



# A Comprehensive Review on Comparative Analysis of Steel Space frame and Post-Tension System

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## Abstract—

The requirement for large-span structural systems has grown considerably in contemporary architecture, especially in facilities such as shopping malls, educational institutions, auditoriums, exhibition centers, airports, and sports complexes where column-free spaces are essential. In such applications, the selection of an appropriate structural system is governed by factors like structural efficiency, optimal material utilization, and overall cost-effectiveness.

This study provides a comparative evaluation of Steel Space Grid systems and RCC Post-Tensioned (PT) systems for large-span applications, emphasizing their structural behavior, efficiency, and practical suitability. Space frame systems, which function as three-dimensional truss configurations, offer high stiffness, efficient load transfer, and significant architectural flexibility; however, they often require intricate joint detailing and involve higher fabrication and erection costs. In contrast, post-tensioned structures employ prestressing tendons to effectively limit deflection and control cracking, thereby reducing self-weight and allowing for more slender structural members, leading to improved material efficiency. The comparative assessment is conducted based on parameters such as span capability, structural performance, construction methodology, economic feasibility, and serviceability criteria. The results indicate that space frame systems are more suitable where architectural adaptability and uniform load

distribution are priorities, while PT systems prove to be more economical and efficient for larger spans with better deflection control. Overall, the study underscores the importance of selecting structural systems based on span requirements to achieve optimal performance and cost efficiency in large-span construction projects.

**Keywords—** Space frame system, Post-tensioned (PT) system, Prestressed concrete, Structural performance, Deflection control.



## I. INTRODUCTION

The increasing demand for large-span structures in modern construction has necessitated the development and adoption of efficient structural systems capable of providing unobstructed spaces while ensuring safety, serviceability, and economy. Structures such as auditoriums, airports, exhibition halls, commercial complexes, and industrial buildings require long spans with minimal intermediate supports, making system selection a crucial aspect of structural design. Among the various available systems, Steel Space Grid structures and RCC Post-Tensioned (PT) systems have gained significant attention due to their distinct advantages in addressing large-span requirements.

Steel space grid systems, as discussed by Ramaswamy, Eekhout, and Suresh (2014), are three-dimensional frameworks that efficiently distribute loads through axial forces, resulting in high stiffness and redundancy. Their adaptability to complex geometries and suitability for large spans make them a preferred choice in architecturally demanding projects. Recent studies, such as Zhong et al. (2025), have further enhanced the efficiency of space grid structures through optimization techniques considering load combinations, topology, and member sizing. Additionally, nonlinear behavior and geometric imperfections in space truss systems have been explored by Ojha, Verma, and Patel (2022), highlighting the importance of accurate modeling in predicting structural performance.

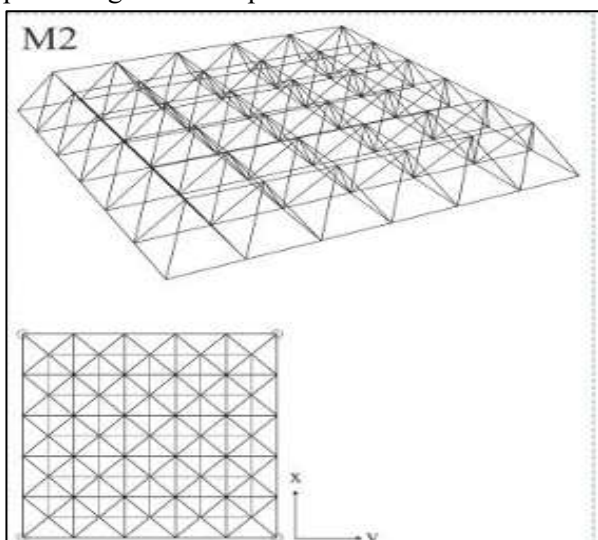


Fig. 1 steel space grid [Shahbazi 2024 etc.]

