial building. The structure is modelled using the ETABS, and the model considered is having basement, ground and 4 floors. Further they stated that concrete needed for R.C.C Flat Slab construction with edge beams is 330 m^3 and that for PT Slab with drop panels is 247 m^3. Also, the cost of steel required for the R.C.C Flat Slab construction is Rs. 39,15,751 /- and the cost of steel and tendons required for PT Slab construction is Rs. 34,45,148 /-. Hence, for the structure considered (commercial complex), the concrete and steel quantities required are much less in case of PT slab construction compared to R.C.C Flat Slab construction which concludes economical construction with PT Slab than with the conventional R.C.C. Flat Slab.

Shubham Nighot et al. (2020)[8] have done analysis and design of post tension slab using ETABS software. They selected rectangular plan with area of 1,438.97

sq.m. of G+7 story. The materials used are M30 grade concrete and steel of grade Fe 500. The methodology includes following steps, modelling structure in ETABS, defining material properties, defining section properties, assigning restraints, assigning of dead load and live load, analysis of structure, design of structure. After Analysis and design they concluded that, the structure may reduce the cost of construction because of lesser thickness of slab and as slab thickness is reduced the number of columns and beams required is less which results in less quantity of concrete and steel. Hence post tensioning method is the economical and proves more effective in case of slab with large span. For slabs having span more than 8 meters, post-tensioning is very effective and cost saving.

Nyome Tin (2019)[16] presented comparative study of quantity and cost on post tensioned slab and reinforced concrete slab in structures. They considered 16-storeyed reinforced concrete slab building and flat slab building with perimeter beams building; Maximum dimension - 110 ft × 110 ft; Location - Zone 2B; Ground floor height - 12 ft; Typical floor height - 10 ft. Loading considered is, after analysis of results, they concluded that, the quantity and cost of steel in PT structure is less by 16.01% than RC structure. Cost of column steel in PT slab building is higher than RC slab building but also the cost of beam steel in PT slab structure is less than the RC slab structure. Also, the quantity and cost of concrete in PT slab structure is 32.41% greater than RC slab structure. The total cost of PT slab structure is increased by 7.39% compared to the RC slab structure. The PT slab buildings are more popular according to the point of architectural view, the free design of space and reduction of construction time but their costs are more expensive than the RC slab buildings.

Maulik G. Kakadiya et al. (2016)[11] presented research on comparison of RCC and post tensioned flat slab with or without drop using software ADAPT-PT and ETABS. Specifications considered were story height: 3m, no of bay: 5, panel sizes: 6x6m, 7×7m, 8x8m, 9×9m, 10×10m, concrete grade for RCC and PT flat slab: m35 beam and slab:m35, concrete grade for pt: m35, strength of steel in RCC: 415 N/mm², post-tensioning details nominal diameter: 12.9 mm, nominal area: 98.7 mm², weight: 0.785 kg/m, strength of steel: 860 n/mm². After analyzing and representing

results in tabular form, the concluded that, for the 6x6m panel sizes, the cost is almost same so up to 6m panel size R.C.C flat slab is economical compared to all cases, for the 7×7m and 8×8m panel sizes, the cost is almost same so up to 7m panel size post tensioning slab without drop is economical, for the 9x9m panel size, the post tensioning slab with drop is economical. From both post-tensioned slab system building the post-tensioned flat slab with drop is more economical than the post-tensioned flat slab without drops. The quantity of prestressing steel is 4 Kg/m² for post-tensioned flat slab without drop and 3.2 Kg/m² for post-tensioned flat slab with drop. The reinforcing steel required for the post-tensioned flat slab with drop, post- tensioned flat slab without drop and reinforced concrete flat slab are 15 Kg/m², 20.15 Kg/m² & 25.15 Kg/m² respectively.

