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POST TENSION DESIGN OF SLAB AND BEAM

Aniket Raut[1], Vaibhav Pawar[2] PROF.PRATIBHA PATIL[3]
(Civil Engineering, VIVA Institute of Technology/ Mumbai University, India)

Abstract : *This project presents the design and analysis of post-tensioned (PT) beams and slabs using ADAPT Builder software, focusing on enhancing structural efficiency, durability, and serviceability. Prestressing introduces compressive forces in concrete members prior to loading, effectively controlling deflection, cracking, and material usage. Both bonded and unbonded post-tensioning systems are explored, alongside pre-tensioning methods, to evaluate their performance in beams and slabs of various spans.*
A comprehensive literature survey was conducted, and data on concrete grade, steel properties, beam and slab geometry, and loading conditions were collected in accordance with IS 1343:2012 and IS 456:2000. The PT members were modeled in ADAPT Builder, and analysis was performed to determine bending moments, shear forces, tendon stresses, and deflections. Optimization of tendon profiles and prestress forces ensured compliance with Ultimate and Serviceability Limit States, while minimizing material usage.
The study demonstrates that post-tensioning allows longer spans, reduced slab thickness, and improved crack control compared to conventional reinforced concrete. The project highlights the advantages of software-assisted design, enabling accurate, efficient, and code-compliant solutions. Future work includes BIM integration, AI optimization, sustainable materials, and automation, emphasizing the evolving role of PT technology in modern civil engineering.

Keywords *- Post-tensioned concrete, slab and beam design, structural analysis, tendon layout, prestressing, load optimization, deflection control, moment and shear calculation, construction efficiency, serviceability.*

1. INTRODUCTION

Prestressing is an advanced technique used in structural engineering to improve the performance and load-carrying capacity of concrete members. In conventional reinforced concrete structures, cracks develop when the tensile stresses exceed the concrete's tensile strength. Prestressing overcomes this limitation by introducing internal stresses in the member before it is subjected to external loads. This pre-applied compression counteracts the tensile stresses developed during service, thus enhancing the structure's strength and durability.

The concept of prestressing was introduced to make concrete, which is naturally strong in compression but weak in tension, more efficient as a structural material. By applying tension to steel tendons before or after the concrete is cast (known as pre-tensioning or posttensioning, respectively), the structure achieves better control over deflection, cracking, and material usage.

Prestressed concrete is widely used in bridges, multi-storey buildings, water tanks, industrial floors, and other heavy-duty structures where longer spans and higher load capacity are required. It allows for slender, lighter, and more aesthetic structures without compromising on strength and safety. Moreover, prestressing enhances the service life of structures by reducing maintenance costs and improving structural integrity under varying load conditions.

Overall, the introduction of prestressing has revolutionized the field of concrete construction, making it a vital part of modern civil engineering design and analysis.

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Figure 1.1: Introduction to Prestressing

1.1.2. Types of Prestressing

Prestressing can be achieved in two main ways: pre-tensioning and post-tensioning. In pretensioning, the steel tendons are stretched before casting the concrete, and the concrete bonds to the tendons as it cures. This method is commonly used for precast elements such as beams, slabs, and girders. In contrast, post-tensioning involves stressing the steel tendons after the concrete has hardened. Post-tensioning allows more flexibility in design, as tendons can be placed along complex profiles, and it is commonly used in cast-in-place structures. Posttensioning itself can be further categorized into bonded and unbonded systems, depending on whether the tendons are permanently bonded to the concrete.