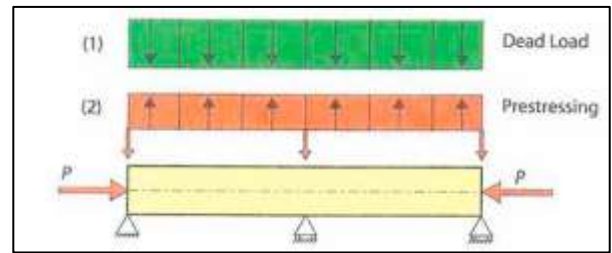


Fig.2 Post tension beam [Török etc. 2019]

On the other hand, RCC post-tensioned systems have been widely studied for their ability to improve structural efficiency by introducing prestressing forces that counteract tensile stresses. Foundational work by Raju (2018) emphasizes the principles of prestressed concrete, while research by Szydłowski and Labuzek (2017) and Török, Puskás, and Virág (2019) demonstrates the effectiveness of PT slabs in achieving longer spans with controlled deflection and reduced cracking. Experimental and numerical investigations by Jancy, Stolarski, and Zychowicz (2023) and Han, Zhang, Liu, and Wang (2023) further confirm the enhanced load-carrying capacity and serviceability performance of prestressed members. Moreover, advancements such as the use of steel fiber reinforced concrete in PT systems, as explored by Lin, Zhao, and Chen (2025), indicate ongoing improvements in material performance.

Several comparative studies have also been conducted to evaluate the relative performance of conventional RCC, PT systems, and steel structures. Parbat, Bahoria, and Deotale (2018) and Patel and Chourasia (2021) highlighted the advantages of PT slabs over conventional RCC in terms of reduced deflection and material consumption. Similarly, Ahmad (2021) and Divya and Murali (2019) examined the economic aspects, indicating that PT systems can be more cost-effective for longer spans, whereas steel systems may be advantageous depending on span and design requirements. Studies using analytical tools such as ETABS, including Nighot, Chinchole, Kapgat, and Ghodmare (2020), further support the practical applicability of PT systems in modern construction.

Despite extensive research on individual systems, limited literature is available that comprehensively compares steel space grid and RCC post-tensioned systems specifically for large-span applications. The selection between these systems often depends on



multiple factors such as span length, structural performance, construction methodology, and economic feasibility, as guided by design standards like IS 456:2000 (Bureau of Indian Standards, 2000), IS 800:2007 (Bureau of Indian Standards, 2007), and IS 1343:2009 (Bureau of Indian Standards, 2009).

Therefore, this review paper aims to critically analyse and synthesize the existing literature on the comparative analysis and design of Steel Space Grid and RCC Post-Tensioned systems for large-span structures. The objective is to identify key performance parameters, evaluate advantages and limitations of each system, and provide a clear understanding to assist engineers and researchers in selecting the most suitable structural system for efficient and economical large-span construction.

## II. LITERATURE REVIEW

The development of efficient structural systems for large-span applications has been a significant area of research in structural engineering. Various studies have investigated the performance, design, and optimization of Steel Space Grid systems and RCC Post-Tensioned (PT) systems, focusing on parameters such as deflection, load-carrying capacity, cost efficiency, and serviceability.

Steel space grid structures have been widely recognized for their ability to efficiently distribute loads through three-dimensional truss action. Ramaswamy, Eekhout, and Suresh (2014) provided a comprehensive understanding of the analysis, design, and construction of space frame systems, highlighting their structural redundancy and suitability for long-span applications. Further advancements in optimization techniques have been explored by Zhong et al. (2025), who developed methods considering multiple influencing factors such as load combinations, grid topology, and member sizing to enhance structural efficiency. Similarly, Shahbazi et al. (2024) applied genetic algorithm-based optimization to double-layer space structures, demonstrating improvements in weight reduction and structural performance. The nonlinear behavior of space truss systems, including the influence of geometric imperfections, has been studied by Ojha, Verma, and Patel (2022), emphasizing the need for accurate modeling in design.

On the other hand, RCC post-tensioned systems have gained prominence due to their ability to control

deflection and cracking while enabling longer spans with reduced member sizes. The fundamental principles of prestressed concrete have been well established by Raju (2018), forming the basis for modern PT design. Studies by Szydłowski and Labuzek (2017) and Török, Puskás, and Virág (2019) highlighted the application of post-tensioned slabs in modern construction, demonstrating improved serviceability and structural performance. Experimental and numerical investigations conducted by Jancy, Stolarski, and Zychowicz (2023) and Han, Zhang, Liu, and Wang (2023) confirmed that prestressed concrete members exhibit higher load-carrying capacity and better flexural performance compared to conventional reinforced concrete. Additionally, Lin, Zhao, and Chen (2025) explored the use of steel fiber reinforced concrete in PT slabs, indicating further enhancement in structural behavior.