Er. Shubham R. Nikam et al. (2021)[18] have presented behavioral study of RCC slab, flat slab and post tensioned slab structures in severe earthquake prone areas. Methodology followed was, modelling in Etabs & assigning of various properties, further analysis of all three slabs under seismic zone III, IV, V. From the graphical representation, the story drift for post-tensioned slab is 1.11 times greater than rcc slab and flat slab. The value of post-tensioned slab for storey displacement is 2.89 times greater than rcc slab and flat slab. In seismic zone IV also post tensioned slab is 1.6 times greater than rcc slab and flat slab for storey drift. Hence, in seismic zone III and IV the post tensioned slab is more effective as compared to flat slab and rcc slab. And in seismic zone V the RCC slab is effective than flat slab and post tensioned slab.

Thayapraba M (2014)[20] has studied cost effectiveness of post - tensioned and reinforced concrete flat slab systems. The floor systems of RCC and Post Tensioning are analyzed using SAP and the limit state design of the slab systems are done according to the specifications given in IS456:2000, BS8110:1997, ACI318:2003 and IS1343–1983 respectively. No of storey considered was G+8; Storey height of 3.5 m; Panel sizes: (8×8) m, (9×9) m, (10×10) m, (11×11) m, (12×12) m; After analyzing he concluded that for all the panel sizes considered, post-tensioning floor systems have proved to be cost effective compared to Reinforced concrete floor systems. For the increase in the panel sizes, the cost is also increasing gradually.

The amount of concrete required for a floor is more for RCC flat slab while it is least for the post-tensioned flat slab floor system.

B.   Post-Tensioned Slab Modelling & Analysis

Ila Vamsikrishna et al. (2021)[5] analyzed and designed a commercial building with post-tensioning slab by using ETABS. Analysis is done for G+4 story plan. Upon analyzing with desired load patterns and cases along with load combinations, the results of bending moment, shear force and displacements are presented in tabular form and concluded that the maximum bending moment values decreases for post-tensioned flat slab for Ground floor. Also, it was observed that the drop in bending moment in post tensioned slab to RC slab is between 58 – 66%. The maximum shear force and displacement values are considerably less in PT flat slab as compared to RC flat slab and displacements decreased in post-tensioned flat slab.

Vanteddu Satwika et al. (2021)[17] compared RCC and post-tensioned flat slabs using ETABS software. Tendons are made to balance 80-60% of the dead weight. 270 grade steel tendons are used. Initial losses of 10% and final losses of 15% of the jacking force are assumed. Their study concluded that, flat slabs have a wide range of uses, but the fundamental disadvantage is the lack of punching shear capacity. Most flat slabs fail in shear, even if they have sufficient flexural capacity hence, Flat slabs are strengthened using post tensioning to achieve acceptable punching shear capability at lower depths. Depth can be safely reduced by the provision of drops. For very larger spans strengthening the flat slab by post-tensioning by the provision of drops can be very beneficial to obtain very less depths. Distributed tendons are more effective in obtaining lesser depths compared to the banded tendons. Support reactions are less in post-tensioned flat slab due to the reduction of dead weight, which results in less material requirement for construction. Hence cost of construction is reduced.

C.   Raft Foundation

Suman M. Sharma et al. (2014)[7] have compared raft foundation and beam and slab raft foundation for high rise building. They represented comparative study of analysis and design of raft foundation and beam and slab raft foundation for high rise building considering different structural configurations and with different load combinations such as dead load, live load, wind load, seismic load with different values of soil bearing capacity such as 180, 220 and 250 kN/m² considering all interacting factors. Quantitative Study has been carried out for different SBC and concluded that, in raft foundation concrete quantity is larger compared to beam & slab raft foundation. From the overall cost analysis of both types of foundations, it is concluded that the beam and slab raft foundations are economical and safe for the given values of S.B.C.