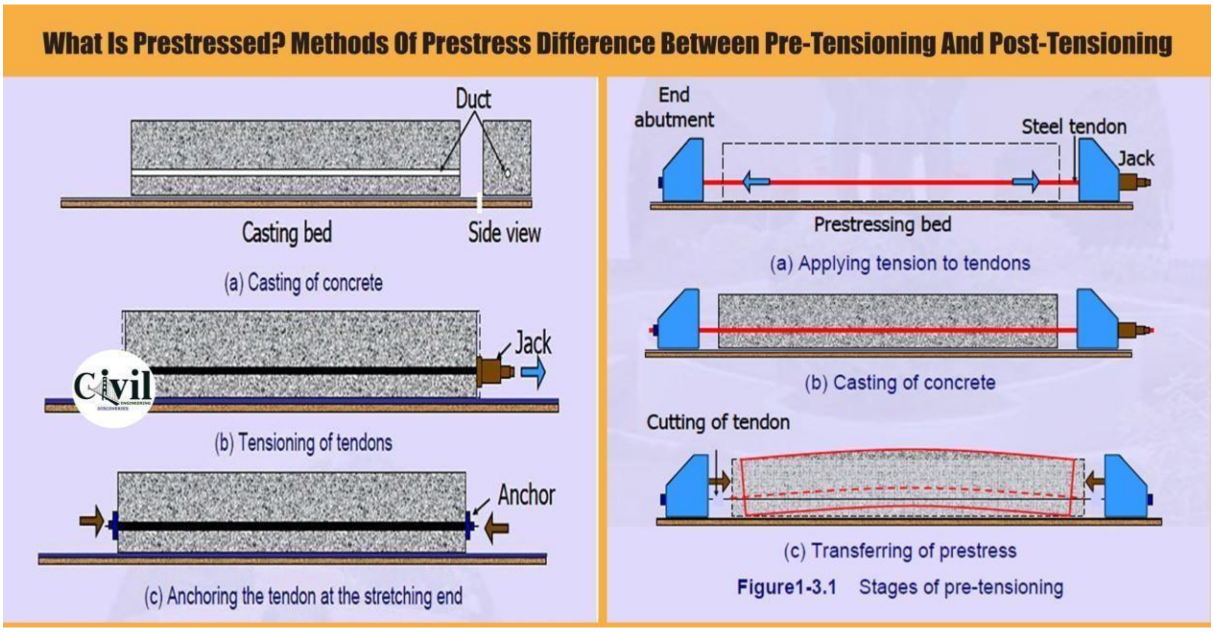

Figure 1.2: Type Of Prestressing

1.3. Post-Tensioning Methods

Bonded post-tensioning involves placing tendons inside ducts and grouting them after tensioning. The grout protects the steel from corrosion and ensures a good bond with the surrounding concrete, improving overall structural performance. Bonded PT systems are preferred for long-span bridges and high-rise building slabs due to their durability and stiffness. Unbonded post-tensioning, on the other hand, uses tendons coated with grease and placed inside plastic sheaths, leaving them free from the surrounding concrete. Unbonded systems are easier to install and repair, and they are often used in residential slabs and industrial floors. While bonded systems offer better corrosion protectioTypen, unbonded systems offer flexibility and simplicity in construction.

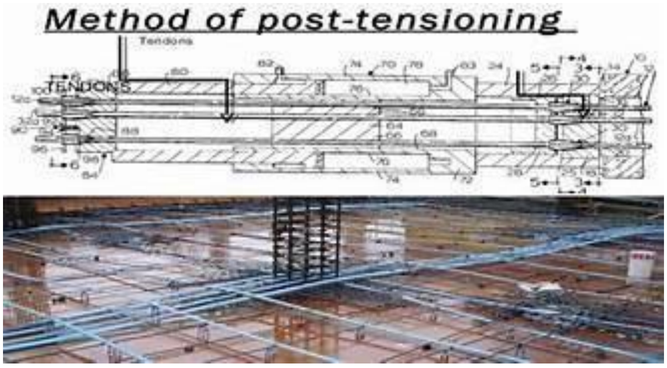

Figure 1.3:Method of post-tensioning

1.2.1 Types of Post-Tensioning
Post-tensioning is one of the most widely used prestressing techniques where the tendons are tensioned after the concrete has hardened.
It can be classified into two types based on the bond between the concrete and the tendons:

1. **Bonded Post-Tensioning**
2. **Unbonded Post-Tensioning**

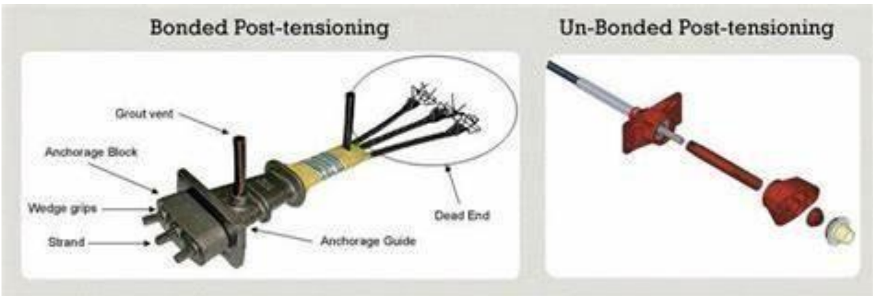

Figure 1.4: Type of Post-Tensioing

1.2.2 Bonded Post-Tensioning
In the bonded post-tensioning system, **steel tendons (cables or strands)** are placed inside metal or plastic ducts that run through the concrete member before casting. Once the concrete gains sufficient strength, the tendons are tensioned using hydraulic jacks. After the desired prestressing force is achieved, the ducts are filled with cement grout to bond the tendons permanently to the surrounding concrete.

This bonding ensures that the prestressing force is uniformly distributed along the length of the member. It also provides excellent protection against corrosion and improves the overall stiffness and durability of the structure. Bonded post-tensioning is commonly used in bridges, girders, and heavy structural members, where long spans and high strength are required.

Advantages:

- Better crack control and load transfer
- Enhanced corrosion protection due to grouting

- Suitable for long-span bridges and large beams
- Improved structural stiffness and stability

Figure 1.4 : Bonded Post-Tensioning

1.2.3 Unbonded Post-Tensioning

In the unbonded post-tensioning system, the steel tendons are not bonded to the concrete. Each tendon is coated with grease or corrosion-inhibiting material and enclosed in a plastic sheath to prevent direct contact with concrete. After the concrete hardens, the tendons are tensioned using hydraulic jacks and anchored at both ends only.

Since there is no bond between the steel and the concrete, the prestressing force is transferred only at the anchorages. The tendons can move freely within the concrete, which allows for easy adjustment and replacement if required. This system is widely used in floor slabs, parking decks, bridges, and water tanks, where flexibility and ease of construction are essential.

Advantages:

- Easy installation and tensioning
- Lower cost due to no grouting
- Tendons can be inspected or replaced
- Ideal for slabs and lightweight structures

Figure 1.5 : Unbonded Post-Tensioning

1.3 Pre-Tensioning

Pre-tensioning is a method of prestressing in which the steel tendons or wires are tensioned before the concrete is placed. This technique is commonly used in precast concrete construction where members are manufactured in a controlled factory environment.

In this process, high-strength steel wires or strands are stretched between fixed abutments on a casting bed. The tendons are tensioned to a predetermined force using hydraulic jacks. Once the tendons are properly tensioned, concrete is poured around them and allowed to harden. After the concrete gains sufficient strength, the tension in the steel is gradually released. The bond between the hardened concrete and the steel transfers the prestressing force to the concrete, placing it in a state of compression.