Several researchers have focused on the comparative performance of different slab and structural systems. Parbat, Bhorja, and Deotale (2018) and Patel and Chourasia (2021) compared conventional RCC slabs with post-tensioned slabs and reported significant reductions in deflection and material consumption in PT systems. Dobariya, Agrawal, and Patel (2017) further examined bonded and unbonded post-tensioning systems, concluding that unbonded systems provide better performance for long-span beams. Priyanka and Ramesh (2022) analyzed slab deflection under various configurations, reinforcing the advantages of prestressing techniques in controlling deflection. Ahmad (2021) conducted a financial comparison and concluded that PT slabs are more economical than conventional RCC slabs for longer spans.

In addition to PT systems, comparative studies between steel and RCC structures have also been carried out. Divya and Murali (2019) analyzed the design of steel and RCC frame structures based on span length and found that steel structures are advantageous in terms of reduced structural weight and faster construction, whereas RCC systems offer cost benefits depending on project conditions. The behavior of post-tensioned structural members under various loading conditions has been extensively studied by Soudki, Green, and Bisby (2012) and King Saud University Researchers (2017), highlighting their improved performance in terms of strength and serviceability.

The application of analytical tools such as ETABS has



been widely adopted in structural analysis and design. Nighot, Chinchole, Kapgat, and Ghodmare (2020) demonstrated the effectiveness of ETABS in analysing post-tensioned slab systems, enabling accurate prediction of deflection and stress distribution. Similarly, Elvin and Sinatra (2022) investigated the role of prestressed beam systems in enhancing long-span structural performance.

Design standards also play a crucial role in guiding structural design practices. The Bureau of Indian Standards provides comprehensive guidelines through IS 456:2000 (Bureau of Indian Standards, 2000) for reinforced concrete, IS 800:2007 (Bureau of Indian Standards, 2007) for steel structures, and IS 1343:2009 (Bureau of Indian Standards, 2009) for prestressed concrete, ensuring safety, durability, and serviceability of structures.

Despite the extensive body of research on individual systems, there is a noticeable lack of direct comparative studies between steel space grid and RCC post-tensioned systems under similar conditions. Most studies focus either on optimization of space grids or performance enhancement of PT systems independently. Therefore, a comprehensive comparative analysis considering parameters such as span capacity, deflection behaviour, vibration characteristics, structural weight, and cost is essential to establish clear guidelines for system selection in large-span structures.

### III. METHODOLOGY

The reviewed literature demonstrates a combination of analytical, numerical, and optimization-based methodologies to evaluate the performance of different structural systems, particularly reinforced concrete (RCC), post-tensioned slabs, and grid structures. The methodologies primarily focus on comparative design approaches, parametric studies, and advanced computational techniques to assess structural efficiency, serviceability, and economy.

In one approach, methods such as load balancing and equivalent frame analysis are used to design flat slabs, where prestressing forces are introduced to counteract a significant portion of the applied loads, thereby reducing bending stresses and deflections. Parametric variations, especially in span lengths, are considered to study their influence on slab thickness, tendon requirements, prestressing force, and overall structural

behavior. Additionally, case study-based methodologies are employed in which multi-story buildings are designed under different structural configurations (such as RCC slabs, flat slabs, and post-tensioned systems), followed by comparative evaluation based on serviceability criteria and cost efficiency. The slab design was carried out using the Load Balancing Method and the Equivalent Frame Method in which 65–80% of the dead load was balanced to minimize bending stresses. Design assumptions based on prestressed concrete behavior and crack control. A comparison was made between RCC and PT slab thicknesses to evaluate slenderness and building height reduction, while material consumption and construction benefits of PT slabs were also checked (Parbat, Bahoria, & Deotale, 2018).