Zia-abe Deen. S. Punekar et al. (2017)[9] have presented analysis and design of raft foundation for 12 story structures. The methodology adopted was, ETABS modelling and analyzing using Response spectrum method, then exporting the axial loads at the base of the column to the SAFE V12 in F2K text format. Modelling the raft foundation in SAFE V12. And assigning the actual material properties. Strips to be drawn both in X and Y direction at an interval of 1ft keeping the strip width of 0.5 ft. After inspecting the results, they concluded that the mat/raft foundation is safe against punching shear or two-way shear i.e. the punching shear ratio is less than 1. Also, there will be a slight hogging deflection in the raft footing, but it will not affect the building and is within the limit.

Sunesra Shakira et al. (2020)[10] analyzed raft and pile raft foundation using SAFE software. The objectives were analysing behaviour of the piled raft foundation for the increments in the pressure load on the raft. To examine the behaviour of piled raft foundation ETABS 2016 and SAFE-12.3.2 is used. Further they defined various material, section properties and defined load combinations and analyzed the structure. Further they concluded that Pile with Raft foundation is economical when compared to a single pile foundation or Raft foundation. Analysis done by SAFE (ver.13.3.2) is very efficient and user friendly and software is developed for the analysis of raft using finite difference method, estimation of stiffness for soil and pile. Also piled raft foundation is adopted to reduce the total and differential settlement of foundations.

Devesh Ojha, et al. (2021)[12] have studied the structural design of raft foundation for 30 story high rise building using SAFE software for analysis and design of raft foundation. In their study they concluded that, for

loose soil bending moment is sagging in nature, over entire of raft. However, as soil stiffness increases tension zone is created. From the edge as we proceed toward center the intensity and extent of tension zone goes increasing. For loose soil, pressure distribution beneath the raft is lower at edge and goes on increasing towards the center. In the central zone, in between column, it remains almost constant. For medium soil, at the edge, pressure distribution is high and goes on reducing towards the center with very mild rate. For hard soil, pressure distribution at the edges is high, reduces under the edge columns and then after increases in the central part. The punching shear factors are less than 1 and settlement observed is less than 50 mm.

Joshna Manjareakar et al. (2018)[13] have analyzed and designed mat foundation using SAFE software for G+5 building. Specifications used are mat thickness 600 mm; Grade of Concrete M25; Grade of Steel Fe415; Bearing Capacity of Soil 100 KN/m2. When the mat foundation is subjected to axial and lateral loads, soil pressure is excreted on the mat at the interaction of soil and mat in upward direction. There for causing the displacement in the mat. The resultant displacements due lateral loads as compared to axial loads is negligible. After analysis they concluded that, the area of steel required for Dynamic loading is 37.6% more than the area of steel required for Static loading of the mat foundation. Also, it is observed that the displacement in the mat foundation for the applied lateral load is very small. And the area of steel required for Dynamic load is 37.6% more than the steel required for Static loading.

Amit Dhage et al. (2023)[14] has presented comparative analysis of raft, pile & piled raft foundation using designing software. In their research, they used Safe software for design and analysis of Raft. Specifications adopted are as follows, plan of building: 20m x 20m; total height of building: 60m; floor height: - 3m; pile size: 500mm; thickness of raft: 1500mm; thickness of raft of pile raft: 1000mm; thickness of pile cap:1000mm; distance between piles: - 1450mm; depth of pile 10m; SBC of soil-100 kN/m^2. After analysis, they concluded that the Pile and Raft foundation is more cost-effective than a single pile or just a raft foundation. When piles are installed beneath the raft base, the load sharing between the pile and the raft results in progressive soil settlement decrease.

Nabanita Sharma et al. (2015)[15] has studied structural design of raft foundation based on geotechnical analysis. They adopted foundation length as 30m and breadth 25m. Columns are provided at a center-to-center distance of 5m for both longitudinal and transverse directions. The total number of columns at the exterior side is 22 and the total number of columns for interior side is 20. Further it has been considered that the load carried by the exterior columns is 500KN and load carried by interior columns is 700kN. The size of the columns is considered to be 400mm × 400mm. After design it was concluded that soil undergoes local shear failure. Also, the basics of the design of the raft foundation along with its reference to various geotechnical aspects are studied and implemented in the design required to be completed.