This pre-compression significantly improves the concrete's resistance to tensile stresses, reducing the chances of cracking and enhancing the member's load-carrying capacity. Pretensioning ensures uniform prestress distribution and superior quality control since the process is performed under factory conditions.

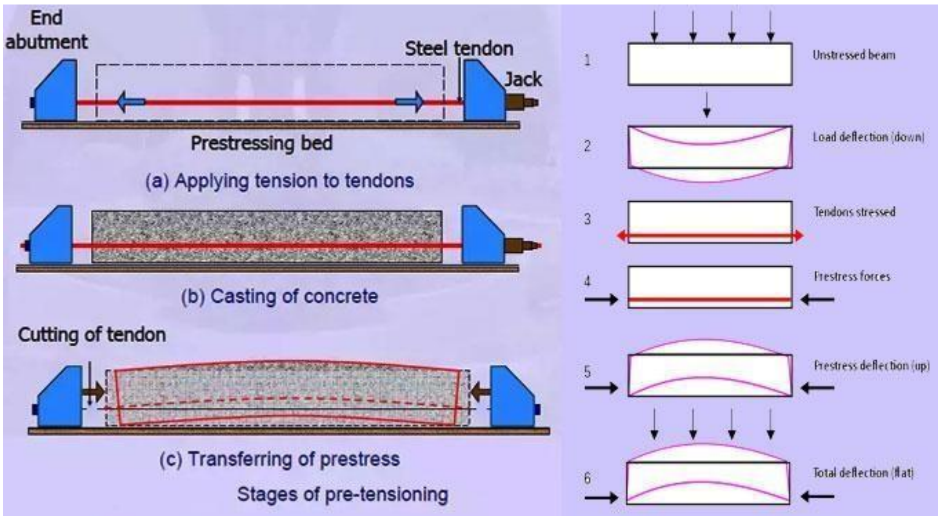

Figure 1.6: Pre-Tensioning

1.2 APPLICATION OF PRESTRESS

1.2.1. Buildings:

In multistorey and commercial buildings, prestressed concrete is widely used for beams, floor slabs, and girders. It allows architects and engineers to design larger open spaces without the need for many internal columns, making the interiors more flexible and spacious. The posttensioned floor system reduces slab thickness, which decreases the overall dead load and lowers the cost of foundations. Prestressing also minimizes cracks due to shrinkage and temperature changes, providing smoother and more durable floors. The technique ensures structural safety and long-term performance while improving the building's aesthetic appearance and functionality.

1.2.2. Bridges:

Prestressed concrete is one of the most preferred materials for bridge construction because it offers strength, stability, and long spans with fewer supports. Both pre-tensioned and posttensioned girders are used in highway bridges, flyovers, and railway bridges. The use of prestressing reduces material consumption while providing higher load-carrying capacity. It also improves the bridge's ability to resist vibrations, fatigue, and temperature variations caused by continuous traffic movement. Additionally, prestressed bridges require less maintenance and have a longer service life, making them a cost-effective and sustainable solution for infrastructure projects.

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1.2.3. Water Tanks and Reservoirs:

Prestressing is used in circular and rectangular water tanks, silos, and reservoirs where the structure must resist internal water pressure. The circumferential prestressing keeps the walls in compression, preventing the formation of tensile cracks that could cause leakage. This ensures water-tightness and maintains the structural integrity of the tank over time. Prestressed concrete tanks also require less steel reinforcement, making them more economical. They are durable, resistant to corrosion, and have a long lifespan with minimal maintenance. Such tanks are widely used for municipal water supply, irrigation, and industrial storage.

1.2.4. Pavements and Runways:

Prestressed concrete pavements and airport runways are designed to handle heavy wheel loads from vehicles and aircraft while maintaining a smooth and crack-free surface. Prestressing reduces tensile stresses caused by temperature changes, shrinkage, and repeated loading. As a result, the pavement remains durable and requires less maintenance over its service life. The joints between slabs are minimized, which improves driving comfort and safety. This method is ideal for highways, industrial floors, container yards, and airstrips where high performance and longevity are essential. Prestressed pavements also reduce downtime due to fewer repairs and faster construction.

1.2.5. Poles, Piles, and Sleepers:

Pre-tensioned prestressed concrete poles are extensively used for electric transmission and distribution lines due to their strength and light weight. Prestressed piles are ideal for foundations in soft or waterlogged soils where high bearing capacity is required. Railway sleepers made from prestressed concrete are durable and resistant to dynamic loads, impact, and vibrations from train operations. These elements are factory-produced, ensuring uniform quality and precision. They are economical for large-scale use and have a longer lifespan than conventional reinforced concrete components. Prestressed poles, piles, and sleepers are key elements in infrastructure and transport systems.

1.2.6. Marine and Offshore Structures:

Prestressed concrete is used in constructing jetties, docks, breakwaters, sea walls, and offshore platforms where structures are continuously exposed to harsh marine environments. Prestressing enhances resistance against wave impact, corrosion from seawater, and fatigue caused by tidal forces. It also reduces maintenance costs and extends the service life of these critical structures. Prestressed components are lighter and can be precast, which simplifies construction in remote or offshore locations. This technique ensures strength, stability, and durability, making it an ideal choice for modern marine infrastructure projects.