[Another study employs a numerical modeling and simulation-based methodology using ETABS software to compare conventional slab, flat slab, and post-tensioned flat slab systems. A G+10 multi-story building is modeled with defined geometric dimensions, material properties, and loading conditions as per Indian standards. Each slab system is separately modeled by assigning appropriate section properties and, in the case of post-tensioning, additional prestressing parameters. The study involves structural analysis and design of all three systems, followed by extraction of results such as bending moments, shear forces, and material quantities. A comparative evaluation is then performed to assess differences in structural behavior, efficiency, and material consumption across the slab systems (Patel & Chourasia, 2021).

In a third study, the methodology follows a design-oriented approach focusing on the application of post-tensioning in flat slabs for public buildings. The approach begins with defining slab geometry and span-to-depth ratios based on design guidelines, followed by the division of slabs into column strips for simplified analysis. The prestressing force is determined by balancing applied loads using tendon profiles, which generate upward forces to counteract gravity loads and reduce bending moments. Material selection, including concrete grades and prestressing steel properties, is incorporated into the design process. Comparative case studies are carried out for different span lengths to evaluate material efficiency and structural performance, highlighting the economic and functional advantages of post-tensioned systems (Török, Puskás, & Virág, 2019).



Another research methodology involves developing parametric models of six different flat double-layer space structure geometries using computational design tools, followed by performing both single- and multi-objective optimization to evaluate structural performance in terms of mass and deflection. Key design variables—such as the number of constitutive units, structural depth, and member cross-section diameter—are systematically varied within defined constraints, while structural behavior is analyzed under multiple load combinations using simulation software. A genetic algorithm is employed to iteratively search for optimal solutions by minimizing cost functions (structural mass and/or deflection) while satisfying geometric and behavioral constraints. Additionally, sensitivity analysis is conducted by independently varying each parameter to assess its influence on performance outcomes, thereby providing a comprehensive understanding of the relationship between design variables and structural efficiency (Shahbazi, Abdkarimi, Ahmadinejad, Mokhtari Kashavar, Fotouhi, & Pedrammehr, 2024).

#### IV. RESULTS AND DISCUSSION

The comparative evaluation of different floor systems indicates that post-tensioned flat slabs provide the most economical solution among all considered alternatives, primarily due to reduced slab thickness, lower concrete consumption, and faster construction time. In comparison, reinforced concrete flat slabs exhibit approximately 12.5% higher thickness and around 27% greater cost, highlighting the efficiency of prestressing. Although post-tensioned flat slabs require slightly higher prestressing steel (about 4 kg/m<sup>2</sup>), they significantly reduce conventional reinforcement compared to other systems, particularly beam-supported configurations where higher reinforcement is needed due to load transfer through beams. Additionally, post-tensioned flat slabs minimize overall concrete usage and allow greater floor-to-floor height due to the absence of beams, improving architectural flexibility. Construction duration is also reduced because early formwork removal is possible, further contributing to cost savings. Overall, these factors demonstrate that post-tensioned flat slab systems offer superior structural, economic, and functional advantages over conventional RCC and beam-supported slab systems

(Parbat, Bahoria, & Deotale, 2018).

TABLE 1  
RATE ANALYSIS FOR THE CASES CONSIDERED

Item	Concrete (m <sup>3</sup> )	Reinforcing steel (Kg)	Prestressing steel (Kg)	Form work	Rate per sqm
PT flat slab	507.52	31659.56	8400	2100	Rs. 2800/-
RCC flat slab	549.69	85550.78	----	2100	Rs. 3600/-
PT slab with RCC beam	641.33	42271	6720	2100	Rs. 3200/-
RCC slab with beam	626.31	86701.2	----	2100	Rs. 3800/-

(Rate of concrete=4400/-per m<sup>3</sup>, Rate of steel=50/-per kg, Rate of form work=400 /-), Rate of prestressing steel=130/-per kg)

Using ETABS software to analyze a G+10 commercial building, this research compares the material consumption of conventional, flat, and PT flat slabs. The discussion focuses on the weight of concrete required: while a conventional slab system utilizes approximately 42,890.01 kN of concrete for beams, a flat slab system (including PT) dramatically reduces this to 2,271.38 kN. The study notes that PT methods are increasingly popular in India for designing safe and economic structures, though they require more rigorous safety measures for shear and deflection. The authors conclude that the PT flat slab is the most viable option for reducing the overall material weight and cost in multi-story developments. Concrete amount is reduced in post-tensioning slab rather than normal slab, and flat slab. The amount of concrete is reduced by 29% in PT slab rather than conventional flat slab and 41% is reduced in concrete compared with normal slab (Patel & Chourasia, 2021).