Dr. Nezar Hassan Mohamed et al. (2018)[19] designed a suitable raft foundation for several sites in maysan province using a program safe. Raft foundation has been modelled in SAFE software. Effective bearing stress for the soil qall = 60 kN/m^2; Sub-grade modules (60×3) ×40=7200 KN/m3; Concrete strength of raft 25 Mpa; Reinforcement Steel strength 415 Mpa; Thickness of Slab = 600mm. In SAFE software, the raft is automaticity divided to different strips. Each direction has a column strip and middle strips. The moments analyzed by SAFE software are the strip moments per one meter width of the strip. And in this project, the punching shear has been checked using the SAFE software and all the factors are less than 1. This means that the load shear is less than the raft shear resistance.

Harpreet Singh et al. (2023)[21] studied linear dynamic analysis and design of raft foundation considering long-term deflection and uplift check. The various responses of raft foundations were investigated in terms of uplift pressure, settlement, and punching shear. In this study, they have taken a G+7 story building for which a raft foundation is to be designed. Support reactions are imported from ETABS to SAFE software. The Building Plan dimensions are 20×20m. and story height is 3m. After modelling, analyzing and designing they concluded that, CSI Safe makes the foundation design very simple and it gives the

reinforcement design based on strip design or on basis of the finite element method. Also, weight of the foundation should be enough to balance the uplift pressure. And to keep long-term deflection within limits we have to increase the area or thickness.

Harshil Vaghani et al. (2025)[22] have studied the performance of raft foundations resting on soft soil and subjected to different building geometries rectangular, and circular. Their study utilized ETABS for modelling superstructures and SAFE for raft analysis, focusing on settlement, soil pressure distribution, and punching shear behavior. They also incorporated IS 456:2000 and IS 2950 guidelines for design and soil structure interaction principles. Further they concluded that the settlements, the soil pressures, and punching shear stresses were all within permissible limits for the models analyzed. They emphasized that raft foundations are efficient for low-bearing-capacity soil, and finite element modelling significantly enhances accuracy in predicting raft performance.

Aniket Patale et al. (2025)[23] have studied the design and analysis of flooring systems and foundations for a G+8 multi-storey building using CSI SAFE software, integrating ETABS for seismic evaluation in India's Zones II and V. Their technical findings reveal that in Seismic Zone II, maximum settlement reached 10.8 mm with soil pressures up to 130 kN/m² (soil bearing capacity 250 kN/m²), while Zone V showed higher values of 17 mm settlement and 440 kN/m² pressure (soil bearing capacity 450 kN/m²); both remained within permissible limits of 50 mm settlement per IS 456:2000 and geotechnical standards, with maximum displacements at the structure's center and peak pressures at outer edges under raft foundation. In conclusion they stated that CSI SAFE proves efficient and user-friendly for raft foundation analysis, also the higher seismic zones demand increased structural member dimensions and soil bearing capacities to ensure stability as per relevant IS codes.

III. CONCLUSION

This review study presents a comparative evaluation of post-tensioned (PT) slab systems and reinforced concrete (RC) slab systems along with raft foundation design for multistorey buildings. Based on findings from various analytical and numerical studies using ETABS and SAFE software, post-tensioned slabs demonstrate improved structural performance through reduced bending moments, deflections, slab thickness, and material consumption compared to conventional RC slabs. These advantages contribute to lower dead load, enhanced serviceability, and overall cost efficiency, particularly for large-span and high-rise structures.

The reviewed studies also indicate that raft foundations provide effective load distribution and settlement control for multistorey buildings, especially on soils with low to moderate bearing capacity.

Overall, the combined application of post-tensioned slab systems and raft foundations offer a sustainable, economical, and structurally efficient solution for modern multistorey construction.

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