1.3 .Limit state design criteria for prestresed concrete members

A comprehensive knowledge of the behaviour of structural concrete elements under different types of loading is essential for producing safe, serviceable and economic designs of concrete structures. According to Bennett1 , design is essentially a creative rather than a routine analytical activity in which the structural behaviour is only one of a number of functional, constructional, aesthetic and economic considerations. A successful design should not only satisfy the requirements of safety against total collapse of the structure due to various causes, but also ensure that the serviceability of the structure is not impaired while resisting normal working loads. Rowe et al.2 have defined the purpose of design as "the provision of a structure complying with the client's requirements". A structural engineer is often required to assist the client in defining his requirements more precisely. Once the basic requirements have been defined, the structural engineer becomes a member of an integrated team. The primary object of structural design is to obtain a structural solution which can result in the greatest overall economy by providing the maximum assistance in satisfying all the other requirements of the structure. The limit-state design philosophy recognises the need to provide safe and serviceable structures at an economic price and at the same time presents a clearer idea of the margins of safety actually employed to cover uncertainty and ignorance of the function as well as the performance of structure in actual practice. It is important to note that the limitstate design proposals have been evolved from the provisions of various earlier codes, and the resulting changes in design, being minimal, provide the designer a greater freedom of choice. In addition, the formulation of new design proposals are such that any new research data on loads, variability of materials and workmanship, and methods of analysis can be readily incorporated in the comprehensive limit-state format.

1.3.1 Criteria for limit state

1.3.2 Design Loads and Strengths

The design loads for various limit states are obtained as products of the characteristic loads and partial safety factors, and are expressed as: Fd = gf Fk where Fd = appropriate design load gf = partial safety factor for loads Fk = characteristic load The characteristic load Fk, which is independent of the limit state considered and is seldom exceeded in service is defined as, Characteristic load = (mean load + k ¥ standard deviation) where k is a factor, so chosen as to ensure that the probability of the characteristic load being exceeded is small. A value of 1.64 for k ensures the probability that the characteristic load is exceeded by only five per cent during the intended life of the structure. The statistical data required to define the characteristic loads for different types of occupancy is not readily available, since loading statistics are invariably difficult to compile as they need systematic observations and recording of data over a long period of time. In the absence of statistical observations and recording of data on loading, the nominal imposed loads provided in various national codes, such as IS: 875–198716, BS: 639917, CP3–197218 and standards ANSI–A–58.119 may be treated as characteristic loads. The characteristic values of the loads take account of expected variations but do not allow for the following: 1. Possible unusual increases in load beyond those considered in deriving the characteristic load. 2. Inaccurate assessment of effects of loading and unforeseen stress distribution within the structure. 3. Variations in dimensional accuracy achieved in construction. Partial safety factors, gf , are therefore used for each limit state being reached. The values of partial safety factors for loads recommended in the British, Indian and American codes and FIP recommendations are compiled in Tables 1.1 to 1.6.

Persistent or Transient Design Situation	*Permanent Actions (G_k)*		*Leading Variable Actions ($Q_{k,1}$)*		*Accompanying Variable Action (Q_{k1})*	
	Unfavorable	*Favorable*	*Unfavorable*	*Favorable*	*Unfavorable*	*Favorable*
(a) For checking the static equilibrium of a building structure	1.10	0.90	1.50	0	1.50	0

(b) For the design of structural members (excluding geotechnical actions)	1.35	1.50	1.50	0	1.50	0
(c) As an alternative to (a) and (b) to design for both situations with one set of calculations	1.35	1.15	1.50	0	1.50	0

Where, G_k = Characteristic permanent load and Q_k = Characteristic variable load

Load Combination	*Limit State of Collapse*				*Limit State of Serviceability*			
	DL	*IL*	*WL*	*P*	*DL*	*IL*	*WL*	*P*
(i) $(DL + IL + P)$	1.5	1.5	-	1.0	1.0	1.0	-	1.1 or 0.9^{+}
(ii) $(DL + WL + P)$	1.5 or 0.9^{*}	-	1.5	1.0	1.0	-	1.0	1.1 or 0.9^{+}
(iii) $(DL + IL + WL + P)$	1.2	1.2	1.2	1.0	1.0	0.8	0.8	1.1 or 0.9^{+}

Notes

1. While considering earthquake effects, substitute *EL* for *WL*.
2. While assessing the long-term effects due to creep, the dead load and that part of the imposed load likely to be permanent may only be considered.
3. While verifying the limit state for stability, with external prestress, where an increase of the value of prestress can be unfavorable, partial factor of 1.3 shall be used.

* This value is to be considered when stability against overturning or stress reversal is critical.

\+ The structure shall be checked both for upper and lower characteristic values shown. The values are for post tensioning with bonded tendons. In case of pretensioning or unbonded tendons, it shall be taken as 1.05 or 0.95 instead of the above value.