This paper focuses on the material economy of unbonded PT flat slabs for spans ranging from 7 to 10 meters, identifying a direct economy of at least 10%. The results demonstrate that as the span increases, the price difference between RC and PT slabs grows: for a 7-meter span, the price difference is 10.27% (€2,652), increasing to 16.36% (€11,450) for a 10-meter span. The discussion emphasizes that PT slabs reduce the total weight of the structure, which in turn positively influences the design of vertical bearing elements and foundations. For optimal economy, the authors recommend a minimum precompression effort of 0.7 to 0.86 MPa and note that the system is most efficient for buildings with spans larger than 7 meters where openings do not vary significantly (Török, Puskás, & Virág, 2019).

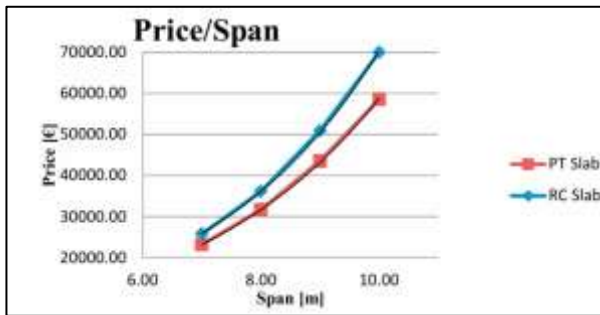


Fig. 3 Price comparison [3]

This research utilizes a genetic algorithm to compare the structural performance and material efficiency of six diverse flat double-layer grid geometries (labelled M1 to M6). The multi-objective optimization results, aimed at minimizing both mass and deflection, identify the semi-octahedron upon a square grid (M2) as the most efficient configuration, achieving a minimum overall structural mass of 15,093.9 kg under its critical load combination. In contrast, the hexagonal pyramid upon a honeycomb grid (M1) exhibits the maximum structural mass but provides the lowest maximum deflection, while models M3 and M6 show significantly higher deflections because their constitutive units do not form a stable full pyramid shape. Single-objective optimization, which focuses solely on mass with a deflection constraint of  $L/200$  (5 cm), further confirms the superiority of the M2 model, reducing its mass to approximately 5,745 kg under specific load conditions. Sensitivity analyses indicate that the number of constitutive units and cross-section diameter are the most critical design variables influencing the structural mass (Shahbazi, Abdkarimi, Ahmadinejad, Mokhtari Kashavar, Fotouhi, & Pedrammehr, 2024).

## V. CONCLUSION

The comprehensive review of analytical, numerical, and optimization-based studies clearly establishes that post-tensioned flat slab systems and optimized structural configurations offer significant advantages over conventional reinforced concrete systems. The findings consistently indicate that post-tensioned slabs achieve superior performance in terms of reduced slab thickness, lower self-weight, and improved control of deflection and cracking. The incorporation of prestressing forces effectively counteracts applied loads, leading to reduced internal forces and enhanced serviceability. Moreover, numerical studies using ETABS confirm that post-tensioned systems require less concrete and reinforcement, thereby improving overall material efficiency and reducing the load on

supporting elements such as columns and foundations.

In addition to slab systems, the application of advanced optimization techniques in grid and space structures demonstrates substantial improvements in structural efficiency. Methods such as topology optimization enable optimal material distribution, resulting in increased stiffness and enhanced load-carrying capacity while minimizing material usage. The inclusion of stability constraints further improves structural safety, making optimized systems more reliable under complex loading conditions. These approaches highlight the growing importance of computational techniques in modern structural engineering design.

From an economic and practical perspective, post-tensioned flat slabs emerge as the most efficient solution among various floor systems due to their lower construction cost, reduced material consumption, and faster construction cycle. The ability to achieve larger spans without beams also enhances architectural flexibility and increases usable space. However, for very large spans and complex geometries, advanced systems such as optimized grid structures may provide better performance, particularly when stability and load distribution become critical design considerations.

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