Table 1.2 Partial safety factor for loads (gf) (IS: 1343-2012)

$$U = 1.2\,D + 1.6\,L + 0.5\,(L_r \text{ or } S \text{ or } R)$$
$$U = 1.2\,D + 1.6\,(L_r \text{ or } S \text{ or } R) + (1.0\,L \text{ or } 0.5\,W)$$
$$U = 1.2\,D + 1.0\,W + 1.0\,L + 0.5\,(L_r \text{ or } S \text{ or } R)$$
$$U = 1.2\,D + 1.0\,E + 1.0\,L + 0.2\,S$$
$$U = 0.9\,D + 1.0\,W$$
$$U = 0.9\,D + 1.0\,E$$

Table 1.3 Partial safety factor for loads (gf) (ACI: 318-2011)

Where U = Ultimate load D = Dead load L = Live load S = Snow load R = Rain load or related internal moments and forces W = Wind load E = Earthquake loads Lr = Roof live load

Type of Loads	*Limit State of Collapse*	*Limit State of Serviceability*
Permanent loads	1.35	1.00
Variable loads	1.50	1.00

Table 1.4 Partial safety factor for loads (gf) (FIP-1984)

FIP recommendations regarding partial safety factors are comprehensive, as they provide for a combination coefficients for basic variable actions as well as for other variable factors depending upon different types of structures, such as dwellings, offices, parking areas and highway bridges. The design strength of materials are expressed as, fd = (fk/gm) where fk is the characteristic strength of the material which corresponds to the 28-day cube compressive strength of concrete or the tensile strength of tendons below which the failures are not more than five per cent. In the absence of statistical data, the characteristic strengths of concrete and steel may be taken as the works cube strength and the specified proof or yield strength, respectively, as provided for in the codes. The partial safety factor (gm) for materials has a value which depends upon the importance of the limit state being considered, materials to which it applies, and differences between the strengths of the materials when tested and when incorporated in construction during the service life of the structure. The design strengths of materials for each limit state are obtained by using the values of the partial safety factors compiled in Table 11.5 (a) and (b) as provided for in the various codes. The American Code ACI 318M–2011 provides for reduction factors to be applied to the nominal strength of structural members in flexure, shear, torsion and compression to account for the inaccuracies in construction. The reduced strength of a member is defined as its design strength. The values of reduction factors for various types of structural elements are compiled in Table 1.6.

Materials	*Partial Safety Factor (γ_m)*
Steel	1.15
Concrete	1.50

Table 1.5 (a) Partial safety factors for materials (gm) (IS: 1343-2012)

Limit State	*Persistent and Transient*		*Accidental*	
	Concrete	*Reinforcing and Prestress-ing Steel*	*Concrete*	*Reinforcing and Prestresing Steel*
Strength				
Flexure	1.50	1.15	1.20	1.00
Shear	1.50	1.15	1.20	1.00
Bond	1.50	1.15	1.20	1.00
Serviceability	1.00	1.00	-	-

Table 1.5 (b) Partial safety factors for materials (gm) (IS: 1343-2012)

2. Review of Literature

2.1 R., “Design Optimization of Post-Tensioned Beams”, 2021

This research presents a comprehensive study of bonded and unbonded post-tensioned (PT) beam systems, analyzing their structural performance under various loading conditions. The study finds that bonded PT beams offer superior ductility, stiffness, and crack resistance, making them ideal for structures where long-term durability and minimal deflection are critical. On the other hand, unbonded PT beams allow for easier installation, tendon replacement, and simplified maintenance, which can be advantageous in retrofit or large-span projects. The study emphasizes that tendon type selection must consider structural requirements, exposure conditions, and intended service life. Analytical and experimental investigations are performed to validate stress distribution, deflection behavior, and crack control, showing clear performance differences between bonded and unbonded systems. The research also discusses prestress losses, including immediate and long-term losses, and the importance of optimizing tendon profiles and eccentricity to control midspan deflection. The study provides practical guidelines for efficient and safe PT beam design, balancing costeffectiveness with structural performance. It highlights that proper tendon layout, anchorage detailing, and prestress force selection are key to maximizing beam performance. Overall, this work contributes to a better understanding of PT beam behavior, offering design insights for engineers working on modern high-rise, commercial, and infrastructure projects.

2.2 Lee H., Kim J., “Software-Based PT Slab Analysis and Design”, 2022

This research focuses on the application of ADAPT Builder software for the design and analysis of post-tensioned slabs. The study demonstrates that software-based analysis significantly reduces design time and manual calculation errors, while accurately predicting bending moments, shear forces, and tendon stresses. Complex slab geometries, including varying spans and column arrangements, are easily handled using the software. The authors highlight the importance of tendon profile optimization, including parabolic and straight tendon layouts, to achieve the desired camber, deflection control, and serviceability. The study compares software outputs with traditional hand calculations, showing that softwarebased design improves accuracy and safety margins. Recommendations include using ADAPT Builder for iterative design processes, which helps in achieving material-efficient and cost-effective slab solutions. The study also discusses prestress losses, anchorages, and tendon stressing sequences, ensuring that service load requirements and deflection limits are met. The research emphasizes integration with building models, automated reinforcement detailing, and design verification, making the process highly efficient. It concludes that software-assisted PT slab design enhances structural reliability, reduces labor-intensive calculations, and facilitates optimization for multi-storey buildings and complex floor plans.

2.3 Singh A., “Post-Tensioned Concrete Beams: A Review”, 2020

This review examines the evolution and practical applications of post-tensioned concrete beams, particularly in bridges and high-rise buildings. The study emphasizes material efficiency, improved serviceability, and enhanced durability as the key advantages of PT construction. It reviews prestressing techniques, tendon types, and anchorage systems, providing insights into how these factors influence beam performance. The paper also examines IS 1343:2012 and other relevant standards for the design and construction of prestressed concrete members, highlighting essential provisions for strength, deflection, and crack control. The study discusses the impact of prestress losses, tendon eccentricity, and load distribution on the long-term performance of PT beams. It highlights practical design considerations such as tendon layout optimization, minimum steel requirements, and serviceability checks, which are critical for meeting durability and safety criteria. Comparative analysis with conventional reinforced concrete beams shows that PT beams allow longer spans with reduced structural depth and material usage. The paper also explores construction methods, post-tensioning procedures, and quality control practices. It concludes that careful attention to prestress force, tendon positioning, and code compliance is essential to maximize performance, making PT beams highly suitable for modern infrastructure, multistorey buildings, and bridge construction.

2.4 Malcolmson N.M., "Analysis of a Post-Tensioned Slab with Concentrated and Uniform Loads", 2023

This thesis investigates the behavior and design of post-tensioned flat slabs under concentrated and uniform loads. The study provides a detailed explanation of post-tensioning mechanics, prestressing equipment, losses, and calculation principles, and includes a practical example to illustrate design procedures. It emphasizes the importance of accurately modeling load types, as concentrated loads, such as machinery or furniture, can produce significantly different stress distributions compared to uniformly distributed floor loads. The research also highlights prestress loss considerations, including immediate elastic shortening, creep, shrinkage, and relaxation of steel, which affect the long-term performance of PT slabs. Tendon layout, parabolic profiles, and eccentricity are optimized to control midspan deflection and cracking under service loads. The study demonstrates that ignoring the effects of concentrated loads can lead to underestimation of bending moments and inadequate serviceability. Analytical models and software simulations are used to verify slab performance and structural safety, ensuring compliance with IS 1343 and IS 456. Overall, the work provides practical design guidelines for engineers to achieve safe, durable, and serviceable PT slab systems in both commercial and residential applications.

2.5 Farid A.F., "An Automated Optimized Design of Practical PostTensioned Slabs", 2024

This paper explores the use of software tools such as ADAPT-Builder for the design and optimization of post-tensioned slabs. It points out that traditional iterative design approaches, while widely used, often lead to overdesign and material inefficiency. The study advocates for automated optimization, which considers parameters like tendon profile, spacing, prestress force, slab thickness, and deflection criteria simultaneously to achieve cost-effective and structurally efficient designs. The research demonstrates that optimized designs reduce concrete and steel quantities while meeting serviceability limits and safety factors, including deflection control and crack width compliance. Comparisons with conventional designs show significant improvements in structural performance and resource efficiency. The study also addresses integration with design codes IS 1343 and IS 456, showing how automated tools can assist engineers in ensuring compliance. Recommendations include using optimization software for multi-storey buildings, complex slab geometries, and large-span floor systems, improving design reliability, accuracy, and constructability.

2.6 Ajay N., Harsha S., Chethan Kumar S., Vittal Kashyap J., "Feasibility Studies on Performance of Post-Tensioning (Bonded) Flat Slab for Residential Building", 2022

This study evaluates the structural performance of bonded post-tensioned flat slabs compared to conventional reinforced concrete (RC) slabs in residential buildings. The analysis and design were carried out using ADAPT-PT software, focusing on serviceability, strength, and material efficiency. Results indicate that PT slabs exhibit better performance in terms of deflection, cracking control, and load-carrying capacity compared to conventional RC slabs. The research examines tendon layout, prestress force, slab thickness, and reinforcement detailing, demonstrating that bonded PT systems provide enhanced durability and long-term serviceability. The study also discusses construction feasibility, cost-effectiveness, and reduced structural depth, making PT slabs suitable for residential projects where floor-to-floor height and material optimization are important. Recommendations include proper tendon profiling, prestress loss consideration, and adherence to IS 1343/IS 456 standards to ensure safety, reliability, and performance efficiency.

2.7 Farouk K., "Evaluation of Post-Tensioned Concrete Slabs Using Finite Element Programs", 2023

This research explores the design of post-tensioned flat slabs using finite element analysis (FEA) programs, including ADAPT Builder. It evaluates the efficiency of different tendon layouts and profiles in reducing deflection and controlling cracking. The study provides design tables with recommended post-tensioning rates, considering various spans, loadings, and span-to-depth ratios, facilitating practical application by engineers. Detailed simulations show that optimized tendon patterns can significantly improve serviceability and structural performance while minimizing material usage. The research also examines prestress loss effects, anchor

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3. METHODOLOGY

3.1 Literature Survey and Data Collection

The study began with a comprehensive literature survey, reviewing research papers, textbooks, design manuals, and relevant codes, particularly IS 1343:2012. This provided a thorough understanding of post-tensioning principles, types of PT systems (bonded and unbonded), and their applications in beams and slabs. Data on material properties such as concrete grade, modulus of elasticity, tendon type, and yield strength were collected. Additionally, geometric parameters like beam dimensions, slab thickness, span lengths, and support conditions were determined. Service loads, including dead and live loads, were calculated following IS 875 standards to reflect realistic design conditions.

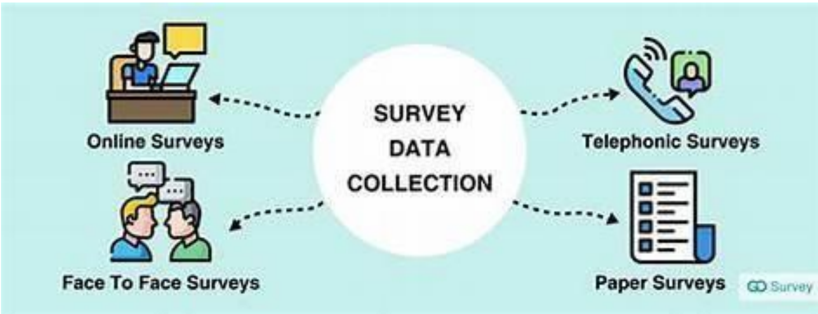

Figure 3.1 :Literature Survey and Data Collection

3.2 Modeling in ADAPT Builder

The next step involved structural modeling in ADAPT Builder, a software chosen for its advanced capabilities in 3D modeling, analysis, and post-tensioning design. The geometry of PT beams and slabs, material properties, and loading conditions were accurately input into the software. Tendon profiles were defined for both bonded and unbonded systems, and the software performed linear elastic analysis to calculate bending moments, shear forces, deflections, and stress distribution along the concrete and tendons.

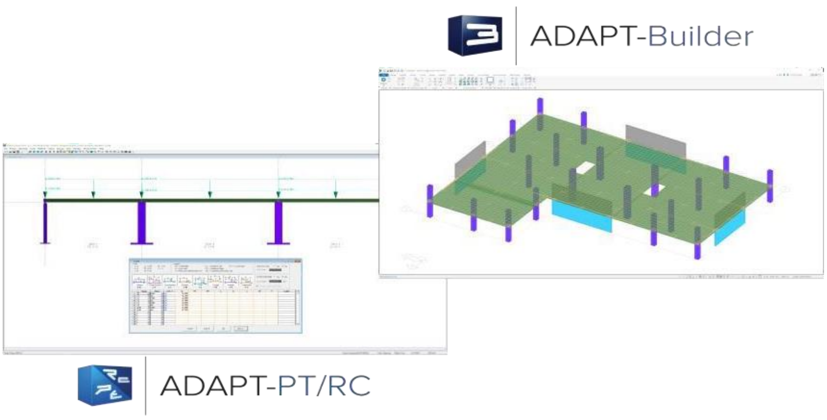

Figure 3.2 Modeling in ADAPT Builder

3.3 Design and Optimization

Based on the analysis, prestressing forces were calculated to counteract the applied loads. Tendon layouts were optimized to minimize deflection, control cracking, and ensure efficient use of materials. The design was checked for Ultimate Limit State (ULS) to ensure safety under maximum loads, and Serviceability Limit State (SLS) to confirm performance under working loads. Detailed design reports from ADAPT Builder, including tendon profiles, bending moment and shear force diagrams, and deflection plots, were generated for documentation and comparison with conventional reinforced concrete designs.

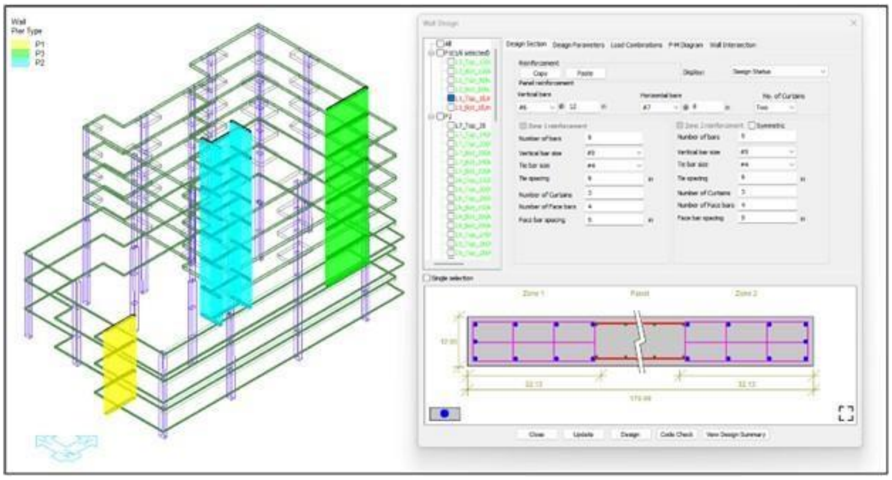

Figure 3.3: Design and Optimization

3.4 Assumptions and Limitations

Several assumptions were made for simplification and accuracy: the concrete was considered homogeneous and isotropic, tendons followed the defined profiles exactly, and prestress losses due to creep, shrinkage, and relaxation were accounted for according to IS 1343:2012.
Nonlinear effects, such as cracking propagation beyond service loads, were not considered. The study focused on typical beam and slab configurations; irregular or highly complex geometries may require additional analysis.

3.5 Summary

This methodology provides a systematic and reproducible approach for the design and analysis of PT beams and slabs. By integrating ADAPT Builder software with code provisions and optimization techniques, the study ensures safe, durable, and efficient structural designs while minimizing material usage and deflection.

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4. RESULT AND DISCUSSION

Using the above layout and input parameters, provide a post-tensioned slab and beam design (IS 1343/IS 456). Include slab tendon layout, calculation of required number and spacing of strands (using 140 kN strand force), beam tendon requirement, check controlling service (deflection, camber, crack width), and provide reinforcement schedule.

Here's a step-by-step post-tensioned slab and beam design based on your layout and inputs using IS 1343/IS 456 principles. This includes tendon layout, calculation of required strands, beam tendon recommendations, and reinforcement schedule guidelines.

4.1 Design Inputs

- Slab size: 17,370 mm x 29,330 mm
- Slab thickness: 200 mm
- Concrete grade: M40
- Steel grade: Fe500
- Beam size: 1,000 mm x 600 mm
- Beam span: 17,370 mm
- Column size: 1,200 mm x 900 mm
- Live load: 4 kN/m²
- Floor finish: 2 kN/m²
- Stressing force per strand: 140 kN
- Camber target: 25 mm (at midspan)
- Applicable codes: IS 456, IS 1343

4.2 Load Calculation

- Slab self-weight = 0.20 m × 25 = 5.0 kN/m²
- Floor finish = 2.0 kN/m²
- Live load = 4.0 kN/m²
- Total service load (q_s) = 5 + 2 + 4 = 11.0 kN/m²
  For a 1.0 m strip, uniform service load w = 11.0 kN/m

4.3 Slab Tendon Layout & Strand Calculation

Moment Calculation:

- For initial estimation, use the ultimate moment formula:

$$M_u = \frac{wL^2}{8}$$

-For the longest span (6,670 mm):

$$w = 11 \text{ kN/m}^2,\ L = 6.67 \text{ m}$$

-Therefore,

$$M_u = \frac{11 \times 6.67^2}{8} = 61.3 \text{ kNm per meter strip width}$$

Prestressing Requirement:

-Recommended prestress (IS 1343/IS 456): typically designed to balance 60–80% of the dead load.

-Approximate prestress per meter width:

$$0.6 \times 7 = 4.2 \text{ kN/m}^2$$

-Required tendon force per meter width:

$$4.2 \text{ kN} \times \text{strip width}$$

Number of Strands:

- Stressing force per strand: 140 kN

- For a 1 m strip, the required prestressing force is approximately 42 kN

$$(4.2 \text{ kN/m}^2 \times 1 \text{ m width} = 4.2 \text{ kN/m})$$

-Number of strands per meter:

$$\frac{42}{140} \approx 0.3$$

-For typical flat slabs, 2–4 strands per meter width are provided, spaced 600–1000 mm apart across the slab width.

-Tendons are arranged parabolically, with maximum eccentricity at midspan and minimum eccentricity near column supports.

4.4 Beam Tendon Layout

- For 17.37 m span, high post-tensioning is required.

- Typical number: 8–12 strands (based on beam moment and shear). Use 140 kN/strand to size total tendons to balance 65–70% of dead load plus 40–50% live load [1][2].

- Tendons placed at beam bottom (midspan) and raised near supports.

4.5 Reinforcement Schedule

Slab

- Minimum mild steel (IS 456): 0.12%of gross cross-section (for exposure and crack control).

- For 200 mm slab:

$$A_{s,\min} = 0.0012 \times 1000 \times 200 = 240 \text{ mm}^2\text{/m width}$$

- Provide reinforcement in both directions at the bottom, with distribution bars at the top where required.

Beam

- As per IS 456 and IS 1343, provide minimum reinforcement: 0.2% − 0.3%of cross-section.

For 600 mm depth and 1000 mm width:

$$A_{s,\min} = 0.002 \times 1000 \times 600 = 1200 \text{ mm}^2$$

- Main bars at the bottom, closed links/stirrups for shear along the length.

4.6 Service Checks (Deflection, Camber, Crack Width)

- Deflection: Check slab for long-term deflection, aim to keep below span/250 (IS 456).

- Camber: Adjust tendon profile to achieve 25 mm at midspan (raise tendon eccentricity at center).

- Crack Width: Ensure residual stress > tensile stress at the top fibers under service load; mild steel and PT keep cracks tightly closed [3][1].

4.7 Summary Table

Element	Tendon Layout	Strands per unit	Mild Steel Required
PT Slab	Parabolic, 2–4/m width 2–4 (140 kN)	240 mm²/m (bottom) PT Beam	Parabolic, at
bottom	8–12 (140 kN) 1,200 mm² (bottom)		

General Notes

- Punching shear needs review near columns.

- Typical tendon spacing: 600–1,000 mm.

- Tendon profile (eccentricity) set to maximize camber at midspan.

- Mild steel must be lapped through strips/panel.

5. CONCLUSION

The project focuses on the design and analysis of post-tensioned (PT) beams and slabs using ADAPT Builder software, highlighting the advantages of prestressed concrete in modern structural engineering. Prestressing is a technique that introduces internal compressive stresses in concrete members before external loading, enhancing strength, reducing deflection, and controlling cracking. The study explores both pre-tensioned and post-tensioned systems, with post-tensioning further classified into bonded and unbonded methods.

Through a comprehensive literature survey, the project examined PT behavior, tendon layouts, prestress losses, and performance under various service and ultimate load conditions. The data collected included concrete and steel properties, geometric parameters of beams and slabs, and loading conditions in compliance with IS 1343:2012 and IS 456:2000.

Using ADAPT Builder, PT beams and slabs were modeled, analyzed, and optimized. The software facilitated the determination of bending moments, shear forces, deflection, tendon forces, and stress distribution. The study emphasizes tendon layout optimization for parabolic profiles, achieving desired camber, deflection control, and serviceability while ensuring efficient material use. Both bonded and unbonded tendon systems were evaluated for practical applications, highlighting differences in installation, maintenance, and performance.

The design results include:

- Slab tendon layout with 2–4 strands per meter width, parabolic profile.
- Beam tendon layout for long spans with 8–12 strands, bottom placement with raised eccentricity near supports.
- Reinforcement schedules for both slab (240 mm²/m) and beam (1,200 mm²) following IS 456 minimum requirements.
- Service checks for deflection, camber, and crack width, ensuring compliance with IS limits.

The project demonstrates that post-tensioning allows longer spans, thinner slabs, and reduced material usage, making structures more economical and durable. ADAPT Builder proved to be an effective tool for modeling, analysis, and design optimization, ensuring accuracy, code compliance, and safe structural performance.

Finally, the project explores future scope such as integration with BIM, use of AI for optimization, adoption of sustainable materials, performance-based design approaches, and automation in PT construction. These advancements highlight the potential for more efficient, economical, and sustainable prestressed concrete systems in modern civil engineering.

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